KNOWN AND POSSIBLE MINERAL DEPOSIT TYPES IN THE SILVER CITY 1° x 2° QUADRANGLE, NEW MEXICO AND ARIZONA—DESCRIPTIONS, RECOGNITION CRITERIA, AND RESOURCE EVALUATIONS

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COPPER

Copper is the premier metal commodity in the quadrangle and will probably retain this dominant position well into the 21st century. It is the principal metal in the porphyry Cu (Mo)[1], Cu-Zn-Fe replacement, Cu-Ag-Au (Pb-Zn) vein, and Cu vein deposits and a secondary commodity in many precious and base metal vein and replacement deposits throughout the quadrangle. Production of Cu began about 1801 and has continued with only short interruption to the present time. Currently, major production is from the Santa Rita porphyry Cu (Mo) deposit in the Central mining region, the Tyrone porphyry Cu (Mo) deposit in the Big Burro and Little Burro Mountains area, and from a few Cu-Zn-Fe replacement deposits in the Central mining region (figs. 1 and 2, map sheet). Copper is also being produced from leaching operations at the small San Juan porphyry Cu (Mo) deposit in the Gila and northern Peloncillo Mountains area and from some of the Au-Ag-base metal vein deposits in the Summit Mountains and Black Mountain area as a minor coproduct. The Dos Pobres porphyry Cu (Mo) deposit in the Gila and northern Peloncillo Mountains area is currently under development for mining.

[1]Metals in parentheses denote commodities that are generally present in the deposit type but are of secondary importance.

PORPHYRY Cu (Mo) DEPOSITS

Two morphologically different types of porphyry Cu deposits occur in the quadrangle. The Safford type, which includes a number of deposits in the Gila and northern Peloncillo Mountains area (figs. 1 and 2, map sheet), has characteristics of volcanic deposits (Sutherland Brown, 1976) and is similar to many of the porphyry Cu deposits of the Canadian Cordillera, South America, and the Philippines. The Santa Rita-Tyrone type in the Central mining region area and the Big Burro and Little Burro Mountain area (figs. 1 and 2, map sheet) are more akin to plutonic deposits and have features in common with many porphyry Cu deposits in the southwestern United States. Safford type deposits apparently formed relatively high in the crust within the volcanic pile whereas the Santa Rita-Tyrone type appear to be deeper seated and confined chiefly to the source pluton. The porphyry Cu deposits of the quadrangle and in most of the southern Basin and Range province are genetically related to medium-K, calc-alkaline, volcnic-plutonic arcs that developed during compressional tectonism in Late Cretaceous to early Tertiary time (80-50 m.y.). The deposits are associated with plutonic and hypabyssal rocks, chiefly of granodiorite to quartz monzonite composition (the granodiorite system of Mutschler and others, 1981) and may form a continuum with more differentiated, calc-alkaline, stockwork Mo deposits (Westra and Keith, 1981).

Description

Safford type deposits consist of disseminations, veins, fracture coatings, and breccia fillings in roughly cylindrical to lenticular bodies as much as 1,200 m long, 900 m wide, and more than 500 m thick. Host rocks are chiefly subaerial, medium-K, calc-alkaline, andesitic to dacitic flows and associated volcaniclastic rocks of Late Cretaceous age and cogenetic intrusive complexes consisting of small plutons, dikes, and breccia pipes of Late Cretaceous to early Tertiary age (67-52 m.y.). The host intrusive rocks (assumed source rocks) are epizonal, metaluminous to peraluminous granodiorite-quartz monzonite porphyries containing 60-66 percent SiO_2, and about 8 percent $Na_2O + K_2O$ with Na_2O generally equal to K_2O. Accessory minerals include sphene, allanite, and Cl-rich apatite; fluorite and ilmenite are generally absent. The ore bodies and intrusive complexes are localized within strong northeast to east-northeast fault-fracture zones as much as 2,000 m wide. Primary ore minerals are chalcopyrite, bornite, molybdenite, and pyrite with rare sphalerite, tetrahedrite, and galena; secondary ore minerals are chiefly chrysocolla, cuprite, malachite, chalcocite, and brochantite. Gangue minerals are quartz, calcite, magnetite, hematite, limonite, and a variety of hydrothermal alteration silicates. The deposits are characterized by hydrothermal alteration zones as much as 3,600 m in diameter, generally with a quartz-sericite-brown biotite central zone and a green biotite-chlorite-epidote outer zone, both superimposed on an earlier pervasive propylitic alteration. The ore zone generally corresponds to the central K_2O-enriched zone; a pyritic halo may extend as much as 1,500 m beyond the ore zone. Enriched oxidized ore occurs below an irregular leached cap; supergene enrichment is minor.

Deposits of the Santa Rita-Tyrone type are generally similar in form to the Safford type, but ore bodies tend to be more blanket shaped as a result of supergene enrichment. The deposits are confined to their source plutons and immediate contact zones. At Santa Rita massive replacement deposits occur in Paleozoic carbonate rocks peripheral to the pluton. The source plutons are medium-K, calc-alkaline rocks compositionally similar (60-69 percent SiO_2) to the Safford intrusive rocks but more mesozonal in character. Textural and compositional zoning is common, and both equigranular and porphyritic variants are present. Ages range from 70 to 56 m.y. Accessory minerals are chiefly sphene and allanite; ilmenite, rutile, monazite, and chlorapatite are also present in the Santa Rita pluton. The stocks are emplaced in, and are also cut by, pronounced northeast to east-northeast fault-fracture zones; at Santa Rita, the stock occurs at the intersection of this northeast trend and a less pronounced north to northwest-trending fault-fracture zone, which may be part of a fissure system peripheral to a complex eruptive system. Primary ore minerals are chalcopyrite, bornite, molybdenite, marcasite, pyrrhotite, pyrite, and sphalerite; secondary ore minerals are chalcocite, covellite, native Cu, chrysocolla, malachite, azurite, tenorite, cuprite, and turquoise. Gangue minerals are quartz, hematite, jarosite, supergene clay minerals, and hydrothermal alteration silicates. Alteration zonation is generally masked by development of supergene minerals; the Santa Rita deposit exhibits an intense orthoclase-biotite central zone and a quartz-sericite outer zone. Ore bodies consist almost entirely of oxidized and supergene-enriched ore overlain by irregular leached capping.

Tonnage and grade and some salient features of the known Safford and Santa Rita-Tyrone porphyry Cu (Mo) deposits are shown in table 1. All deposits contain values in MoS_2, Ag, and Au, but grades of these byproducts are available only from the Safford type Dos Pobres deposit.

Table 1.—*Porphyry Cu (Mo) deposits, Silver City 1° x 2° quadrangle, New Mexico-Arizona*

[Leaders (—) indicate no data available]

Deposit (letters refer to figs. 2 and 3)	Host or source pluton			Ore type	Tonnage and grade (prior to development)	Status (1980)
	Rock type	Chemistry	Age (m.y.)			
Safford type						
Dos Pobres (A)	Quartz monzonite porphyry	65% SiO_2 $K_2O > Na_2O$	67–52	Sulfide (primary)	363x10[6] metric tons, 0.72% Cu, 0.003–0.015% MoS_2, 1–6 g/t Ag, and about 0.7 g/t Au	Under development for underground mine
San Juan (B)	Quartz monzonite porphyry, minor granodiorite porphyry (San Juan stock	65% SiO_2 $K_2O > Na_2O$	58	Oxide	20x10[6] metric tons, 0.5% Cu	Active in-site leaching
Safford-KCC (C)	Granodiorite porphyry, minor quartz diorite and quartz monzonite porphyry (Lone Star stock)	60% SiO_2 $Na_2O > K_2O$	58–53	Sulfide (primary) and oxide	1,800x10[6] metric tons, 0.41% Cu	Inactive
Horseshoe (D)	Quartz monzonite porphyry	66% SiO_2 $Na_2O > K_2O$	—	Oxide	0.07x10[6] metric tons, 1% Cu	Inactive
Sanchez (E)	Quartz monzonite porphyry	—	—	Oxide	72x10[6] metric tons, 0.18% Cu	Inactive
SOL (F)	Quartz monzonite porphyry(?)	—	—	—	3–15% sulfides	Inactive
Santa Rita-Tyrone type						
Hanover Mountain (G)	Granodiorite porphyry and granodiorite (Fierro-Hanover stock)	60–66% SiO_2 $Na_2O > K_2O$	70–58	Sulfide (supergene)	9.5x10[6] metric tons, 0.6% Cu	Inactive
Santa Rita (H)	Quartz monzonite porphyry (Santa Rita stock)	65–67% SiO_2 $K_2O > Na_2O$	63–56	Sulfide (supergene), oxide and massive replacement	600x10[6] metric tons, 0.82% Cu	Active open-pit mine
Tyrone (I)	Quartz monzonite porphyry and quartz monzonite (Tyrone stock)	68–69% SiO_2 $Na_2O > K_2O$	56	Sulfide (supergene) and oxide	360x10[6] metric tons, 0.8% Cu	Active open-pit mine
Liberty Bell-Copper Mountain (J)	do.	do.	do.	Oxide	1–1.2% Cu	Inactive

Resource evaluation

The know porphyry Cu deposits in the quadrangle constitute a very large and important Cu resource, and the probability of finding additional deposits, especially of the Safford type, is encouraging. Six areas (1-6, fig. 2, map sheet) considered favorable for the occurrence of Safford type porphyry Cu (Mo) and the principal criteria used to delineate them are outlined below:

Criteria	Areas of favorability					
	1	2	3	4	5	6
Known Safford type deposits___	x					
Necessary conditions						
Late Cretaceous-early Tertiary volcanic terranes intruded by cogenetic granodiorite-						

quartz monzonite porphyries	x	x	x	x		
Pronounced NE- to ENE-trending fault-fracture-dike zones	x	x				
Potassic and phyllic hydrothermal alteration	x					
Suggestive conditions						
Cu vein deposits	x					
Broadly anomalous Pb, Zn, Ba, Mn ± Cu, Ag, Sn, and Mo in the magnetic fraction of panned stream sediments			x	x	x	
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag, ± Mo, Be, Sn in either, or both, the magnetic and nonmagnetic fractions of panned stream sediments	x	x	x	x	x	x
Pervasive propylitic alteration	x	x	x	x	x	
Late Cretaceous-early Tertiary volcanic terranes without known associated hypabyssal or plutonic rocks					x	
Base and precious metal vein and replacement deposits		x	x	x	x	
Covered or nonexposed plutonic rocks inferred from gravity or magnetic anomalies	x					
NE-trending zones of structural weakness inferred from gravity or magnetic features						x

Seven areas (7-13, Fig. 2, map sheet) considered favorable for the occurrence of Santa Rita-Tyrone type deposits and their criteria are outlined below:

Criteria	Areas of favorability						
	7	8	9	10	11	12	13
Known Santa Rita-Tyrone type deposits	x	x					
Necessary conditions							
Upper Cretaceous to lower Tertiary granodiorite to quartz monzonite plutons	x	x	x	x	x		
Pronounced NE- to ENE-trending fault-fracture zones	x	x	x				
Potassic and phyllic hydrothermal alteration	x	x	x				
Suggestive conditions							
Cu vein deposits		x					
Turquoise vein deposits		x					
Areas of pyritization	x	x	x	x		x	x
Anomalous (as much as percent range) Bi, W, Mo, Pb, Cu, Ag ± Au V, Be, F, and Nb in the nonmagnetic fraction of panned stream sediments	x	x	x	x	x	x	x
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag ± Mo, Be, Sn, and fluorite in either, or both, the magnetic and nonmagnetic fractions of panned stream sediments	x	x	x	x	x	x	
Pervasive propylitic alteration	x			x	x		
Base and precious metal vein and replacement deposits	x	x	x		x		

Cu-Zn-Fe REPLACEMENT DEPOSITS

Cu-Zn-Fe replacement deposits are one of four subtypes (Fe, Zn, Cu-Zn-Fe, and Zn-Pb replacements) of the Fierro-Hanover massive replacement deposits in the Central mining region (figs. 1 and 2, map sheet). The distinction between subtypes is based largely on differences in ore mineral content; however, gradations between subtypes are the rule, and all appear to have a common genesis. The deposits are skarn-associated, moderate- to high-temperature replacements in Paleozoic carbonate rocks near Upper Cretaceous to lower Tertiary, medium-K, calc-alkaline stocks.

Description

Deposits are lenticular or podlike masses as much as 300 m long, 300 m wide, and 40 m thick, chiefly in Pennsylvanian and Mississippian carbonate rocks within 2 km of a plutonic rock contact. Host rock favorability is a function of permeability and probably composition, with dolomitic limestones apparently preferred. The most productive deposits occur in steeply dipping beds; some deposits may be localized where favorable host strata are intersected by dikes and faults. The ore bodies are commonly separated by septa and masses of marble or calc-silicate minerals. Primary ore minerals are chalcopyrite, sphalerite, and magnetite with subordinate pyrite, pyrrhotite, cubanite, molybdenite, galena, and tetrahedrite-tennantite; secondary ore minerals are chiefly Cu carbonates. Gangue minerals vary from calcite in pure limestones to andradite and minor epidote, hedenbergite, ilvaite, calcite, and tremolite in nearly pure limestones to complex assemblages of quartz, calcite, serpentine, magnesite, idocrase, wollastonite, talc, tremolite, and minor actinolite, andradite, epidote, ilvaite, and hedenbergite in impure dolomitic limestones. The general sequence of mineralization is (1) calc-silicate minerals, (2) magnetite-Fe-rich pyroxenes, and (3) sulfide minerals. The deposits are spatially and genetically related to medium-K, calc-alkaline granodiorite - quartz monzonite stocks, Late Cretaceous to early Tertiary in age (80 to 56 m.y.), that have been forcefully intruded high in the crust, probably along northeast-trending zones of structural weakness.

Resource evaluation

Conditions favorable for the occurence of Cu-Zn-Fe replacement deposits are locally present throughout the quadrangle. Seven areas of favorability (1-7, fig. 2, map sheet) are delineated on the basis of the following criteria:

Criteria	Areas of favorability						
	1	2	3	4	5	6	7
Known deposits	x						
Necessary conditions							
Upper Cretaceous to lower Tertiary stocks intruding Paleozoic carbonate rocks	x	x	x	x	x	x	

Suggestive conditions							
Scheelite, garnet, and dioside in stream-sediment concentrates							x
Anomalous Bi, W, Mo, Pb, Cu, Ag ± Au, V, Be, and Nb in the nonmagnetic fraction of panned stream sediments			x	x	x	x	x
Broadly anomalous Pb, Zn, Ba, Mn, ± Cu, Ag, Sn, and Mo in the magnetic fraction of stream-sediment concentrates	x						
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag, ± Mo, Be, Sn, and fluorite in either, or both, fractions of panned stream sediments		x	x	x	x	x	x

Areas 1, 2, 3, and 4 in the Central mining region have a high probability of containing deposits of the same general size and grade as the known deposits in the area. Areas 5 and 6 in the Dos Cabezas and Chiricahua Mountains area appear less favorable, and deposits in these areas would probably be small.

