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GEOLOGY AND MINERALIZATION OF THE MCCOY SKARN, LANDER COUNTY, NEVADA

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ABSTRACT

The McCoy gold deposit is a proximal calcic skarn developed within rocks of the Triassic Augusta sequence adjacent to a Tertiary granodioritic stock and dike system. Skarn occurs as stratiform bodies along clastic - limestone contacts, as steeply plunging contact skarn along the intrusive - sediment contact, and as xenoliths or pendants within the dike system. Gold is associated with disseminated pyrite and oxidized pyrite in calcic exoskarn and endoskarn, and along fractures and shear zones within the stock and clastic member of the Augusta Mountain Formation. Mineralization is best developed in areas where retrograde alteration and late stage oxidation were most intense. January 1987 mineable reserves total 8.7 million mt (9.6 million st) of ore grading 1.85 g/t Au (.054 opt) with a stripping ratio of 3.4:1.

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INTRODUCTION

The McCoy gold skarn lies in the northern half of the Fish Creek Mountains approximately 48 km (30 miles) southwest of Battle Mountain, Lander County, Nevada (Figure 1). Gold was discovered in the district in 1914 by Joseph McCoy. Sporadic mining through the late 1930's exploited free gold in faults, fractures, shear zones, and in shallow calc-silicate skarn bodies (Schrader, F. C., 1934). Total gold production through 1938 was less than $200,000 (Stewart, et al, 1977, p. 87). Iron ore was discovered in the district in the 1940's and was mined intermittently until the early 1960's for ship ballast. Total production of iron ore is estimated at less than one million dollars (Stewart, et al, 1977, p. 86).

More recent interest in the district began in the 1970's. Various companies including Bear Creek, Summa, Houston Oil and Minerals Corporation (subsequently Houston International Minerals which was purchased by Tenneco Minerals Company) and Gold Fields Mining Corporation were involved in drilling, sampling, geophysical, and mapping programs through 1984. In 1984, Tenneco began an evaluation of all previous work; this led to corporate approval to proceed with mining in September, 1985. The mineable reserve at start-up was 4.99 million mt (5.5 million st) of ore grading 1.89 g/t Au (.055 opt) using a 0.55 g/t Au (.016 opt) cut-off. Additional drilling by Tenneco Minerals Co. increased the mineable reserve to 8.7 million mt (9.6 million st) of ore grading 1.85 g/t Au (.054 opt) using a 0.55 g/t (.016 opt) cut-off by December, 1986.

Echo Bay Minerals Company acquired the precious metals holdings of Tenneco Minerals Company in November, 1986. The McCoy project now produces approximately 85,000 ounces of gold per year through cyanide heap-leach, carbon recovery circuits.

GEOLOGY

Regional

The northern Fish Creek Mountains consist predominantly of Tertiary ash flow tuffs (Figure 2). Erosional windows through the tuffs expose Paleozoic and Mesozoic sedimentary rocks which have been intruded by Jurassic, Cretaceous, and Tertiary stocks.

The Paleozoic stratigraphy consists of the Pennsylvanian to Permian Havallah Formation, a sandstone, limestone, and chert unit exposed only in the north end of the range, 12.8 km (8 miles) from McCoy. The Mesozoic stratigraphy consists of the Triassic Augusta sequence, dominantly a limestone package with subordinate amounts of conglomerate and sandstone. The Augusta sequence is divided into the Favret Formation, the Panther Canyon Formation, the Augusta Mountain Formation, the Cane Spring Formation, and the Osobb Formation.

Intruding the sedimentary rocks are Jurassic, Cretaceous, and Tertiary stocks, dikes, and sills varying in composition from granite to diorite. Tertiary ash flow tuffs of the Oligocene to Miocene Caetano Tuff, Fish Creek Mountain Tuff, and Bates Mountain Tuff cover most of the northern half of the range. Minor Tertiary and Quaternary basalt flows and cinder cones crop out in the north and northwestern portion of the range.