Cu-Ag-Au (Pb-Zn) VEIN DEPOSITS

Copper-tourmaline type Cu-Ag-Au (Pb-Zn) vein deposits are restricted to the Lordsburg district in the northern Pyramid Mountains area (figs. 1 and 2, map sheet). They are large fissure fillings that both laterally and vertically display a remarkably uniform metal content. The deposits were mined almost continuously from the late 1880's to 1975, and produced about $60,000,000, chiefly in Cu, Ag, and Au.

Description

The deposits are quartz-rich vein fillings along two sets of local faults, one trending east and the other northeast within the contact zone of the Lordsburg granodiorite stock of Laramide age (56-59 m.y.) and host andesitic volcanic rocks of Cretaceous age. The veins, which typically splay and rejoin, are as much as 600 m long and average 2-3 m wide; they have been mined to a depth of at least 720 m. Primary ore minerals in order of abundance are chalcopyrite, pyrite, specular hematite, sphalerite, and galena; gangue minerals are chiefly quartz, sericite, chlorite, calcite, tourmaline, barite, and manganoan siderite. Secondary base metal sulfide and oxide minerals are erratically distributed to depths of 450 m, but supergene enrichment apparently only locally increased the tenor of Ag in the deposits. The vein fillings, consisting largely of breccias containing abundant wallrock fragments, formed during a number of stages of vein reopening throughout the period of faulting. The volcanic and granodioritic wallrocks are sericitized and silicified as much as 4 m beyond the veins. The average grade of primary ore from the largest deposit in the area was 2.8 percent Cu, 42.2 g/metric ton Ag, and 3.8 g/metric ton Au, and was evidently consistent from the surface to the lowest levels of mining. The deposits are apparently genetically related to the final stages of emplacement and cooling of the Lordsburg granodiorite stock.

Resource evaluation

Copper resources are still present at depth in the mines of the Lordsburg district, but the high cost of deep underground mining has discouraged further exploitation of these ores. Smaller, undiscovered surface or near surface deposits are likely to occur in the district, but their total resource is probably small. The area of known deposits (fig. 2, map sheet) has anomalies of B, Cu, Ag, Pb, Zn, and fluorite in the nonmagnetic fraction of panned stream sediments. No other recognition criteria are known to assess areas of favorability outside the Pyramid Mountains area, and it is very possible that the Cu-Ag-Au (Pb-Zn) vein deposits occur only in the Lordsburg district.

Cu VEIN DEPOSITS

Most of the Cu vein deposits in the quadrangle are spatially and genetically related to known porphyry Cu (Mo) deposits, and many were operated as underground mines prior to the recognition and development of the porphyry deposits.

Description

The richest Cu vein deposits are in the vicinity of the Tyrone porphyry Cu (Mo) deposit in the Big Burro and Little Burro Mountains area (figs. 1 and 2, map sheet). They are supergene- and oxide-enriched fissure fillings, chiefly along northeast and east-northeast-trending fault zones cutting Precambrian granite peripheral to the Tyrone quartz monzonite porphyry stock of Laramide age. The mineralization is similar to that of the Tyrone deposit, with chalcocite, chrysocolla, malachite, and azurite the principal ore minerals. Many of the veins were extremely high grade, with some ore averaging as much as 17 percent Cu.

The Cu vein deposits in the Gila and northern Peloncillo Mountains area are associated with Safford type porphyry Cu (Mo) deposits. The deposits are oxidized quartz-rich fracture fillings and mineralized shears in wide east-northeast-trending fault zones chiefly in Upper Cretaceous andesitic volcanic rocks. Chrysocolla is the principal ore mineral.

Cu vein deposits, not associated with known porphyry Cu (Mo) deposits, occur in the Summit Mountains and Black Mountain area at the northwest end of a zone of precious and base metal vein deposits. The deposits are oxidized fissure and fracture fillings along northwest-trending faults in middle Tertiary volcanic rocks. The principal ore minerals are chrysocolla, chalcopyrite, pyrite, native Cu, and Cu carbonates.

Resource evaluation

Production of Cu from the Cu vein deposits has been limited to enriched ores from the upper parts of the vein systems, and it is doubtful if primary ores at depth constitute a significant resource. The deposits near the Tyrone porphyry Cu (Mo) deposit may be developed in the future if present mining and leaching operations are expanded. Copper vein deposits of middle Tertiary age in the Summit Mountains and Black Mountain area are small and probably more a mineralogical anomaly than a potential resource.

OTHER DEPOSIT TYPES

Copper minerals occur in most all of the other precious and base metal vein and replacement deposit types in the quadrangle, but production of Cu is as a relatively minor coproduct and has been recorded from only five deposit types: Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits and the Pinos Altos type Au-Ag (base metal) vein deposits in the Central mining region, Steeple Rock type Au-Ag-base metal vein deposits in the Summit Mountains and Black Mountain area, Au-Ag-base metal vein and replacement deposits in the central Peloncillo Mountains and the Dos Cabezas and Chiricahua Mountain areas, and Pb-Ag (Cu-Zn-Au) vein deposits in the Victorio Mountains area (figs. 1 and 2, map sheet). Total production from these deposits has been about 10,000 metric tons of Cu, with more than half of that from the Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits. The deposits are described elsewhere in this report under the principal commodity of the deposit type.

Favorable environments for volcanic-hosted, stratabound massive sulfide deposits and stratiform "red bed" type deposits may be present in the quadrangle. Stratabound massive sulfide deposits could occur in the Late Creataceous to early Tertiary volcano-plutonic terranes, but the apparent absence of submarine volcanism in these terranes argues against such an occurrence. The Permian Abo Formation, exposed locally in the Central mining region, is a favorable host for stratiform Cu deposits elsewhere in New Mexico, but there have been no reported indications of mineralization in the Abo rocks of the Silver City quadrangle.

Resource evaluation

The areally restricted Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits in the Central mining region, which currently are under exploration and development, appear to have the most potential as a Cu resource. Small amounts of Cu may be produced from the other precious and base metal vein and replacement deposits in the future, but no attempt is made to assess this minor resource on a deposit type basis. A Cu resource in deposits not presently known to occur in the quadrangle cannot be totally discounted; however, data to support the possible presence of such deposits are not encouraging.

RESOURCE SUMMARY

The identified Cu resource in the quadrangle is more than 16 million metric tons or about 20 percent of the total identified Cu resource of the United States (Cox and others, 1973). In addition, the undiscovered hypothetical resource is conservatively estimated at nx10^6 metric tons. These resources are chiefly in porphyry Cu (Mo) deposits but also include some contributions from Cu-Zn-Fe replacement deposits and a few precious and base metal vein and replacement deposits (table 2). Although no attempt is made to assess the speculative resource, the possibility of finding new districts should not be discounted.

Table 2.—*Estimated production, reserves, and resources of copper in the Silver City 1° x 2° quadrangle, New Mexico and Arizona*

[Values are in metric tons; leaders (—) indicate no data available]

	Porphyry Cu (Mo) deposits	Cu-Zn-Fe replace-ment deposits	Cu-Ag-Au (Pb-Zn) vein deposits	Cu vein deposits	Other precious and base metal vein and replacement deposits
Production	3,805,000	520,000	104,000	20,000	10,250
Reserve	7,700,000	500,000	—	—	—
Identified resource	7,600,000	nx10^5	nx10^4	—	nx10^3
Undiscovered resource	nx10^6	—	—	—	—

MOLYBDENUM

Molybdenite, the principal ore mineral of Mo, is an important secondary commodity, along with Ag and Au, in the porphyry Cu (Mo) deposits of the quadrangle and is currently a major byproduct of the Santa Rita porphyry Cu ores in the Central mining region. It also occurs in very small amounts in some of the Fierro-Hanover Cu-Zn-Fe replacement deposits and the Pinos Altos Au-Ag (base metal) veins in the Central mining region and in some of the Cu veins, Au-Ag-base metal veins, and Ag-Pb (Cu-Bi-U) veins peripheral to the Tyrone porphyry Cu (Mo) deposit in the Big Burro and Little Burro Mountains area (figs. 1 and 3, map sheet). Sparse wulfenite has also been reported in the oxidized ores in the Bayard Zn-Pb (Cu-Ag-Au) vein and replacement deposits in the Central mining region and the Lordsburg Cu-Ag-Au (Pb-Zn) veins in the Pyramid Mountains area. In addition, and perhaps of greater importance, are possible undiscovered stockwork Mo deposits that may be associated with middle Tertiary eruptive centers in the quadrangle.

PORPHYRY Cu (Mo) DEPOSITS

The porphyry Cu (Mo) deposits of the quadrangle are described in the preceding section on Cu. These deposits are genetically related to medium-K, calc-alkaline plutonic and hypabyssal rocks of Late Cretaceous to eary Tertiary age. They contain up to 0.02 percent MoS_2, and Mo:Cu on the order of 1:200. The total identified resource is about 88,000 metric tons MoS_2, and the undiscovered resource, in new deposits within areas of favorability (fig. 3, map sheet) may be significant. Deposits of this type in which Mo is dominant, like the Thompson Creek, Idaho, or Hall, Nevada, deposits, are not known in the quadrangle, but such variants could be present in, or associated with, the plutonic rocks hosting the known Cu-dominant deposits and in areas favorable for such deposits.

STOCKWORK Mo DEPOSITS

Two types of stockwork Mo deposits—granodiorite (F-poor) Mo deposits and granite (F-rich) Mo deposits—are distinguished in the western United States and Canada chiefly on the basis of differences in source pluton chemistry and tectonic setting (Mutschler and others, 1981). Although neither type is currently known to occur in the Silver City quadrangle, geologic environments are favorable for them, especially those of the granite Mo type. Granodiorite Mo type deposits are associated with medium-K, calc-alkaline intermediate composition plutonic rocks and may be part of a continuum of Mo-Cu deposit types of which the porphyry Cu (Mo) deposits represent a Mo-poor end member. Molybdenum-rich deposits of this type are discussed very briefly in the preceding section of porphyry Cu (Mo) deposits and are not considered further here. Granite Mo deposits, like those at Climax, Colo., and Questa, New Mex., probably have the greatest chance for discovery in the quadrangle. A brief descriptive model, taken largely from the data of Mutschler and others (1981) and Westra and Keith (1981) is presented below to provide criteria for evaluating the stockwork Mo potential in the quadrangle.

Granite Mo deposits are genetically associated with high-K, calc-alkaline epizonal plutons emplaced during, or just prior to, extensional tectonism in the western orogenic continental margin. In the Silver City quadrangle this period of crustal extension and concomitant eruption and emplacement of high-K magmas occurred in middle Tertiary time, about 15-30 m.y. ago. The source (and host) plutons are typically small plugs of high-silica (>75 percent SiO_2) peraluminous granite or rhyolite porphyry containing 8-10 percent $Na_2O + K_2O$, with K_2O invariably greater than Na_2O. The rocks are generally enriched in the incompatible elements, F, Be, Mo, Nb , Rb, Sn, Ta, Th, U, and W; accessory minerals include, Nb-ilmenite, fluorite, F-biotite, F-apatite, and a variety of complex black multiple oxides. The ore zone typically forms a hemispherical shell of quartz-molybdenite-fluorite stockworks at the apex of the source pluton and may grade upward into a tungsten-rich zone consisting of quartz-huebnerite-pyrite veins. Late stage veins of base sulfides, metal fluorite, and rhodochrosite may locally cut the ore zone and alteration halo. Ore grades are generally greater than 0.2 percent MoS_2; tungsten (and tin) may be present in economic amounts. Idealized hydrothermal alteration zonation outward from the ore zone, consists of a potassic core (chiefly K-feldspar), an intermediate quartz-sericite zone, and an outer argillic (clay minerals) zone.

Resource evaluation

Epizonal environments favorable for hosting granite molybdenum systems may underlie many of the middle Tertiary, high-K, calc-alkaline eruptive centers in the quadrangle. From criteria based on known deposits, eight eruptive centers, where fractionated high-silica rhyolites have been erupted or emplaced, are deemed most favorable for the occurrence of stockwork Mo deposits. These eruptive centers and intrusives, along with some geologic and geochemical recognition criteria, are listed in table 3 and outlined in figure 3 on the map sheet. Although Mo has been stressed as the principal commodity in these suspected metal systems, the possibility of other significant commodities, particularly tungsten and tin, either in combination with molybdenum or as separate deposit types should not be overlooked. Other middle Tertiary eruptive centers in the quadrangle (fig. 1, map sheet and Drewes and others, 1984), which are associated with less fractionated low-silica rhyolites and locally characterized by Zn, Pb, Mn, Ag, and Bi geochemical anomalies, may be centers of weak hydrothermal systems but their stockwork Mo potential does not appear significant.

Table 3.—*Middle Tertiary eruptive centers in the Silver City 1° x 2° quadrangle, New Mexico and Arizona that have stockwork Mo potential*

[Leaders (—) indicate no data available]

Eruptive center (numbers refer to figure 3, map sheet)	Age (m.y.)	Principal rock type and form	Accessory minerals	Associated ore deposit types	Geochemical signature from stream-sediment concentrates	Other remarks
1. Granite Gap	29–33	Leucogranite stock (73-76% SiO_2).	Nb-ilmenite, U- and Th-minerals, Nb-, Y-, Ti-complex oxides.	Au-Ag-base metal veins, W replacements, fluorite veins.	Pb, Zn, Ag, Bi, W, minor fluorite	High Rb.
2. White Signal and Shrine	28	Rhyolite domes, plugs, and dikes (77% SiO_2).	—	Au (Cu-Bi-U and Ag-Pb (Cu-Bi-U) veins, fluorite veins.	Bi, W, Mo, Pb	Forms arcuate zone around Tyrone stock (56 m.y.); highly altered.
3. Greasewood Mountain	23	Rhyolite dikes (76% SiO_2).	Yttro-fluorite REE-fluorite.	Small U vein deposits.	Bi, Mo, U, W, Sn, Pb, Ag, Ba, Cu, Mn, Th, Au, As, abundant fluorite.	Dikes associated with 24 m.y. eruptive center; high Rb.
4. Victorio Mountains	25	Rhyolite and granite porphyry dikes (76% SiO_2).	—	Pb-Ag (Cu-Zn-Au) veins, W-Be veins and replacements.	W, Bi, Be, Cu, Zn, Pb, Ba, Sn, Ag, fluorite.	Li-bearing clay alteration minerals; high Nb and Rb.
5. Lordsburg	—	Rhyolite plugs.	—	—	Sn, Bi, Pb, Mo, Ba, Mn.	Argillic alteration.
6. Ash Peak-Rhyolite Peak	21–23	Rhyolite domes and flows (75-77% SiO_2).	Fayalite, ilmenite, Ti-magnetite.	Ag (Au) veins, Mn veins.	Mn, Pb, Zn, Ba, Be, Cu, fluorite, cassiterite.	High Rb.
7. Tollgate Wash	17–21	Rhyolite dome (77% SiO_2).	Fayalite, Nb-ilmenite.	—	Mn, Pb, Zn, Cu, Ba, Be, fluorite cassiterite.	Argillic alteration.
8. Steeple Rock-Twin Peaks	21–28	Rhyolite dike swarm (73-78% SiO_2).	—	Ag-Au-base metal veins, Cu veins fluorite veins.	Cu, Pb, Ba, Ag, Sn, Be, Mo, fluorite.	Alunitic alteration.

RESOURCE SUMMARY

The porphyry Cu (Mo) deposits in the quadrangle have produced approximately 23,000 metric tons of MoS_2 and contain a total identified resource of about 88,000 metric tons of MoS_2. In addition, the resource in undiscovered porphyry Cu (Mo) deposits may be as much as 10^4 to 10^5 metric tons MoS_2. The favorable geologic environments for stockwork (Mo) deposits in the quadrangle suggest a possible resource potential in that deposit type.

ZINC AND LEAD

The Silver City quadrangle has produced significant amounts of Zn and Pb chiefly from replacement deposits in the Central mining region. Although some lead was produced from rich oxidized Ag-Pb ores in a number of vein and replacement deposits as early as 1880, major Zn production began about 1902, when the Fierro-Hanover massive replacement deposits were developed. Zinc is a principal commodity in the Fierro-Hanover Zn and Cu-Zn-Fe replacement deposits and, with Pb, is the principal metal in the Fierro-Hanover Zn-Pb replacements and the Bayard Zn-Pb (Cu-Ag-Au) vein and replacement deposits. Outside the Central mining region Pb was a principal commodity in the Pb-Ag (Cu-Zn-Au) vein deposits in the Victorio Mountains area, and both Zn and Pb are locally important secondary commodities in many of the base and precious metal vein and replacement deposits throughout the quadrangle. Some Zn is now (1981) being produced from two Cu-Zn-Fe replacement deposits, and both Zn and Pb are minor co-products from a few Au-Ag-base metal vein deposits in the Summit Mountains and Black Mountain area.

Zn, Zn-Pb, AND Cu-Zn-Fe REPLACEMENT DEPOSITS

These three subtypes of the Fierro-Hanover massive replacement deposits in the Central mining region (figs. 1 and 4, map sheet) account for most of the Zn and a considerable part of the Pb produced in the quadrangle. The deposit types are gradational and distinguished from each other chiefly on the basis of ore mineralogy. With the exception of some of the Zn-Pb deposits, all are skarn-associated, high- to medium-temperature metasomatic replacements in Paleozoic carbonate rocks near the contact of Laramide stocks. The Zn-Pb replacements occur in the outermost aureole of the contact zone and are not all associated with calc-silicate skarn minerals.

Description

The description of the Cu-Zn-Fe replacement deposits in the section on copper suffices as a generalized description of the Fierro-Hanover deposits, and only some of the salient features of the Zn and Zn-Pb replacement deposits are presented here. The Zn replacements, renown for their large Fe-rich sphalerite ore bodies, are localized principally around the south lobe of the Fierro-Hanover granodiorite-granodiorite porphyry stock (58-70 m.y.) in favorable strata of the Mississippian Lake Valley Limestone, or less commonly in limestones of the Pennsylvanian Syrena and Oswaldo Formations. Smaller Zn replacement deposits are associated with the Copper Flat quartz latite porphyry stock. The average grade of the 5 million metric tons of ore mined from the principal deposits up to 1952 was about 8.5 percent Zn. The Zn-Pb ratio ranges from 95:1 to 300:1 in the Zn replacement deposits and decreases southward away from the stock to 6:1 in the Zn-Pb replacements, concomitant with a decrease in the volume of silicated rock. The Zn-Pb replacement deposits occur south of the Fierro-Hanover stock, where they appear transitional between the Zn replacement deposits and the Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits, and locally on the west side of the Pinos Altos quartz monzonite stock (57-80 m.y.). The deposits occur chiefly in Mississippian and Pennsylvanian limestones; one deposit is in carbonate strata of the Permian Abo Formation. Ore grades were generally in the range of 9-15 percent Zn, 1-3 percent Pb, 0.2-1 percent Cu and 68-206 g/metric ton Ag. Both deposit types contained appreciable quantites of supergene-enriched ore above depths of 20 m, chiefly smithsonite in the Zn deposits and smithsonite and cerussite in the Zn-Pb deposits.

Resource evaluation

Geologic environments favorable for the occurrence of Zn, Zn-Pb and Cu-Zn-Fe replacement deposits, namely Paleozoic carbonate rocks intruded by Laramide stocks, are present in six areas in the quadrangle (fig. 4, map sheet). Areas 1-4 in the Central mining region are probably most likely to contain new deposits comparable in grade and size to known deposits. Although all of the known deposits occur in upper Paleozoic carbonate rocks, the more deeply buried lower Paleozoic carbonate rocks in the areas could also be favorable hosts. No data on Zn or Pb reserves are available; however, modest amounts of Zn are being produced from two active Cu-Zn-Fe deposits along the west side of the Fierro-Hanover stock. An identified resource of as much as 500,000 metric tons Zn may still remain in the known, inactive Zn replacement deposits, and a limited Pb and Zn resource may be present in the inactive Zn-Pb replacement deposits.

Zn-Pb (Cu-Ag-Au) VEIN AND REPLACEMENT DEPOSITS

Mesothermal veins and carbonate-hosted replacements occur in an east-northeast-trending zone, 2 km wide and 7 km long, in the Bayard district of the Central mining region. The northeast end of the mineralized zone is terminated a few kilometers south of the Laramide Fierro-Hanover granodiorite porphyry stock, and the southwest end is covered by Tertiary volcanic rocks and Quaternary and Tertiary basin fill. The desposits may represent an outer zone of metallization in a fissure system associated with emplacement of the Fierro-Hanover and Santa Rita stocks in a large complex eruptive center. Significant amounts of Zn, Pb, Cu, and Ag and minor Au and V have been produced, chiefly between 1900 and 1953. The Groundhog mine is being reopened.

Description

Deposits are fissure fillings along complex northeast-trending linked fault systems and, at depths below about 300 m, are massive, skarn-associated replacement deposits. The veins, as much as 1,200 m long, 7.5 m wide and dipping steeply southeast, occur in shale and sandstone of the Cretaceous Colorado Shale cut by a large quartz diorite sill and numerous granodiorite and quartz monzonite porphyry dikes. Ore shoots plunge gently northeast and tend to be localized where intrusive rocks form the vein walls. The replacement deposits are known only at the Groundhog mine, where they consist of tabular bodies parallel to faults, dikes, and locally bedding planes, chiefly in limestones of the Pennsylvanian Syrena and Oswaldo Formations and the Mississippian Lake Valley Limestone. Primary ore minerals in both vein and replacement deposits are sphalerite, galena, and chalcopyrite; secondary ore minerals, found at depths as great as 120 m along the veins include cerussite, smithsonite, anglesite, wulfenite, pyromorphite, endlichite, cuprodescloizite, chalcocite, Cu carbonates and native Cu, Ag, and Au. Pyrite, quartz, magnetite, specular hematite, clay minerals, sericite and calcite are the principal gangue minerals of the vein deposits; quartz, hedenbergite, andradite, ilvaite, rhodonite, and calcite occur in the replacement deposits. The grade of 200,000 metric tons of vein ore from the Groundhog mine averaged 14 percent Zn, 10 percent Pb, 5 percent Cu, and 340 g/metric ton Ag. Other vein deposits contained more Pb and less Cu. The replacement deposits at the Groundhog mine contain about the same amount of Zn, but less Pb, Cu, and Ag. Mineralization is related to complex Laramide intrusive activity centered at the Fierro-Hanover and Santa Rita stocks. The general sequence of ore-forming events is: (1) quartz-pyrite veining along pre-existing faults accompanied by intensive propylitic alteration and development of sericite and clay minerals, (2) emplacement of granodiorite and quartz monzonite porphyry dikes, and (3) renewed faulting, brecciation, and deposition of quartz and base metal sulfides.

Resource evaluation

The complex structural-intrusive environment that controlled the deposition of the Bayard Zn-Pb (Cu-Ag-Au) deposits is not apparent elsewhere in the quadrangle, and only the zone of known deposits and its extension under cover to the southwest is considered a potential resource area (fig. 5, map sheet). Known deposits in this area undoubtedly still consitute a significant Zn and Pb resource, especially the replacement ores in upper Paleozoic carbonate rocks. In addition, an undiscovered resource may exist in the deeper and virtually untested lower Paleozoic carbonate rocks in the area.

Pb-Ag (Cu-Zn-Au) VEIN DEPOSITS

The Pb-Ag (Cu-Zn-Au) vein deposits in the Victorio Mountains area (figs. 1 and 4, map sheet) have produced about 7,900 metric tons of Pb as a major coproduct of shallow, enriched Ag ores. Three areas are considered favorable for the occurrence of additional deposits and the Pb resource may be significant. The deposits are described in the section on gold and silver.

Cu-Ag-Au (Pb-Zn) VEIN DEPOSITS

Copper-tourmaline type Cu-Ag-Au (Pb-Zn) vein deposits of the Lordsburg district in the Pyramid Mountains area (figs. 1 and 4, map sheet) have produced about 3,100 metric tons of Pb and 740 metric tons of Zn. The deposits, which may be unique to the Lordsburg district, still contain a Pb and Zn resource at depth, but the high cost of deep underground mining may preclude their development. The deposits are described in the section on copper.

Ag (Pb-Mn) VEIN AND REPLACEMENT DEPOSITS

Some Pb was probably produced as a coproduct from the supergene-enriched Ag (Pb-Mn) vein and replacement deposits in the Central mining region (figs. 1 and 4, map sheet). Four areas have been delineated as favorable for their occurrence, but the probability of finding additional shallow deposits is not encouraging, and the Pb resource is not considered significant. The deposits are described in the section on gold and silver.

Ag-Pb (Cu-Bi-U) VEIN DEPOSITS

These deposits in the Big Burro and Little Burro Mountains area may have produced some Pb in conjunction with the early mining of shallow, enriched Ag ores. Only one area (fig. 4, map sheet), based chiefly on the presence of known deposits, is considered favorable for the occurrence of additional deposits; however, the lead resource is probably not significant. The deposits are described in the section on gold and silver.

OTHER BASE AND PRECIOUS METAL VEIN AND REPLACEMENT DEPOSITS

Five other precious and base metal vein and replacement deposit types have produced some Zn and(or) Pb as coproducts of precious metal ores. The deposits are described in the section on gold and silver.

Of significance are the Au-Ag-base metal vein and replacement deposits in the central Peloncillo Mountains area and the Dos Cabezas and Chiricahua Mountains area, and the Au-Ag-base vein deposits in the Summit Mountain and Black Mountain areas (Steeple Rock type) and the Big Burro and Little Burro Mountains area (Tyrone type). The former have produced about 8,300 metric tons of Pb and about 4,800 metric tons of Zn, chiefly as coproducts of Ag ores. The Steeple Rock type deposits have produced about 1,500 metric tons each of Zn and Pb from Au-Ag ores and a few mines are currently active. Production data for the Tyrone type deposits are very inadequate, but some Zn and Pb have been produced from a number of deposits. Four areas of favorability for the occurrence of these deposit types are delineated based on criteria outlined in the section on gold and silver (fig. 5, map sheet). Although modest Zn and Pb resources are present in many of the known deposits and the probability of discovering additional small deposits is good, development of the resource will undoubtedly depend on a substantial precious metal content of the ores.

Unknown, but apparently minor amounts of Zn and Pb have been produced from the Au-Ag (base metal) veins in the Pinos Altos district in the Central mining region, and some Pb has been recovered from the ores of the Au (base metal) veins and Telegraph type Au-Ag-base metal veins in the Big Burro and Little Burro Mountains area, and the Au (Ag-base metal) veins in the Dos Cabezas and Chiricahua Mountains area. The Zn and Pb resource in these deposits is probably not significant.

Table 4.—*Estimated production and resources of zinc and lead in the Silver City 1° x 2° quadrangle, New Mexico and Arizona*

[Values are in metric tons]

	Zinc		Lead	
	Zn, Zn-Pb, and Cu-Zn-Fe replacement and Zn-Pb (Cu-Ag-Au) vein and replacement deposits	Other precious and base metal vein and replacement deposits	Zn-Pb replacement and Zn-Pb (Cu-Ag-Au) vein and replacement deposits	Other precious and base metal vein and replacement deposits
Production	991,000	7,000	115,000	21,000
Resource	$nx10^5$	$nx10^3$	$nx10^4$	$nx10^3$

RESOURCE SUMMARY

The Fierro-Hanover type massive replacement deposits (Zn, Zn-Pb, and Cu-Zn-Fe replacements) and the associated Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits have accounted for more than 95 percent of the Zn and 75 percent of the Pb produced in the quadrangle (table 4). The total resource in these deposit types, which includes a modest reserve in a few active deposits, is about nx10^5 metric tons of Zn and nx10^4 metric tons of Pb. The Zn and Pb resource in all other deposit types may be locally significant, but development of the resource will depend largely on the content of other metals, especially Au and Ag, in the ores.

GOLD AND SILVER

Gold and silver were the principal metals sought by the early prospectors between the mid-1800's and early 1900's. Many shallow high-grade vein deposits were discovered and mined during that period, but records of this early activity are either incomplete or lacking entirely. The two precious metals are the principal commodities, generally along with the base metals, in a wide variety of vein and replacement deposits distributed throughout the quadrangle. Gold has also been produced from small placer deposits, and both metals are significant secondary commodities in the porphyry Cu (Mo) deposits. Current production is almost entirely byproduct Au and Ag from the porphyry Cu mining operations; only a few small vein and replacement deposits and one placer are being mined.

Au-Ag-BASE METAL VEIN DEPOSITS

Three subtypes of Au-Ag-base metal vein deposits—Steeple Rock, Tyrone, and Telegraph—are recognized within the quadrangle. All the deposits are predominantly telethermal to mesothermal quartz-rich fissure fillings, associated with precious and base metal minerals, localized along pre-existing faults. Each subtype has a relatively distinct mineralogy, geologic setting, and possibly distinct age. The Steeple Rock type deposits are in the Summit Mountains and Black Mountain area and the Tyrone and Telegraph types are in the Big Burro and Little Burro Mountains area (figs. 1 and 5, map sheet). Both the Steeple Rock and Tyrone type deposits have produced significant amounts of Au, Ag, Pb, and Zn, and some Cu and minor Bi. The deposits at Steeple Rock are the only ones currently being mined.

Description

Veins of the Steeple Rock type are intensely silicified and locally brecciated zones, as much as 15 m in width and 3 km in length, along and probably localized by major northwest and west-northwest-trending faults cutting a sequence of middle Tertiary, high-K andesite and dacite flows with minor intercalated pyroclastic rocks. The veins are commonly banded with comb structures. The principal ore shoots generally occur at fault intersections or at abrupt changes of strike along the fault-vein systems. Primary ore minerals are native silver(?), argentite, Au, pyrite, sphalerite, galena, and chalcopyrite; secondary ore minerals are silver, cerargyrite, and minor chalcocite, covellite, and manganese oxides. Quartz, locally amethystine, and occasional fluorite are the principal gangue minerals. The host volcanic rocks are propylitized and locally have been converted to alunite. Enriched oxidized ores, chiefly native Ag and cerargyrite with some native Au, extend to depths of 180 m. Below the oxidized zone Au and Ag contents decrease with an increase in base metal content. Deposition of Au and Ag was late in the paragenetic sequence; native Au generally occurs in vuggy open spaces. Known ore grades range from 3 to 22 g/t Au and from 280 to 1,500 g/t Ag with as much as 50 percent combined Pb, Zn, and Cu; the average district-wide ratio of Au:Ag has been about 1:40. The mineralization may be related to an episode of rhyolitic intrusive activity from 20 to 22 m.y. old. Fluorite vein, Cu vein, and Mn vein deposits peripheral to the Steeple Rock type deposits on the north, west, and south suggest the presence of a large, zoned, elongate hydrothermal system.