Local

Stratigraphy

The oldest unit exposed in the vicinity of the McCoy Mine is the Triassic Augusta Mountain Formation (Figure 3). The formation is approximately 400 m (1300 ft.) thick and is informally divided into two members, the lower Augusta Mountain limestone (340 m (1100 ft.)) and upper Augusta Mountain conglomerate (60 m (200 ft.)). The Augusta Mountain limestone, the main ore host at McCoy, is an impure, medium gray to dark-gray, medium-bedded to massive limestone with subordinate dolomite and clastic interbeds. The upper conglomerate consists of thin to medium-bedded siliceous siltstones, quartzites, and chert-pebble conglomerates. The conglomerate is a minor host for ore.

The Triassic Cane Spring Formation conformably overlies the Augusta Mountain Formation. The Cane Spring Formation consists of gray to dark-gray, medium-bedded to massive limestone approximately 430 m (1400 ft.) thick. It is a minor host for ore but appears not to have been as receptive to mineralization as the Augusta Mountain limestone. The lower-most 9 m (30 ft.) of the Cane Spring Formation is composed of limestone interbedded with siliceous siltstone. In outcrop, the Cane Spring Formation is virtually indistinguishable from the Augusta Mountain limestone. The intervening conglomerate is used as a marker bed where possible.

Conformably overlying the Cane Spring is the Triassic Osobb Formation (180 m (600 ft.)), a fine to medium-grained, moderately well-sorted sandstone with minor interbedded limestone and dolomite.

The oldest intrusion is the Jurassic McCoy pluton (151 m.y.b.p.), a coarse-grained granite exposed 2.4 km (1.5 miles) south of the mine. At the surface, the McCoy pluton has an intrusive contact with the Osobb Formation. Metasomatism along the contact has altered dolomitic beds in the Osobb to magnetite skarn. This skarn has no precious metal value but was mined for ship ballast.

The Brown stock is the informal name given to the most important intrusion in the mine area. Three potassium-argon age dates average 39.7 ± 1.6 m.y.b.p. The Brown stock is a medium to fine-grained granodiorite/tonalite (in-house whole rock analyses) with plagioclase, biotite, ± hornblende and ± quartz as the dominant phenocrysts. The Brown stock hosts ore along fractures and faults as well as in endoskarn.

The surface outcrop of the Brown stock is elliptical; 365 m (1200 ft.) in a NE - SW direction and 305 m (1000 ft.) along the NW - SE axis. The stock is bounded by faults on its southeast and northwest margins.

A dike swarm texturally and compositionally similar to the Brown stock extends 490 m (1600 ft.) northeast of the stock along a NE structural trend. Caught up within the dike system are pendants and septa of the country rock.

Overlying the sedimentary and intrusive rocks are the Caetano and Bates Mountain Tuffs, 32.6 and 23.7 m.y.b.p. respectively (Stewart, et al, 1977, p. 40, 42). The Caetano Tuff is a gray or purplish, crystal-rich welded rhyolite or quartz latite tuff with phenocrysts of quartz, sanidine, plagioclase, and biotite. It is usually less than 150 m (500 ft.) thick. The Bates Mountain Tuff is generally a pink, reddish-brown or tan, crystal-poor rhyolite 15 m - 45 m (50 - 150 ft.) thick.

Structure

The McCoy deposit lies at the intersection of a series of northeast trending normal faults and a northwest trending normal fault. These structures were important in localizing the emplacement of the Brown stock and the northeast trending dike swarm (Figure 3). For much of its exposure through the pit, the Brown stock/sedimentary contact is faulted. A third structural trend, north-south, is also present in the pit and probably represents basin and range faulting.

Reactivation has occurred on almost all fault trends obscuring their age relationships. Generally, the northwest trending faults dip steeply (65°- 85°) southwest and are probably the oldest set. The northeast trending faults dip steeply (70°- 85°) northwest and appear to cut the northwest set. The north-south set is essentially vertical. The total offset along any of the structural trends is typically less than 15 m (50 ft.). Drag folding is evident along some structures.

The intrusion of the Brown stock was not without some local stress. Evidence for compression includes bedding plane brecciation and low angle (<40°) shears, minor folding along an axis parallel to the intrusive contact, and minor high angle reverse faults.

Locally, the sediments strike N55E and dip 25SE. Regionally, the Mesozoic sequence is gently folded into a series of south-plunging anticlines and synclines; one such anticline is exposed in the north wall of the pit. These folds apparently played no role in localizing mineralization.