The Tyrone type deposits are silicified and locally brecciated fissure veins, as much as 2 km long, along northeast to east northeast-trending faults in Precambrian granite peripheral to the Tyrone quartz monzonite stock (56 m.y.). Rhyolitic dikes of possible middle Tertiary age occupy many of the fault zones and locally are mineralized. Primary ore minerals are native Au, and Ag(?), pyrite, chalcopyrite, bornite, sphalerite, galena, argentite, molybdenite, bismutite, bismuth, and minor radioactive minerals; secondary ore minerals include native Ag, cerargyrite, secondary Cu minerals, and Mn oxides. Quartz and locally fluorite, barite, and hematite are the principal gangue minerals. Argillic alteration of the host granite and rhyolite is locally pronounced. The deposits are generally oxidized and early mining was apparently restricted to shallow enriched oxide ores. With the exception of a few deposits, Au predominates over Ag; the area-wide range of the Au:Ag ratio is about 2:1 to 13:1. Although the veins are peripheral to the Tyrone stock, they may be genetically related to a younger middle Tertiary metallization event, associated with rhyolitic volcanism, centered to the north and south of the Tyrone stock. The Tyrone deposits appear to be gradational into the Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) vein deposits that are concentrated to the southeast of the Tyrone stock.

The Telegraph type deposits, in the northern part of the Big Burro and Little Burro Mountains area, consist of small quartz veins and silicified breccia zones chiefly in Precambrian granite and Cretaceous Beartooth Quartzite. The veins fill fractures and small faults in a broad northwest to east curvilinear zone of faulting that may be related to subsidence associated with the middle Tertiary (30-35 m.y.) Cliff eruptive center. Primary ore minerals are galena, sphalerite, chalcopyrite, bornite, and silver minerals; secondary ore minerals include malachite, azurite, chrysocolla, and Mn oxides. Quartz, generally iron-stained and locally amethystine, is the principal gangue; fluorite is occasionally present. The host granite at some of the deposits is intensely kaolinized. No data are available on the grade of the ores; some Ag has been produced, probably from shallow, oxidized parts of the veins.

Resource evaluation

Three areas (fig. 5, map sheet) considered favorable for the occurrence of Au-Ag-base metal vein deposits and their criteria are outlined below:

Criteria	Areas of favorability: 1 (Steeple Rock type)	2 (Telegraph type)	3 (Tyrone type)
Known deposits	x	x	x
Necessary conditions			
NW-trending faults associated with middle Tertiary rhyolitic intrusives	x		

NE-trending faults and rhyolitic dike swarm associated with subvolcanic middle Tertiary rhyolitic eruptive centers			x
Faults peripheral to middle Tertiary Cliff eruptive center		x	
Suggestive conditions			
Alunitic alteration	x		
Anomalous Bi, W, Mo, Pb, Cu, Ag ± Au, V, Be, F, and Nb in the nonmagnetic fraction of panned stream sediments			x
Broadly anomalous Pb, Zn, Ba, Mn ± Cu, Ag, Sn, and Mo in magnetic fraction of panned stream sediments	x	x	

The known Steeple Rock deposits in area 1 (fig. 5, map sheet) contain a minor identified Au and Ag resource. Development of this resource and of the possible undiscovered resource in other known and new deposits will probably depend on a high base metal content of the ores.

Au (Cu-Bi-U) AND Ag-Pb (Cu-Bi-U) VEIN DEPOSITS

Au, Ag, Cu, U, Bi, and probably Pb have been produced intermittently from the 1880's to about the mid-1950's from two similar precious-metal-bearing vein deposits that are confined chiefly to the White Signal district in the Big Burro and Little Burro Mountains area (figs. 1 and 5, map sheet). The deposits also share some characteristics with, and are probably genetically related to, the Tyrone type Au-Ag-base metal vein deposits northwest of the White Signal district. Production probably has been less than $200,000 in Au and Ag.

Description

The deposits are vein-filled fractures, fracture zones, and fault breccias, chiefly in Precambrian granitic rocks, with some local replacement of adjacent wallrock. The veins are small and commonly podlike, rarely more than 1 m wide and 2,000 m long, and are generally localized at the intersection of north-northwest-trending faults and associated Precambrian diabase dikes with east-northeast-trending faults and associated lower to middle Tertiary quartz monzonite and rhyolite dikes. Many of the Tertiary dikes occupy fault zones and form one wall of the vein system. Uranium minerals tend to be concentrated where veins cut or are adjacent to Precambrian diabase dikes. Primary minerals common to both deposit types are quartz, chalcopyrite, galena, uraninite(?) and Bi and Ag minerals. Other minerals in the Au (Cu-Bi-U) deposits are sphalerite, pyrite, magnetite, specular hematite, and native Au. Limonite, malachite, azurite, torbernite, autunite, and bismutite are the common secondary minerals in all deposits; cerargyrite and wulfenite occur in the Ag-Pb (Cu-Bi-U) deposits. All the veins are intensely oxidized, and minable Au and Ag ores were restricted to enriched zones within 30 m of the surface. The few assays available indicate ore grades as high as 300-600 g/metric ton Au, with as much as 30 percent Cu in the Au (Cu-Bi-U) deposits and as much as 2,400 g/metric ton Ag in the Ag-Pb (Cu-Bi-U) deposits. The deposits are concentrated in an area of highly altered subvolcanic rhyolitic intrusives of probable middle Tertiary age, in which the Ag-Pb (Cu-Bi-U) deposits are generally peripheral to the Au (Cu-Bi-U) deposits.

Resource evaluation

Only one area (fig. 5, map sheet) seems favorable for the occurrence of Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) vein deposits. Criteria used to define this area are: (1) known deposits, (2) intersections of north-northwest-trending faults and Precambrian diabase dikes with east-northeast-trending faults and Tertiary felsic dikes, (3) subvolcanic middle (?) Tertiary rhyolite centers, (4) intense hydrothermal alteration, and (5) anomalous Bi, W, Mo, Cu, Ag, ± Au and fluorite, and locally, within vicinity of felsic dikes, Be and Nb in the nonmagnetic fraction of panned stream sediments.

The Au and Ag resource in the area is probably small. Shallow, enriched deposits may still be present in the area, and primary ores in some of the larger known deposits may constitute an additional minor resource.

Au (BASE METAL) VEIN DEPOSITS

Au (base metal) vein deposits are restricted to the Gold Hill district in the Big Burro and Little Burro Mountains area (figs. 1 and 5, map sheet). The deposits are epithermal or telethermal Au-bearing quartz veins locally containing Ag and base metal minerals. Mining has been limited to shallow oxidized ore, and by 1900 these were largely exhausted. There has been no activity in the district since 1940; total production from the deposits is unknown.

Description

The veins are small, irregular fracture fillings, 2 cm to 1 m wide and less than 100 m long, with banded and drusy textures. Generally, they are localized along the contact of Precambrian diabase dikes or mafic schist and gneisses with Precambrian granite or granite gneiss. Very little is known about the primary ore minerals in the deposits. Native Au, quartz, pyrite, and limonite are the principal minerals in the veins in the central part of the district, and native Ag, ruby silver minerals, and cerussite are also present in a few deposits along the eastern periphery of the district. Galena and sphalerite are present in some of the dumps. The Au ores probably averaged 35 to 70 g/metric ton. Age of mineralization is not known.

Resource evaluation

Only the immediate area of known deposits (fig. 5, map sheet) is considered favorable for the occurrence of Au (base metal) vein deposits; the geochemical signature is not diagnostic. The amount of Au remaining in the known deposits and in any new deposits is probably small.

Au-Ag-BASE METAL VEIN AND REPLACEMENT DEPOSITS

Hydrothermal vein and closely related, skarn-associated metasomatic replacement deposits occur in the central Peloncillo Mountains area and the Dos Cabezas and Chiricahua Mountains area (figs. 1 and 5, map sheet). Au, much of it from highly oxidized ores, has been the principal precious metal commodity, and Pb and Zn the major base metals; Au and Cu have been the principal commodites in some of the deposits, generally in the Dos Cabezas and Chiricahua Mountains area. Most of the deposits were mined prior to 1920, and data on physical features and production are almost nonexistent. A few of the deposits are currently being reexplored for precious metals. Tungsten-bearing veins and replacements are locally associated with the deposits.

Description

The deposits are small, quartz-rich fissure fillings and carbonate-hosted replacements within two complex northwest-trending structural-intrusive zones. The largest deposits, in the central Peloncillo Mountains area, are replacements of Mesozoic and Paleozoic limestones, chiefly the Cretaceous Mural Limestone, at the contact of quartz monzonite and quartz latite porphyry sills and dikes of middle Tertiary (29-30 m.y.) age. Galena, sphalerite, chalcopyrite, and minor pyrite and magnetite are the principal primary ore minerals; gangue minerals are garnet, wollastonite, quartz, and calcite. Known ore grades were approximately 12 percent Pb, 5 percent Zn, and 68-114 g/metric ton Ag. The associated vein deposits, chiefly in Paleozoic limestone and Upper Cretaceous to lower Tertiary andesite, contain the same primary ore mineral assemblage, locally completely oxidized to masses of cerussite and smithsonite. In the Dos Cabezas and Chiricahua Mountains area the replacement deposits are confined to Upper Paleozoic limestones; the vein deposits occur in Paleozoic limestone and in Cretaceous sedimentary rocks and Upper Cretaceous and lower Tertiary volcanic rocks. Ore minerals are chalcopyrite, bornite, galena, sphalerite, and locally secondary base metal minerals. The age of the deposits is equivocal as small stocks and dikes of Laramide (56-62 m.y.) and middle Tertiary (28-34 m.y.) age both appear to be associated with the mineralization.

Resource evaluation

Two areas (fig. 5, map sheet) considered favorable for the occurrence of Au-Ag-base metal vein and replacement deposits and their criteria are outlined below:

Criteria	Areas of favorability 1	2
Known deposits	x	x
Necessary conditions		
Favorable Paleozoic carbonate host rocks intruded by Laramide and middle Tertiary felsic plutons	x	
Favorable Paleozoic and Mesozoic carbonate host rocks intruded by middle Tertiary felsic dikes, sills, and plutons		x
Suggestive conditions		
Complex NW-trending fault zones	x	x
Anomalous Bi, W, Mo, Pb, Cu, Ag ± Au, V, Be, F, and Nb in the nonmagnetic fraction of panned stream sediments	x	x
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag ± Mo, Be, Sn, and F in either or both the nonmagnetic or magnetic fractions of panned stream sediments	x	x

Although Au- and Ag-bearing ores may still be present in the known deposits and additional small deposits are likely to be discovered in both areas, the total amount of Au and Ag is probably small and development is probably dependent on the base metal content of the ores.

Au (Ag-BASE METAL) VEIN DEPOSITS

Deposits are gold-quartz veins that probably share a common genesis with closely associated Au-Ag-base metal vein and replacement deposits in the Dos Cabezas and Chiricahua Mountains area (figs. 1 and 5, map sheet). They are distinguished from other deposits largely on differences in ore mineralogy and host rocks. Very little information is available on the deposits; they were mined chiefly between 1800 and 1920, with intermittent and local activity to 1941.

Description

The deposits are small, quartz-rich fissure veins chiefly within a wide northwest-trending fault-intrusive zone. Most of the principal deposits occur along a major fault that juxtaposes metamorphosed Cretaceous shales against Precambrian granitic and metamorphic rock. Ore minerals are native Au and auriferous pyrite with subordinate base metal sulfides and locally some secondary Mn and Cu minerals. As with the associated Au-Ag-base metal vein and replacement deposits, the age of mineralization is uncertain as both small Laramide and middle Tertiary plutons appear to be related to the deposits.

Resource evaluation

One extensive area (fig. 5, map sheet) is considered favorable for the occurrence of Au (Ag-base metal) vein deposits on the basis of the following criteria: (a) known deposits, (b) complex northwest-trending fault zone, (c) favorable (?) Mesozoic sedimentary host rocks intruded by small Laramide and middle Tertiary felsic plutons, and (d) anomalous Bi, W, Mo, Cu, Ag, Be, and locally B, Co, and Mn in the nonmagnetic fraction of panned stream sediments. Shallow ores in the known deposits are apparently depleted. Small deposits are likely to be present in the favorable area, but the Au and Ag resource is probably minor.

Au-Ag (BASE METAL) VEIN DEPOSITS

Mesothermal(?) Au- and Ag-bearing quartz veins of the Au-Ag (base metal) type are limited mostly to a small area along the west side of the Pinos Altos stock in the Central mining region (figs. 1 and 5, map sheet). Two deposits in the Dragoon Mountains that have produced some Au and Ag are also classified under this deposit type, but details of their geology are lacking. The description below is based almost entirely on the Pinos Altos deposits, which produced about $2,000,000 in Au and Ag, mostly prior to 1910. None of the deposits are currently being mined.

Description

The veins are simple fissure fillings, as much as 1.6 km long, 1-2 m wide, and have been mined to depths of 25 m along north-northeast to northeast-trending fractures and faults in a zone about 3 km wide and less than 5 km long. Host rocks are quartz monzonite porphyry and more mafic variants of the Laramide (57-80 m.y.) Pinos Altos stock and Upper(?) Cretaceous andesite breccias. The primary ore minerals, chiefly base metal sufides and argentite, native Au, and auriferous pyrite, occur in bands alternating with a gangue of quartz, siderite, calcite, rhodochrosite, barite, and dolomite. Most veins contained free-milling Au near the surface associated with native Ag, cerargyrite, and secondary Cu and Pb minerals. No change in the character of the primary ore with depth has been recognized. Au:Ag ratios for the primary ores were about 1:3-5, with grades ranging from 9 to 48 g/metric ton Au, 26 to 238 g/metric ton Ag, and up to 20 percent combined based metals. Mineralization may be related to the final stages of emplacement of the Pinos Altos stock.

Resource evaluation

Only one area (fig. 5, map sheet), based chiefly on the presence of known deposits, is considered favorable for the occurrence of Au-Ag (base metal) vein deposits. Elsewhere in the quadrangle Laramide plutons in Cretaceous volcanic terranes may host deposits of this type, but in general they are associated with other precious and base metal vein and replacement deposit types. In the one designated favorable area, some ore may still occur at depth in the known deposits, but the probability of discovering new deposits at the present level of erosion is poor. The Au and Ag resource is probably very small.

Ag (Au) VEIN DEPOSITS

Epithermal vein deposits associated with two middle Tertiary eruptive centers occur in the Gila and northern Peloncillo Mountains area and the central Peloncillo Mountains area (figs. 1 and 5, map sheet). Significant amounts of Ag and some Au were mined from the deposits, mostly prior to 1940, with intermittent production and exploration activity continuing to the present.

Description

In the Gila and northern Peloncillo Mountains, the principal deposits are along a prominent fissure vein, 3 km long and as much as 6 m wide, that occupies a fault trending N.60°W. in middle Tertiary andesite flows. The ore consists of streaks and disseminations of fine-grained argentite(?) in dense chalcedonic quartz, locally abundant gray to black calcite, and minor pyrite and rhodochrosite. Mineralization may be genetically associated with the Ash Peak-Rhyolite Peak eruptive center (22-24 m.y.) whose rhyolite domes, flows, and pyroclastic deposits overlie the andesitic host rocks of the veins. To the south in the central Peloncillo Mountains area, similar quartz-rich fissure veins and breccia-fillings occur in the ring-fracture zone of a small, possibly resurgent, caldera in the Steins Peak eruptive center (33-35 m.y.). The deposits are oxidized to depths of 30 m, with cerargyrite the principal ore mineral. Primary ore minerals are argentite and pyrite with subordinate galena, sphalerite, chalcopyrite, bornite, and native Au. The Au:Ag ratio is about 1:500; ore grades average about 1 g/metric ton Au and 500 g/metric ton Ag.

Resource evaluation

Three areas (Fig. 5, map sheet) deemed favorable for the occurrence of Ag (Au) vein deposits and their criteria are outlined below:

Criteria	Areas of favorability 1	2	3
Known deposits	x	x	
Necessary conditions			
NW-trending fault zone associated with large, complex middle Tertiary rhyolitic eruptive center	x		
Ring fracture zone of middle Tertiary eruptive center		x	x
Suggestive conditions			
Argillic alteration		x	
Broadly anomalous Pb, Zn, Be, Mn ± Cu, Ag, Sn, and Mo in the magnetic fraction of panned stream sediments	x	x	x
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag ± Mo, Be, Sn, and fluorite in either, or both, the magnetic and nonmagnetic fraction of panned stream sediments	x	x	x

Known deposits in areas 1 and 2 (fig. 5, map sheet) still contain small tonnages of ore, and the probability of discovering new deposits, especially in areas 1 and 2, is good. The total Au and Ag resource, however, is probably small.

Cu-Ag-Au (Pb-Zn) VEIN DEPOSITS

The copper-tourmaline type Cu-Ag-Au (Pb-Zn) deposits of the Lordsburg district in the Pyramid Mountains area have been major producers of Au and Ag. They were last mined about 1975. The veins continue below the level of deepest mining (720 m) and ore containing as much as 400 g/metric ton Ag and 10 g/metric ton Au is doubtless still present at depth. The deposits are described in the section on copper.

Resource evaluation

The deposits may be unique to the Lordsburg district and only the area of known deposits is considered a potential resource area (fig. 5, map sheet). High contrast anomalies of B (200- >1,000 ppm), Cu, Ag, Pb, Zn, and fluorite in the nonmagnetic fractions of panned stream sediments characterize the area. A significant Au and Ag resource is probably present at depth in the known deposits but the high cost of deep underground mining may preclude their development. Undiscovered small shallow deposits in the area may consitute a limited resource.

Ni-Co-Ag (U) VEIN DEPOSITS

Small, Ag-rich veins, similar in many aspects to the deposits at Great Bear Lake, Canada, and Joachimsthal, Czechoslovakia, are restricted to a northeast-trending zone, 2 km wide by 10 km long, in the Blackhawk district of the Big Burro and Little Burro Mountains area (figs. 1 and 5, map sheet). The deposits have produced an estimated 40,000 kg of Ag, mostly between 1881 and 1893; mining and exploration activity has continued sporadically up to the present time.

Description

The deposits are narrow fissure fillings along two intersecting fault systrems (north to northeast and northeast to east) chiefly in Precambrian quartz diorite gneiss along the southeast side of a small, Laramide (72 m.y.) monzonite porphyry stock. The veins are crudely banded locally and up to 300 m long, 3 m wide, and have been mined to a depth of 230 m. Ore shoots consist of massive lenses and pods in sharp contact with gangue minerals. Primary ore minerals include native Ag, argentite, niccolite, millerite, skutterudite, nickel skutterudite, sphalerite, bismuthinite, and pitchblende. Secondary ruby silver minerals and cerargyrite are locally abundant. The carbonate-rich gangue consists of calcite, dolomite, ankerite, siderite, rhodochrosite, barite, quartz, and pyrite. The apparent abundance of native Ag in the upper levels of the deposits and increase in argentite and sphalerite with depth suggests a secondary origin for some of the ores. Ore grades vary widely; assays of as much as 86,000 g/metric ton Ag, 8.9 percent Ni, 0.9 percent Co, 8.8 percent Zn and 0.24 percent U_3O_8 have been reported. Lead-uranium isotope data support a Laramide age for the mineralization, suggesting a genetic relation with the closely associated monzonite porphyry stock.

Resource evaluation

Only the area of known deposits (fig 5, map sheet) is considered a favorable resource area. Additional undiscovered deposits in the area and primary ores at depth in the known deposits may constitute a small Ag resource.

Ag (Pb-Mn) VEINS AND REPLACEMENT DEPOSITS

Veins and replacements of oxidized and supergene-enriched Ag ores occur in a number of districts in the Central mining region (figs. 1 and 5, map sheet) and were some of the earliest mined deposits in the quadrangle, producing significant amounts of Ag and some Pb , mostly prior to 1893. They are probably genetically related to the Mn (Fe) replacement deposits of the area, and in the Chloride Flat district were mined in the 1940's for Mn-Fe ore. The deposits are similar to the rich Ag-Mn replacement deposits of the Lake Valley, Hermosa, and Kingston districts in the Black Range of New Mexico. Currently, Ag is being produced from the old dumps, and possibly from newly mined ore, in the Georgetown district.

Description

The deposits consist of very irregular lenses and pods, as much as 75 m long, 18 m wide, and a few meters thick, and veinlike stringers replacing favorable host rock outward from faults, fractures, and bedding planes, near major northwest-trending faults. The largest and most productive deposits are localized in the upper beds of the Silurian Fusselman Dolomite immediately below the Devonian Percha Shale. Smaller deposits occur in the Mississippian Lake Valley Limestone, the Cretaceous Beartooth Quartzite, and Precambrian granite. The ore minerals, all secondary in origin, consist of cerargyrite, native Ag, cerussite, argentite(?) and locally pyrolusite, hematite, and limonite. Primary ore minerals are probably galena and argentite. Calcite, quartz, barite, and ferroan-manganoan magnestite are the principal gangue minerals. Host rocks are locally silicified, but skarn type calc-silicate minerals are generally absent. An exception is the Fleming Camp area where scheelite, garnet, and diopside occur as heavy minerals in stream-sediment concentrates. Ore is restricted to the oxidized zone above the present water table or generally above depths of 60 m. Some of the deposits were extremely rich, but data on grades are not available. The deposits are not spatially related to any exposed plutonic rock. Primary mineralization has been attributed to hydrothermal solutions rising from depth along major faults and spreading laterally along minor structures and bedding planes in favorable host rock.

Resource evaluation

Four areas (fig. 5, map sheet) considered favorable for the occurrence of Ag (Pb-Mn) vein and replacement deposits and their criteria are outlined below:

Criteria	Areas of favorability 1	2	3	4
Known deposits	x	x	x	x
Necessary conditions				
Favorable lower Paleozoic carbonate host rocks proximal to known NW-trending major faults	x			
Suggestive conditions				
Favorable lower Paleozoic carbonate host rocks proximal to inferred NW-trending major faults		x	x	x
Associated Mn (Fe) replacement deposits	x	x	x	
Anomalous Bi, W, Mo, Pb, Cu, Ag ± Au, V, Be, F, and Nb in the nonmagnetic fraction of panned stream sediments				x
Broadly anomalous Pb, Zn, Ba, Mn ± Cu, Ag, Sn, and Mo in the magnetic fraction of panned stream sediments	x	x	x	x
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag ± Mo, Be, Sn, and fluorite in either, or both, fractions of panned stream sediments	x	x	x	x

Modest quantites of unmined ore probably remain in some of the known deposits, but the probability of discovering additional enriched deposits is slight. Even though favorable geologic environments are present, the Ag resource is probably not significant.

Pb-Ag (Cu-Zn-Au) VEIN DEPOSITS

The Pb-Ag (Cu-Zn-Au) veins, restricted to a small district in the southern part of the Victorio Mountains area (figs. 1 and 5, map sheet), have characteristics similar to the Au-Ag-base metal vein and replacement deposits of the central Peloncillo Mountains and the Dos Cabezas-Chiricahua Mountains area. Most of the known deposits were mined out prior to 1904, but intermittent production and intense exploration activity have continued to the present. Significant amounts of Pb and Ag and small amounts of Cu, Zn, and Au have been produced.

Description

The deposits are highly oxidized replacement veins in Silurian Fusselman Dolomite within a wide east-trending fault zone. The veins, as much as 7 m wide, trend northeast, possibly reflecting tensional structures within the fault zone. Cerussite, anglesite, smithsonite, secondary Cu minerals, and galena are the principal ore minerals. Mining was apparently restricted to the oxidized zone, or depths of about 100 m; the nature of the primary ore is not known. Grade of some ore mined after1904 averaged 12 percent Pb, 257 g/metric ton Ag, and 4.8 g/metric ton Au. Deposits may be genetically related to middle Tertiary (25 m.y.) rhyolite dikes associated with W-Be vein and replacement deposits a short distance to the north, or possibly to a buried granitic pluton.

Resource evaluation

Three areas (fig. 5, map sheet) considered favorable for the occurrence of Pb-Ag (Cu-Zn-Au) vein deposits and their criteria are outlined below:

Criteria	Areas of favorability 1	2	3
Known deposits	x		
Necessary conditions			
Favorable lower Paleozoic carbonate host rocks	x	x	x
Suggestive conditions			
Major EW-trending fault zone	x		
Major WNW- to NW-trending fault zone		x	x
Middle Tertiary rhyolite dikes	x		
Anomalous Bi, W, Mo, Pb, Cu, Ag ± Au, V, Be, F, and Nb in the nonmagnetic fraction of panned stream sediments	x		
Locally anomalous Pb, Cu, Ba, Mn, Zn, Ag ± Mo, Be, Sn, and fluorite in either, or both, the magnetic and nonmagnetic fractions of panned stream sediments		x	x

Shallow, basin-fill deposits and thin, extrusive Tertiary volcanic rocks may cover a much larger area of favorable geologic terrane, especially between areas 2 and 3. The Ag resource may be significant.

Au PLACER DEPOSITS

Many small Au placer deposits are present throughout the quadrangle generally in dry stream-courses draining areas of known lode gold deposits (figs. 1 and 5, map sheet). Deposits in the Central mining region were last worked in the early 1900's, whereas those in the Big Burro and Little Burro Mountains area and the Dos Cabezas and Chiricahua Mountains area have been mined intermittently until about 1950. Currently one placer deposit in the Gila and northern Peloncillo Mountains area is active. Production of placer Au is conservatively estimated at 1,000 kg.

Description

With the exception of the deposits in the Gila and northern Peloncillo Mountains area, the placers are confined to recent alluvium in small, generally dry streams. Small amounts of native Bi and garnet have also been recovered in the gold placers draining the area of Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) vein deposits in the Big Burro and Little Burro Mountains area. The placer Au in the Gila and northern Peloncillo Mountains area occurs in both the old and modern gravels of the Gila and San Francisco Rivers and apparently was derived from metalliferous deposits in the Clifton-Morenci district just north of the Silver City quadrangle. Abundant black sand and clasts of massive hematite, as large as cobble size, are associated with the native Au. The meager analytical data suggest grades of 0.08 to 0.8 g/m^3 in the old gravels and 0.04 g/m^3 in the modern gravels of the rivers.

Resource evaluation

Only a restricted part of the Gila and San Francisco River drainages is considered a potential resource area (fig. 5, map sheet). The area is delineated chiefly by the distribution of old river gravels and some restricted modern alluvium downstream from the Clifton-Morenci mining district. Elsewhere small deposits of locally-derived placer Au are undoubtedly present in many areas in the quadrangle where lode Au deposits occur, but the high cost of dry placer mining has discouraged the development of known deposits and the exploration for others. The total placer Au resource may be on the order of nx10^3 kg.

OTHER DEPOSIT TYPES

The porphyry Cu (Mo) deposits (figs. 2 and 3, map sheet and table 1) are the major current producers of gold and silver in the quadrangle. Two deposits, mining 6 to 14 million metric tons of ore annually, are currently active and a third is under development for production. Available data on the precious metal content of the porphyry ores indicates widely varying grades of 0.0002-0.7 g/metric ton Au and 0.0007-6 g/metric ton Ag. The deposits are described and areas of favorability outlined in the section on copper.

Silver and some Au have been produced from the Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits and the closely associated Fierro-Hanover type Zn-Pb replacement deposits in the Central mining region (figs. 1 and 5, map sheet). Most of the precious metal production from these deposits has been from shallow oxide ores; however, primary ores, especially in some of the Bayard type deposits, may contain significant values in Au and Ag. The deposits are described in the section on lead and zinc.

The possibility of other Au- and Ag-bearing deposit types occurring in the quadrangle should not be discounted. Potentially favorable host rocks for Carlin-type disseminated Au deposits may be present in the Paleozoic terranes in the southern part of the quadrangle and some of the middle Tertiary volcanic eruptive centers may be favorable areas for the occurrence of disseminated Ag deposits.

RESOURCE SUMMARY

The Au and Ag resource of the quadrangle is limited almost entirely to byproduct metal from the porphyry Cu deposits. The total identified resource is estimated at nx10^5 to 10^6 kg of Au and nx10^6 kg of Ag, which includes reserves of about 200,000 kg of Au and 1,000,000 kg of Ag (table 5). Total production of precious metals is conservatively estimated at 26,000 kg of Au and 1,300,000 kg of Ag, most of which was derived from the early mining of Au- and Ag-bearing vein and replacement deposits. The precious metal resource in deposits of this type, however, is probably not greater than the nx10^3 kg of Au or nx10^5 of Ag. Many of the known vein and replacement deposits, especially those that contained shallow, enriched ores, are mined out and the likelihood of discovering significant new deposits is not encouraging. The Steeple Rock Au-Ag-base metal veins, Bayard Zn-Pb (Cu-Ag-Au) veins and replacements, and the Lordsburg Cu-Ag-Au (Pb-Zn) veins still contain ore at depth and probably constitute the most significant Au and Ag resource in any of the known vein and replacement deposit types.

Table 5.—*Estimated production, reserves, and resources of gold and silver in the Silver City 1° x 2° quadrangle, New Mexico and Arizona*

[Values are in kilograms. Leaders (—) indicate no data available]

	Gold			Silver	
	Vein and replacement deposits	Placer deposits	Porphyry Cu (MO) deposits	Vein and replacement deposits	Porphyry Cu (Mo) deposits
Production	23,000	1,000	2,000	1,100,000	240,000
Reserve	—	—	200,000	—	1,000,000
Identified resource	nx10^3	—	nx10^5	—	nx10^6
Undiscovered resource	nx10^3	nx10^3	nx10^4	nx10^5	nx10^6

VANADIUM

Secondary vanadium minerals, chiefly cuprodescloizite and endlichite, occur in the oxidized zone of a number of Bayard type Zn-Pb (Cu-Ag-Au) vein and replacement deposits in the Central mining region (figs. 1 and 6, map sheet). Recorded production consists only of 14 metric tons of 9 percent V_2O_5 from one deposit in 1911. High Pb and V geochemical anomalies north of Greasewood Mountain in the Pinaleno Mountains (fig. 6, map sheet) may indicate the presence of small vein type deposits. Other than as a byproduct from large scale porphyry copper mining, no significant V resource is indicated.

BISMUTH

Bismuth minerals, including native Bi and bismuthinite in primary ores and bismite and bismutite in secondary ores, are found principally in the Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) vein deposits and the associated Tyrone-type Au-Ag-base metal vein deposits in the Big Burro and Little Burro Mountains area (figs. 1 and 6, map sheet). Bismuthinite, matildite, cosalite, and emplectite also occur in the Zn-Pb replacement deposits related to the Pinos Altos stock in the Central mining region and unknown Bi minerals have been reported in two W vein and pegmatite deposits in the Big Burro and Little Burro Mountains area. Unusually high Bi geochemical anomalies along the Stockton Pass fault zone and in the vicinity of the middle Tertiary Greasewood Mountain eruptive center in the Pinaleno Mountains area (fig. 6, map sheet) also suggest the presence of Bi minerals. Production from the quadrangle has been limited to less than 10 metric tons, all from the Au (Cu-Bi-U) and Tyrone type Au-Ag-base metal vein deposits; the resource is probably not significant.

IRON

Significant quantities of Fe ore have been mined from the Fierro-Hanover type massive replacement deposits in the Central mining region. In the four Fierro-Hanover deposit types (Fe, Zn, Cu-Zn-Fe, and Zn-Pb replacement deposits) Fe is the principal commodity in the Fe replacement deposits and a secondary commodity in some of the Zn and Cu-Zn-Fe replacement deposits. An Fe resource is also present in the oolitic hematite beds of the Cambrian Bliss Formation and possibly in small magnetite deposits of metamorphic origin. Production of iron ore from the Fe replacement deposits ceased in 1944; minor amounts of iron ore are currently being produced from the Cu-Zn-Fe replacement deposits.

Fe, Cu-Zn-Fe, AND Zn REPLACEMENT DEPOSITS

Three subtypes of the Fierro-Hanover massive replacement deposits are skarn-associated moderate- to high-temperature metasomatic deposits in Paleozoic carbonate rocks near the contact of Laramide stocks. The deposit types are gradational and are distinguished from each other solely on differences in dominant ore mineralogy: magnetite and hematite in the Fe deposits; chalcopyrite, sphalerite, and magnetite in the Cu-Zn-Fe deposits; and sphalerite in the Zn deposits. The Fe replacement deposits, which have produced most of the iron ore in the quadrangle, are localized chiefly around the north lobe of the Fierro-Hanover granodiorite-granodiorite porphyry stock (58-70 m.y.). Smaller Fe deposits are associated with the Santa Rita quartz monzonite porphyry stock (56-63 m.y.) and the Copper Flat quartz latite prophyry stock. The known Cu-Zn-Fe deposits occur along the northwest side of the Fierro-Hanover stock and the northwest side of Pinos Altos quartz monzonite stock (57-80 m.y.), and the Zn deposits are concentrated around the south lobe of the Fierro-Hanover stock. Additional descriptive information on these replacement deposits is in the sections on copper and lead and zinc.

Resource evaluation

Six areas (1-6, fig. 7, map sheet) considered favorable for the occurrence of Fe replacement deposits (including Zn and Cu-Zn-Fe replacement deposits) and their criteria are outlined below:

Criteria	Areas of favorability					
	1	2	3	4	5	6
Known deposits	x					
Necessary conditions						
Favorable Paleozoic carbonate host rocks intruded by Laramide stocks	x	x	x	x	x	x
Suggestive conditions						
NE-trending fracture-fault zones	x	x				
Strong positive aeromagnetic anomalies			x	x	x	x

Undiscovered deposits in all favorable areas are likely to be deep and not amenable to mining unless substantial amounts of Cu and Zn are present. The probability of finding new, near-surface deposits is not encouraging.

SEDIMENTARY Fe DEPOSITS

Oolitic hematite beds occur in basal parts of the Cambrian Bliss Sandstone along the west side of the Central mining region area (figs. 1 and 7). The Fe-bearing strata consist chiefly of mixtures of hematite, quartz, and glauconite with local segregations of nearly pure hematite. Known hematitic beds range from a few centimeters to more than a meter thick; in the Sycamore Canyon area a 5-m-thick section contains 3.8 m of 25 percent Fe.

Resource evaluation

Based solely on the distribution of Bliss Sandstone outcrops, two areas have been delineated (fig. 7, map sheet) as favorable for the occurrences of low grade sedimentary Fe deposits.

METAMORPHIC Fe DEPOSITS

A small deposit of banded magnetite and serpentine occurs in Precambrian granite at the northwest end of the Big and Little Burro Mountains area. The deposit is apparently a metamorphosed xenolith or pendant of calcareous rock in granite. The magnetite bands are as much as 0.6 m thick and 3 m long. The small size and very local occurrence of the magnetite-serpentine deposits argues against the possibility of finding sufficient volume of magnetite to be economically significant.

RESOURCE SUMMARY

Production of Fe ore (50-59 percent Fe) in the Silver City quadrangle has been about 7,000,000 metric tons, chiefly from the Fierro-Hanover type Fe replacement deposits, with modest contributions from associated Fierro-Hanover type Zn and Cu-Zn-Fe replacement deposits (table 6). Only two Cu-Zn-Fe replacement deposits are currently producing small amounts of Fe ore as minor coproducts in a Cu-Zn operation. Reserves are not known. The identified Fe resource in the Fierro-Hanover type deposits is about nx10^7 metric tons. This resource is chiefly in the inactive Fe replacement deposits around the north lobe of the Fierro-Hanover stock; included in the estimate are modest resources from the Fe replacement deposits at the Copper Flat stock and the Cu-Zn-Fe replacement deposits associated with the Fierro-Hanover and Pinos Altos stocks.

The low grade (about 25 percent Fe) sedimentary Fe deposits in the Silver City quadrangle constitute a resource of possible future significance. The identified resource in one area of Bliss Sandstone outcrop near Sycamore and Bear Canyons is about nx10^6 metric tons; the undiscovered resource in the Bliss Sandstone may be as much as nx10^8 metric tons.

Table 6.—*Estimated production, reserves, and resources of iron ore in the Silver City 1° x 2° quadrangle, New Mexico and Arizona*

[Values are in metric tons; Leaders (—) indicated no data available]

	Fe replacement deposits (includes Zn and Cu-Zn-Fe replacement deposits) (50–59% Fe)	Sedimentary Fe deposits (about 25% Fe)
Production	7,100,000	None
Reserve	Some, amount unknown	—
Identified resource	nx10^7	nx10^6
Undiscovered resource	—	nx10^8

MANGANESE AND MANGANESE-IRON

Manganese, a metal of strategic national importance, has been produced in small quantity from several deposit types throughout the quadrangle. It occurs as the principal commodity in small Mn vein deposits and, in association with Fe,in Mn (Fe) replacement deposits, and as a secondary commodity in Ag (Pb-Mn) vein and replacement deposits. Local concentrations of both primary and secondary Mn minerals also occur in many of the fluorite vein deposits and in a few of the base and precious metal vein and replacement deposits. There has been no recorded production of Mn in the quadrangle since about 1956.

Manganese-iron (spiegeleisen) is the principal commodity in the Mn (Fe) replacement deposits and, like Mn, is a secondary commodity in some of the Ag (Pb-Mn) vein and replacement deposits. Substantial amounts of Mn-Fe have been produced in the quadrangle, and the largest and most productive deposits (Boston Hill area) are currently being mined (fig.8, map sheet).

Mn VEIN DEPOSITS

The Mn vein deposits in the Silver City quadrangle are of shallow, low-temperature hydrothermal origin (Hewett and Fleischer, 1960). They occur in a broad belt of hypogene Mn oxide deposits that extends from southwest New Mexico, across southern Arizona, and into southern California and Nevada.

Description

The deposits occur as simple fissure-filling veins, veinlets, breccia zones, and locally irregular pods and lenses, as much as 6 m wide and 90 m long, and have been explored to depths of 30 m, chiefly along northwest-trending Basin and Range faults or splayed fracture systems related to these faults. Locally, deposits occur within fracture-fault systems associated with large middle Tertiary eruptive centers. Principal host rocks are middle Tertiary felsic to mafic flows, pyroclastic rocks, and felsic dome-flow complexes. A few deposits occur in Precambrian granitic rocks and late(?) Tertiary volcaniclastic rocks. Primary ore minerals are chiefly psilomelane and cryptomelane(?); secondary ore minerals include wad and pyrolusite. The gangue consists chiefly of calcite (locally manganiferous), quartz, and chalcedony; opal, travertine, fluorite, and gypsum occur locally. As much as 2% W, and traces to a few percent Ba, Zn, Co, Pb, Ag, and Cu are generally present in the manganese oxides. No zoning is apparent within the limited depths of exploration, but the ore bodies are locally enriched by supergene processes. Maximum production for individual deposits is 2,000 metric tons, with the average probably less than 100 metric tons. Grades range from 17 to 40 percent Mn. Deposits are middle to late Tertiary in age (30-5 m.y.) and apparently formed near surface as a result of ascending hydrothermal solutions. Some deposits are near known hot springs.

Recource evaluation

The probability of finding additional small deposits is good. Eleven areas considered favorable for the occurrence of Mn vein deposits (1-11, fig.8, map sheet) and their criteria are outlined below:

Criteria	Areas of favorability										
	1	2	3	4	5	6	7	8	9	10	11
Known deposits	x	x	x	x	x	x					
Necessary conditions											
Middle to upper Tertiary volcanic and volcaniclastic rocks cut by known Basin and Range faults	x	x		x					x	x	x
Suggestive conditions											
Faults and fracture systems associated with middle Tertiary eruptive centers			x			x	x	x			
Basin and Range faults under shallow cover as indicated by magnetics and(or) gravity					x		x				
Hot springs				x			x				
Calcite veins			x	x				x			
Broadly anomalous Pb, Zn, Ba, Mn, ± Cu, Ag, Sn, and Mo in the magnetic fraction of panned stream sediments	x	x	x	x	x	x	x	x	x	x	x

Mn (Fe) REPLACEMENT DEPOSITS

Mn (Fe) replacement deposits are known only in the Central mining region in the northeast corner of the quadrangle (figs. 1 and 8, map sheet). The deposits are supergene-enriched replacement bodies in Paleozoic carbonate rocks, physically similar (and probably genetically related) to the Ag (Pb-Mn) vein and replacement deposits, but lack significant amounts of Ag and Pb minerals. Both Mn and Mn-Fe ores have been produced from the deposits, with the latter being the most significant.

Description

Ore deposits range from irregular, but generally lenticular, masses to vertical pods and lenses replacing favorable carbonate rocks outward from faults, fractures, bedding planes, and fracture/bedding plane intersections. Lenticular deposits are as much as 200 m long, 75 m wide, and 30 m thick; podlike bodies are as much as 12 m in diameter and 20 m long. Deposits are localized chiefly along north- and northeast-trending faults and fractures near major northwest-trending Basin and Range faults. At Boston Hill, the deposits occur below the impervious Devonian Percha Shale in the Ordovician Montoya and El Paso Dolomites and the Silurian Fusselman Dolomite. Deposits also occur in the Pennsylvanian Magdalena Group limestones and the Mississippian Lake Valley Limestone. Ore is an intimate mixture of secondary hematite and pyrolusite with minor wad, limonite, and magnetite restricted to the zone above the water table or generally above depths of 60 m. Minor secondary Pb, Cu, and Ag minerals are locally present. The gangue is chiefly calcite, quartz, barite, and jasper. Primary "ore" consists of ferroan-manganoan magnesite, and minor hematite, pearceite, argentite, and base metal sulfides generally containing less than 4 percent Mn.

Manganese-iron ore averages 10-16 percent Mn and 30-40 percent Fe in bodies generally smaller than 500,000 metric tons. Manganese ore averages 19-40 percent Mn in bodies less than 1,000 metric tons. Mineralization may be due to hydrothermal solutions rising along major structures and migrating along subsidiary faults and fractures into favorable host rocks.

Resource evaluation

Four areas (fig.8, map sheet) considered favorable for the occurrence of Mn (Fe) replacement deposits and their criteria are outlined below:

Criteria	Areas of favorability 1	2	3	4
Known deposits	x	x	x	
Necessary conditions				
Ag (Pb-Mn) vein and replacement deposits that have produced Mn-Fe ore	x			
Favorable Silurian to Pennsylvanian carbonate host rocks above present water table	x	x	x	x
N- to NE-trending faults, fractures, and dikes	x	x	x	x
Suggestive conditions				
Ag (Pb-Mn) vein and replacement deposits that have not produced Mn-Fe ore		x	x	x

Even though favorable geologic terranes for Mn (Fe) replacement deposits are present, the outlook for discovering additional shallow, enriched ores is not encouraging.

OTHER DEPOSIT TYPES

Manganese-iron ore has been mined from the Ag (Pb-Mn) vein and replacement deposits in the Chloride Flat district in the Central mining region. The known deposits may contain a significant Mn-Fe resource, but, like the related Mn (Fe) replacement deposits, the outlook for discovering additional deposits is probably poor. The deposits are described in the section on gold and silver.

Some supergene Mn ore has been mined from a Au-Ag-base metal vein deposit in the Big Burro and Little Burro Mountains area and a Zn-Pb (Cu-Ag-Au) vein and replacement deposit in the Central mining region area (figs.1 and 8, map sheet). The manganese resource is negligible.

Table 7.—*Estimated production, reserves, and resources of manganese and manganese-iron in the Silver City 1° x 2° quadrangle, New Mexico and Arizona*

[Values are in metric tons; leaders (—) indicate no data available]

	Manganese (17–40 percent Mn)			Manganese-iron (10–16 percent Mn, 30–40 percent Fe)	
	Mn vein deposits	Mn (Fe) replacement deposits	Other deposits	Mn (Fe) replacement deposits	Ag (Pb-Mn) vein and replacement deposits
Production	6,860	3,422	1,075	2,000,200	3,300
Reserve	—	—	—	10,000,000	—
Identified resource	$nx10^3$	—	—	$nx10^6$	$nx10^5$
Undiscovered resource	$nx10^3$	—	—	$nx10^6$	$nx10^5$

RESOURCE SUMMARY

The Mn potential of the Silver City quadrangle is not encouraging. Although geologic environments favorable for Mn vein and Mn (Fe) replacement deposits occur throughout the quadrangle, the significance of these deposits in terms of volume and the national need for Mn is very small. Past production of Mn (17-40 percent Mn) has been about 11,000 metric tons (table 7), and no reserves are known. The identified resource, chiefly in the Gila and northern Peloncillo Mountains area, is about 5,000 metric tons; the undiscovered resource in both known and undiscovered districts is probably of similar magnitude.

Manganese-iron ore is currently being mined in the Silver City quadrangle, and a significant reserve and resource is indicated. About 2,000,000 metric tons of Mn-Fe ore (10-16 percent Mn, 30-40 percent Fe) have been produced, chiefly from the Mn (Fe) replacement deposits at Boston Hill in the Central mining region. The Boston Hill deposits contain a reserve of about 10,000,000 metric tons and an identified resource of $nx10^6$ metric tons. An additional $nx10^5$ metric tons of identified resource may be present in the Ag (Pb-Mn) deposits of the Chloride Flat district in the Central mining region.

NICKEL AND COBALT

Ni-Co-Ag (U) VEIN DEPOSITS

The only known occurrence of Ni and Co within the Silver City quadrangle is in the Blackhawk type Ni-Co-Ag (U) vein deposits in the Big Burro and Little Burro Mountains area. The deposits are restricted to a northeast-trending zone, 2 km wide by 10 km long, chiefly along the southeast side of a Laramide monzonite porphyry stock. Skutterudite and Ni skutterudite, the principal Ni an Co minerals, are associated with Ag and locally pitchblende. The deposits have been mined extensively for Ag and are described in more detail in the section on gold and silver. There has been no recorded production of Ni or Co.

Resource evaluation

Only the very restricted area of known deposits (fig.7, map sheet) is delineated as favorable for the occurrence of Ni-Co-Ag vein deposits. The deposits exhibit a distinctive suite of ore minerals which is not known elsewhere in the quadrangle, and, moreover, there is no geochemical evidence to suggest the presence of such an association. Although it is possible that some Ni and Co could be recovered in conjunction with Ag production from these deposits, the resource is probably negligible.

TUNGSTEN

Tungsten minerals, chiefly scheelite, are present in minor amounts as the principal commodity in small W vein and pegmatite, W vein, W replacement, and W-Be vein replacement deposits throughout the quadrangle. Tungsten minerals also occur locally in a few precious and base metal vein and replacement deposits and fluorite vein deposits, and as much as 2 percent W may be present in the Mn oxides of the Mn vein deposits. Production has been limited to a few thousand metric tons of low grade ore (0.1-4 percent WO_3); no mines are currently active.

W VEIN AND PEGMATITE DEPOSITS

Segregations, pods, and disseminations of scheelite occur in a number of small quartz veins and related quartz-rich simple pegmatite dikes in the Precambrian terrane of the Big Burro and Little Burro Mountains area (figs.1 and 9, map sheet). The deposits are generally associated with pendants or xenoliths of hornblende gneiss and amphibolite in Precambrian granite. The scheelite is commonly found with epidote, and occasionally with molybdenite, pyrite, chalcopyrite, wolframite, and Bi minerals. Most of the deposits are in a belt 13 km long by 6 km wide that trends northwest across the Big Burro Mountains. Individual bodies generally contain no more than a few hundred metric tons of ore at grades of less than 2 percent WO_3. About 950 metric tons of 1-3 percent WO_3 and a few metric tons of hand-sorted ore containing 62-71 percent WO_3 have been produced.

Resource evaluation

All the Precambrian terranes in the Big Burro and Little Burro Mountains area may be favorable for the occurrence of W vein and pegmatite deposits (figs. 1 and 9, map sheet). The size of the known deposits, however, suggests that any new discoveries will probably be small and the W resource minor.

W VEIN DEPOSITS

Small, scheelite-bearing quartz-epidote veins in Paleozoic limestone and scheelite-bearing quartz stringers and lenses in Precambrian schist occur in the northern part of the Dos Cabezas and Chiricahua Mountains area (figs. 1 and 9, map sheet). The vein deposits in limestone are closely associated with Au-Ag-base metal vein and replacement deposits within the complex Apache Pass fault zone and mark the end of a zone of W and precious and base metal mineralization that extends southeast beyond the quadrangle. Age of mineralization is uncertain as both Laramide (56-62 m.y.) and middle Tertiary (28-34 m.y.) plutons are associated with the known deposits. Grades range from 0.09 to 3.2 percent WO_3 across widths as much as 1 m; there has been no recorded production.

Resource evaluation

Three areas (fig.9, map sheet) have been delineated as favorable for the occurrence of W vein deposits based on the known presence of W mineralization and the distribution of Paleozoic limestones within the Apache Pass fault zone. Additional deposits will probably be small.

W REPLACEMENT DEPOSITS

Sparse scheelite occurs in small, contact metasomatic skarn deposits peripheral to the middle Tertiary (29-33 m. y.) Granite Gap quartz monzonite stock in the Central Peloncillo Mountains area (fig.9). The deposits appear to be confined to Pennsylvanian and Permian limestones and are locally controlled by structures in a northwest-trending major fault zone. The principal skarn minerals are andradite, tremolite, quartz, and calcite. A few hundred metric tons of ore, averaging 0.1 to 4 percent WO_3, have been mined.

Resource evaluation

A very restricted area of upper Paleozoic limestone in the metamorphic aureole of the Granite Gap stock seems favorable for the occurrence of small W replacement deposits.

W-Be VEIN AND REPLACEMENT DEPOSITS

Tungsten and beryllium minerals occur in a small quartz vein and associated marble and skarn lenses in the Victorio Mountains area (figs.1 and 9, map sheet). The vein, in Ordovician El Paso Limestone, contains minor wolframite, beryl, and muscovite with rare fluorite, galena, pyrtie, wulfenite, and scheelite. The closely associated marble and skarn lenses, which replace both the Ordovician El Paso Limestone and Montoya Dolomite, are composed chiefly of calcite, grossularite, tremolite, and augite with minor and variable helvite, scheelite, fluorite, and beryllian idocrase. The mineralization may be genetically related to subvolcanic high-K rhyolites of middle Tertiary age (25 m.y.) which crop out in the vicinity of the deposits, or possibly to a buried Mesozoic calc-alkaline pluton. The average grade of the quartz vein is about 0.1 percent WO_3 and 0.06 percent BeO; the skarns range from 0.1 to 0.4 percent WO_3. Production has been limited to the vein deposit, where about 1,000 metric tons of wolframite ore containing 1 percent WO_3 has been mined.

Resource evaluation

An area of about 10 km^2 in the southern part of the Victorio Mountains area, underlain by lower Paleozoic carbonate rocks, is favorable for the occurrence of skarn-related W-Be vein and replacement deposits (fig. 9, map sheet). If the deposits are related to middle Tertiary high-K rhyolites as assumed, they will probably be small and the undiscovered hypothetical tungsten resource negligible. If the known deposits are related to a buried Mesozoic pluton, however, as are most of the economic W-skarn deposits in the western Cordillera (Newberry and Einaudi, 1981), larger and more significant ore bodies could be present.

RESOURCE SUMMARY

Small W-bearing vein, pegmatite, and replacement deposits are present throughout the Silver City quadrangle, but the total W resource in both known and undiscovered deposits appears minor. Known production has been about 2,300 metric tons of 0.1-4 percent WO_3 and a few metric tons of 62-71 percent WO_3. The identified resource is less than 4,000 metric tons of 0.1-1.62 percent WO_3 and the undiscovered hypothetical resource is probably not much greater. Other W-bearing deposit types may, however, exist in the quadrangle. Favorable environments appear to be present for skarn type W replacements related to Mesozoic plutons and for stockwork Mo (W-Sn) deposits related to middle Tertiary high-K plutonism. These latter deposits are discussed in more detail in the section on molybdenum.

BERYLLUM

Beryllium minerals occur chiefly in two deposit types in the quadrangle. Beryl is present in a few pegmatite deposits and beryl and helvite occur together in small W-Be vein and replacement deposits. In addition, bertrandite(?) has been reported from two fluorite vein deposits and Be geochemical anomalies are associated with several high-K rhyolite eruptive centers.

Be PEGMATITES

Sparse beryl occurs in pegmatite dikes at three widely separated localities in the Precambrian rocks of the Pinaleno Mountains area, Dos Cabezas and Chiricahua Mountains area, and the Big Burro and Little Burro Mountains area (figs. 1 and 9, map sheet). The pegmatites are simple zoned pegmatites, generally with a quartz core and quartz-feldspar outer zones. The Beryl Hill-Live Oak deposit in the Dos Cabezas Mountains has produced a very small amount of hand-sorted beryl.

Resource evaluation

The beryllium resource in pegmatites in the quadrangle is probably insignificant. All Precambrian terranes are favorable for the occurrence of pegmatites, but the available evidence suggests that their content of beryl is negligible.

W-Be VEIN AND REPLACEMENT DEPOSITS

Beryl and helvite occur in a small vein and associated skarns at an isolated locality in the Victorio Mountains area (figs. 1 and 9, map sheet). The deposits, described in the section on tungsten, may be genetically related to subvolcanic high-K rhyolites of middle Tertiary (25 m.y.) age. No Be is known to have been produced.

Resource evaluation

Although the W-Be vein and replacement deposits are probably not significant as a beryllium resource, they may be indicative of Be deposits not presently known to occur in the quadrangle. Shawe (1966) has pointed out that Spor Mountain type Be deposits in the Thomas Range, Utah, occur in a belt of fluorine and Be-rich rhyolite rocks similar to a belt in southern Arizona and New Mexico that includes most of the Silver City quadrangle. The Spor Mountain deposits are confined to carbonate-rich tuffaceous rocks of Tertiary age closely associated with high-K, high-silica rhyolites with anomalous F and Be contents and with fluorite deposits (Staatz, 1963). Some of the middle Tertiary volcanic highlands and their flanking basins in the Silver City quadrangle have similar characteristics, and thus may be favorable for deposits like those at Spor Mountain.

Four areas (fig. 9, map sheet) have been selected as possibly containing Spor Mountain type Be deposits on the basis of the following criteria:

Criteria	Areas of favorability			
	1	2	3	4
Suggestive conditions				
Presence of nonpegmatitic Be deposits	x			
Fluorite vein deposits or abundant fluorite in panned stream sediments	x		x	
Middle Tertiary high-K, high-silica rhyolites emplaced on Paleozoic carbonate rocks	x	x	x	x
Anomalous Be in the nonmagnetic fraction of panned stream sediments	x	x	x	x

RESOURCE SUMMARY

Production of Be in the Silver City quadrangle has been limited to probably not more than a few kilograms of hand-sorted beryl from a single pegmatite. This and other Be-bearing pegmatites, both known and undiscovered, appear not to consititute a significant Be resource.

Likewise, the expectable Be resource in the W-Be vein and replacement deposits in the quadrangle is considered small. These nonpegmatitic deposits, however, may be indications of the existence of other types of more significant Be deposits, such as the Spor Mountain type, that are now unknown in the quadrangle.

TIN

Anomalous amounts of Sn, including local concentrations of cassiterite, in heavy mineral concentrates from streams draining a number of middle Tertiary high-K eruptive centers and epizonal intrusives suggests that environments favorable for the occurrence of rhyolite-related Sn deposits are present. Potential deposit types may include Sn-rich variants of stockwork Mo deposits associated with high-silica subvolcanic rhyolite or granite porphyry and Sn veins and disseminations in rhyolite effusive rocks, such as those in the central Mexico tin province. Favorable middle Tertiary eruptive centers and intrusives for potential Sn deposits are described and outlined in the section on molybdenum.

URANIUM

Uranium minerals occur as minor components in a number of vein type deposits throughout the quadrangle and in small, sedimentary deposits confined to an area in the San Simon Valley (fig. 10, map sheet). Principal U-bearing veins are the Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) veins and the Blackhawk type Ni-Co-Ag (U) veins in the Big Burro and Little Burro Mountains area. Uranium minerals are also locally present in a number of small radioactive veins and fractures, which are collectively and loosely referrred to as U vein deposits, and in a few fluorite and Tyrone type Au-Ag-base metal vein deposits. With the exception of some of the Au

(Cu-Bi-U) veins that were mined for U minerals during the radium boom ot the 1920's, U production has been limited to a few tens of metric tons of low grade ore. In addition several aerial radiometric anomalies occur over a number of basin areas throughout the quadrangle.

Au (Cu-Bi-U) AND Ag-Pb (Cu-Bi-U) VEIN DEPOSITS

Secondary U minerals are locally abundant in the shallow (<30 m deep) oxide-enriched zones in some of these precious-metal-bearing vein deposits in the White Signal district. Significant, but unknown, amounts of torbernite and autunite were produced in the 1920's, and one deposit yielded about 220 kg of U_3O_8 in the 1950's. One area is considered favorable for the occurrence of additional deposits, but the U resource is probably very minor. The deposits are described in the section on Gold and Silver.

Ni-Co-Ag (U) VEIN DEPOSITS

Pitchblende occurs sparingly in many of these Ag-rich vein deposits in the Blackhawk district. No U has been produced nor does it appear that the deposits constitute a significant U resource. The deposits are described in the section on gold and silver.

U VEIN DEPOSITS

Small, U-bearing veins of probable diverse origins are known to occur in three areas in the quadrangle. In the Pinaleno Mountains area the deposits consist of fractures and quartz-filled cavities, with autunite, uranophane, pyromorphite, and secondary Cu minerals in Precambrian granite and Tertiary volcanic breccia near the contact of the Tertiary Gillespie granite stock (36 m.y.). Grades of 0.27 percent eU_3O_8 have been reported; no production is known. In the Dos Cabezas and Chiricahua Mountains area, quartz and quartz-fluorite veins in Precambrian granite, that contain minor base metal sulfides assay as high as 1.09 percent U_3O_8 and are locally associated with thorium geochemical anomalies. No U- or Th-bearing minerals have been identified and there has been no production. In the Big Burro and Little Burro Mountains area, torbernite and other secondary U minerals coat fractures chiefly in Colorado Shale and Beartooth Quartzite of Cretaceous age. The veins contain as much as 0.1 percent U_3O_8; 35 metric tons, averaging 0.04 percent U_3O_8, has been mined. Although the U vein deposits do not appear significant as a U resource, they may be indicative of other economic deposits at depth. This is especially true in the Stockton Pass-Greasewood Mountain area of the Pinaleno Mountains area where anomalous fluorite, Bi, Au, As, Th, Mo, W, Sn, Be, Pb, and Cu in stream sediments are concentrated in the areas of known U vein deposits.

SEDIMENTARY U DEPOSITS

The term sedimentary U deposits is used here to refer to the whole group of deposit types in which U occurs in sedimentary rocks. Small, sedimentary U deposits, possibly of the "sandstone-type," occur in upper Pliocene basin-fill sediments in an isolated area of the San Simon Valley on the northwest flank of the Whitlock Mountains (fig. 10, map sheet). The deposits consist chiefly of carnotite and allied minerals coating fractures and bedding planes in fluviatile and lacustrine silt, clay, and opalite strata and volcanic tuff beds. Carbonaceous debris is not obviously associated with the deposits, though abundant vertebrate fossils occur in the area. Grades range from 0.01 to 1.38 percent eU_3O_8; production has been 3.6 metric tons of 0.02 percent eU_3O_8. The source of the U may be the airfall tuff beds intercalated within the upper Pliocene lacustrine sequence or possibly the middle Tertiary volcanic rocks of the Whitlock Mountains. The deposits appear to be confined to a shallow-water environment along the margin of a lake where circulation was restricted and coarse clastic sedimentation was held to a minimum.

In addition to these known several deposits, radiometric surveys (U.S. Department of Energy, 1979) have shown several basin areas to be anomalously radioactive. These data together with the hydrogeochemical and remote sensing investigations of this program suggest that other sedimentary U deposits may be present within the quadrangle.

Resource evaluation

Ten areas are considered favorable for the occurrence of sedimentary U deposits (fig. 10, map sheet). Four of these areas (1-4) contain environments similar to that of the Whitlock Mountains, where small "sandstone type" deposits appear to be confined to protected embayments proximal to low-relief range fronts. Deposits in these areas will probably be of small size and low grade.

The other six favorable areas (5-10) are based on aerial radiometric, hydrogeochemical, and remote-sensing data as favorable for some type of sedimentary U deposit. Area 5 on Lordsburg Mesa satisfies several of the criteria proposed by Carlisle and others (1978) for deposits similar to the uranium-bearing nonpedogenic calcrete deposits in western Australia and southwest Africa. These criteria are: (a) adequate source terrane (deeply weathered Precambrian granite of the Burro Mountains including locally abundant, small U-bearing vein deposits), (b) large catchment area, (c) low drainage gradients, and (d) upwelling ground-water flow at a bedrock obstruction (surface limonite concentration defined by Landsat imagery and associated caliche).

The other areas could include deposits similar to the "sandstone type" Whitlock Mountains deposits, playa margin deposits such as at Date Creek Basin, Arizona (Otton, 1978), tabular sandstone deposits (Peterson and Turner-Peterson, 1980), or calcrete-type deposits.

RESOURCE SUMMARY

Other than the U phosphates, torbernite and autunite, mined during the radium boom of the 1920's, probably not more than a few hundred kilograms of U_3O_8 have been produced in the quadrangle. A small indicated U resource is still present in the oxidized zone of some of the Au (Cu-Bi-U) and Ag-Pb (Cu-Bi-U) vein deposits, as primary pitchblende in the Ni-Co-Ag (U) veins, and in the "sandstone type" deposits in the Whitlock Mountains. A speculative U resource is suggested in the areas of favorability for a variety of types of sedimentary U deposits. The magnitude of this speculative resource is not estimated; however, large deposits could occur in the subsurface.

RARE-EARTH ELEMENTS

Rare earth-bearing minerals occur in a few simple pegmatites in the Precambrian granitic rocks of the Burro and Little Burro Mountains area (figs. 1 and 10, map sheet). Some of the pegmatite dikes are crudely zoned with quartz cores and quartz-feldspar intermediate and border zones; others are simple coarse-grained quartz-muscovite-microcline segregations. The REE-bearing minerals include euxenite, allanite, samarskite, and cyrtolite; columbite-tantalite and beryl have been observed in one deposit. Anomalous amounts of REE elements have also been found in the fluorite vein deposits of the Duncan mining district in the Summit Mountains and Black Mountain area and in a number of Au (Cu-Bi-U) vein deposits and a Au-Ag-base metal vein deposit in the Big Burro and Little Burro Mountains area. There has been no recorded production from the pegmatites and none of the deposits appear to constitute a significant REE resource.

FLUORITE

The Silver City quadrangle lies in a broad U-shaped belt of fluorite deposits and F-rich Tertiary igneous rocks that is largely coincident with areas of Basin and Range and Rio Grande rift extensional tectonism (Shawe, 1976). Although known fluorite deposits are limited to the east half of the quadrangle, anomalous concentrations of fluorite in stream sediments are locally distributed throughout the quadrangle. Fluorite is the principal commodity in numerous, but generally small fluorite vein deposits and a local gangue mineral in many precious and base metal vein and replacement deposits and Mn vein deposits. There has been no recorded production of fluorite since about 1960.

FLUORITE VEIN DEPOSITS

Hundreds of small, epithermal, fissure-filled fluorite vein deposits are present principally in the eastern part of the quadrangle (fig. 11, map sheet). They occur in a variety of geologic terranes, but all apparently are middle to late Tertiary in age and probably share a common genesis. The deposits tend to be clustered in five broad groups: the Steeple Rock-Duncan districts in the Summit Mountains and Black Mountain area; the Cliff-Telegraph area, Tyrone district, and Bounds Ranch district in the Big Burro and Little Burro Mountains area; and the Lordsburg district in the Pyramid Mountains area.

Description

The deposits are small veins and breccia fillings rarely more than 100 m long and a few meters wide along preexisting faults. Exceptions are the Burro Chief and Shrine deposits in the Tyrone district (fig. 11, map sheet), which have accounted for more than three quarters of the fluorite produced in the quadrangle. Here the fluorite occurs in wide breccia zones as much as 200 m long, 30 m wide, and 200 m deep (depth of mining). In the Steeple Rock-Duncan districts the veins occur along a major northwest-trending fault system, locally intruded by pre-mineral rhyolite dikes, in middle Tertiary volcanic rocks. The deposits are closely associated with, and locally grade into, Steeple Rock type Au-Ag-base metal vein deposits. The three groups of deposits in the Big Burro and Little Burro Mountains area are confined almost entirely to faults in Precambrian granite. In general, the deposits are localized along footwall splits off major faults or along linkage faults that join larger faults; a few deposits occur at irregularities along major faults. The veins are best developed where at least one wall is in granite; where both walls are composed of younger rocks or Precambrian schist the veins generally pinch out. In the Lordsburg district the veins occupy minor faults in a Laramide porphyritic granodiorite stock and in both Upper Cretaceous to lower Tertiary and middle Tertiary volcanic rocks. Vein minerals are chiefly colorless, green, and purple fluorite, quartz, chalcedony, jasper, and calcite with local and minor pyrite, psilomelane, chalcopyrite, native Au, Ag, galena, and secondary Cu, Mn, Fe, and U minerals. Multiple stages of fluorite mineralization separated by periods of locally intense brecciation characterize many of the deposits. The known deposits do not appear to be associated with any specific middle Tertiary eruptive center or pluton, but rather they are concentrated in areas where faults and fracture systems in competent rocks allowed entry of widespread hydrothermal solutions.

Resource evaluation

Twelve areas (1-12, fig. 11, map sheet) considered favorable for the occurrence of fluorite vein deposits and their criteria are outlined below:

Criteria	Areas of favorability											
	1	2	3	4	5	6	7	8	9	10	11	12
Known deposits	x	x	x	x	x	x						
Suggestive conditions												
Structurally competent Precambrian granite of the Burro uplift	x	x	x	x								
Major faults and fracture systems	x	x	x	x	x		x	x	x			
Associated precious and base metal vein deposits	x	x	x	x	x							
Anomalous fluorite in panned stream sediments	x	x	x	x	x	x	x	x	x	x	x	x

Modest tonnages of fluorite probably remain in many of the known deposits and the chance of discovering new, small deposits, especially in areas 1-5, is good. The cost of mining and shipping these low value per unit volume ores, however, probably precludes development of any but large tonnage, shallow deposits.

RESOURCE SUMMARY

About 190,000 metric tons of fluorite (50-70 percent CaF_2) have been produced from the quadrangle. No reserves are known, and the identified resource is probably about $n \times 10^4$ metric tons. Although favorable geologic environments for fluorite vein deposits are present throughout the quadrangle, the total fluorite resource is probably small.

ZEOLITES

Zeolite minerals are widely distributed throughout the quadrangle, chiefly as alteration products of Tertiary pyroclastic deposits and, in lesser quantities, as the common cement of coarse-grained basin-fill alluvium. Production has been limited to an extensive air-fall ash, about 1 m thick, in Pliocene lacustrine beds north of Bowie in the San Simon Valley. The basal part (10-20 cm thick) of this deposit has been almost completely zeolitized and consists chiefly of chabazite, erionite, and clinoptilolite. About 10,000 metric tons have been mined from this basal unit since 1961. An air-fall deposit in the Safford Valley, 0.3 m thick and containing about 90 percent zeolites, is the only other known zeolitized Pliocene ash bed in the quadrangle. Pyroclastic ash-flow and air-fall deposits of middle Tertiary age contain variable amounts of zeolite minerals. With the exception of lithic fragments, some of these older deposits are locally completely altered, but most contain less than 30 percent zeolite minerals, chiefly clinoptilolite.

Resource evaluation

Four areas of known late Cenozoic lacustrine deposits are considered favorable for the occurrence of zeolitic air-fall beds (fig. 12, map sheet). Extremely significant is area 1 which contains the deposits currently being mined and which has an identified resource on the order of nx10^8 metric tons. The zeolitized middle Tertiary pyroclastic deposits may constitute an additional future resource.

DIATOMITE

Diatomite, composed chiefly of biogenic opaline silica, occurs at a number of localities in the late Cenozoic basins of the quadrangle interbedded with lacustrine sediments and volcanic ash (figs. 1 and 12, map sheet). The known deposits, generally less than 2 m thick and laterally discontinuous, appear to be concentrated proximal to low-relief range fronts where protected embayments inhibited clastic sedimentation. The discontinuous nature of the deposits and the abundance of ash, clay, silt, and calcite impurities have precluded their development. More extensive, thicker, and cleaner deposits may occur in the quadrangle, especially in the areas of favorable terrane outlined in figure 12.

BRINE

Brine has been encountered in two wells drilled into lacustrine and playa facies of late Cenozoic basin-fill sediments in the quadrangle (fig. 12, map sheet). The wells, one in the Safford Valley and the other in Willcox Playa, penetrated aquifers at depths of 375 m and 2 m, respectively, containing waters with more than 100,000 ppm total dissolved solids, chiefly Na, Cl, and SO_4. A second well in Willcox Playa drilled to depths of 322 m to test for lithium did not encounter any brine nor did any of the analyzed water contain more than 0.88 mg/l lithium (Vine and others, 1979). Although these data are very limited and in part inconsistent, they do suggest that a potential brine resource may be present in some of the Cenozoic basins of the quadrangle.

ALUNITE

Alunite, a hydrous sulfate of potassium and aluminum, may be a future Al resource. In the Silver City quadrangle, two areas of intensely alunitized middle Tertiary volcanic rocks occur in the Summit Mountains and Black Mountain area. The alunitic alteration is apparently related to the hydrothermal system responsible for the emplacement of the Steeple Rock type Au-Ag-base metal vein deposits. The largest altered area, at Saddleback Mountain, contains at least 55 x 10^6 metric tons of 30 percent alunite.

GEMSTONES AND ORNAMENTAL STONE

Turquoise has been the principal gemstone mined in the quadrangle. The larger deposits were known and extensively developed by the Indians and early Spanish; between 1880 and 1910 several million dollars of highly prized material were produced. Agate, opal, amethystine quartz, and Apache tears (obsidian nodules) are locally abundant and much sought after by mineral collectors and lapidarists. Very small amounts of ricolite and meerschaum have been produced for ornamental stone.

Turquoise occurs as a secondary mineral in fractures, seams, and nodules, generally within 30 m of the surface, in a number of deposits classified as turquoise vein deposits and in one Au (Cu-Bi-U) vein deposit in the Big Burro and Little Burro Mountains area (figs. 1 and 13, map sheet). The turquoise vein deposits are confined chiefly to northeast-trending faults and fractures in Precambrian granite near the contact of the Tyrone quartz monzonite stock of Laramide age (56.2 m.y.); the Au (Cu-Bi-U) vein deposit occurs in a Tertiary rhyolite dome. Secondary Cu, radioactive, and clay minerals occur locally with the turquoise in both deposit types. All the known deposits have apparently been mined out; additional deposits may be discovered in the course of mining operations at the Tyrone porphyry Cu (Mo) deposits.

Agate, a variety of chalcedony, is locally abundant in most of the middle Tertiary volcanic terranes throughout the quadrangle. It is precipitated from meteoric water in fractures, vesicles, and other open spaces in flows and pyroclastic rocks; it also occurs as residual secondary concentrations in alluvial deposits derived from the volcanic rocks. The two agate localities shown in figure 13 (map sheet) are designated and managed by the U.S. Bureau of Land Management as Rockhound Areas. A white opal that locally exhibits the play of colors of fire opal, occurs in fractures and small faults at a locality in the Central Peloncillo Mountains area (fig. 13, map sheet). Amethystine quartz is a principal gangue mineral in Au-Ag-base metal veins in the Steeple Rock district of the Summit Mountains (fig. 13, map sheet) and gem quality crystals have been found in soil and colluvium derived from the veins. Apache tears as much as 2-3 cm in diameter, probably from sources north of the quadrangle, occur locally in Pliocene basin-fill deposits in the northern part of the San Simon Valley (fig. 13, map sheet). The semiprecious gems and stones constitute an important recreational resource of limited economic significance in the quadrangle.

Ricolite, an attractive banded talc-serpentinite rock, occurs in small thermally metamorphosed xenoliths within Precambrian granite at a locality in the Big Burro and Little Burro Mountains area (fig. 13, map sheet). Minor quantities were quarried intermittently between 1880 and 1940 for use as trim stone and small decorative objects. The resource is limited and not economically significant. Minor amounts of meerschaum (sepiolite), a tough clay material used principally to make smoking pipes, have been mined from small hydrothermal deposits in Ordovician dolomite in the Central Mining Region. Additional deposits are likely to occur in the limited area of known deposits, but the resource cannot be called significant.

BUILDING AND CONSTRUCTION MATERIALS

A variety of building and construction materials occurs throughout the quadrangle, but only a few of these commodities are examined in any detail. No attempt is made to assess commodities that have a low price per unit of volume, such as sand and gravel and construction stone, which locally constitute a large resource but whose economic significance depends largely on proximity to urban centers and the fluctuating demands of local industry.

MARBLE AND LIMESTONE

Small quarries have produced both dimension stone and crushed marble from metamorphosed upper Paleozoic (probably mostly from Pennsylvanian Horquilla Limestone) limestone in the Dos Cabezas and Chiricahua Mountains area and the Dragoon Mountains and Red Bird Hills area (figs. 1 and 13, map sheet). The quarries were active in the early 1900's; there has been no known recent production. The marble resource in the known deposits is still significant; however, a decline in the use of marble as a structural dimension stone has limited the interest in many domestic deposits. Crushed marble, which brings a much lower price, cannot bear the costs of long-distance transportation, and its exploitation depends largely on local needs.

Limestone of the Pennsylvanian Magdalena Group is currently being quarried in the Central mining region (fig. 13), chiefly for use as a metallurgical flux in a nearby copper smelter. Pennsylvanian and older Paleozoic limestones are exposed throughout much of the quadrangle; the resource is adequate to provide for anticipated local demand indefinitely.

LIGHTWEIGHT AGGREGATE

Pumice and perlite are relatively common in many of the middle Tertiary silicic volcanic rocks of the quadrangle, but only a few known deposits contain physically suitable material in sufficient quantity to warrant development as a lightweight aggregate source. Pumice is currently being quarried from a blocky, pumice-rich rhyolite pyroclastic deposit in the northern Peloncillo and Gila Mountains area (fig. 13, map sheet) for local construction purposes in the Safford-Thatcher urban area. The deposit has produced only a few thousand metric tons; however, the pumice resource is probably more than $nx10^5$ metric tons, or more than adequate to meet foreseeable future demands. Perlite, an expandable, hydrated volcanic glass, has been produced from vitric units in thick rhyolite flows and domes in the Big Burro and Little Burro Mountains area (fig. 13). Approximately 3,000 metric tons of perlite were mined during the period 1950-1960; the quarries are now inactive. The identified perlite resource in these deposits is large but development has been hindered by their remoteness.

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