ALTERATION AND MINERALIZATION

Skarn Morphology

At McCoy, exoskarn is often referred to by the position it occupies with respect to the stock. These exoskarn "types", mineralogically indistinguishable, are stratiform or manto skarn, contact skarn, and xenolith skarn (Figures 5 and 6).

Stratiform skarn occurs at clastic/limestone contacts in the Cane Spring and Augusta Mountain Formations (Figure 6). It is thickest adjacent to the stock, and in cross-section, pinches in wedge-like fashion with increasing distance from the stock until it exists as 5 - 15 cm (2 - 6") thick beds of bedding plane calc-silicate hornfels in knife sharp contact with marble/limestone. Stratiform skarn usually extends no further than 90 m (300 ft.) from the stock.

Contact skarn occurs around the perimeter of the stock and is most consistently developed where the intrusive-sedimentary contact is least complex (Figure 6). Contact skarn occurs 5 - 9 m (15 - 30 ft.) laterally away from the stock.

Xenolith skarn occurs at the juncture of the dike system with the stock and consists of pendants or septa of Augusta Mountain limestone (altered to exoskarn), which are now partially to totally enclosed by granodiorite (Figure 5). The top of the xenolith skarn occurs 18 m (60 ft.) below the surface, has an approximate strike length of 210 m (700 ft.), a maximum width of 45 m (150 ft.), and has been traced to a depth of 210 m (700 ft.) by drilling (Kuyper, 1986).

Although petrographically similar, the skarn types differ in their average grade. Xenolith skarn averages 5.1 g/t Au (.150 opt), contact skarn 3.4 g/t Au (.100 opt), and stratiform skarn 2.06 g/t Au (.060 opt). (Kuyper, 1986).

Endoskarn is best developed where the Brown stock intruded limestone; little or no endoskarn developed where the stock intruded siliceous conglomerate. Endoskarn usually extends no more than 9 m (30 ft.) into the stock.

Skarn Mineralization and Paragenesis

The dominant mineral assemblage of calcic-exoskarn is garnet, pyroxene, calcite, ± epidote, ± zeolite (?), ± quartz, ± chlorite. The mineralogy of endoskarn is similar but has additional epidote, ± amphibole, and ± feldspar. Where skarn alteration has been most intense, the original protolith can no longer be identified. A crude foliation can be seen in hand specimen as well as in thin section, attesting to probable differences in original chemical composition and permeability (Theodore Paster, written communication, 1987).

Several garnet generations have been observed (Jeffrey Brooks, personal communication, 1987, T. Paster, 1987). The earliest generation is a fine-grained, isotropic, poikilitic metamorphic grossular garnet. Second generation garnets are metasomatic, coarser-grained, anisotropic, and andraditic. This is the most common garnet generation. Occurring as overgrowths on the andraditic garnets are third generation metasomatic grossular garnets. Microprobe data (J. Brooks, 1987) indicate that this third generation grossular garnet is higher in titanium and magnesium than the other generations. This zonation of Ca-Fe-Ca can occur within individual garnet grains as a grossular core overgrown by an andradite zone which is in turn overgrown by a grossular zone, or in cross-cutting relationships.

Opaque minerals present in skarn include gold, pyrite, chalcopyrite, chalcocite, covellite, sphalerite, galena, pyrrhotite, hematite, and magnetite. Pyrite is by far the dominant sulfide at McCoy. Volumetrically, it constitutes up to several percent of the skarn and can occur as disseminations, veinlets, and rarely, as massive sulfide replacements.

Gold is spatially and temporally associated with pyrite and may occur as free grains, 20 - 100 microns in size, bordering pyrite cubes or pyrite pseudomorphs (Russell Honea, written communication, 1987, T. Paster, 1987). Copper and silver are the only other metals of importance in the skarn. Gold and copper are strongly correlated; silver has a more independant distribution. Silver values range from trace to 410 g/t (12 opt) but average 11.00 g/t (.321

opt). Copper concentrations range from 10 ppm to greater than one percent (Kuyper, 1986).

Paragenesis, as it is currently understood at McCoy, is divided into the following 5 stages (J. Brooks, personal communication): (1) initial contact metamorphism producing hornfels, wollastonite, idocrase, pyroxene, and garnet; (2) metasomatism producing garnet-rich skarn, pyroxene-rich skarn (although garnet is still the dominant mineral), and then idocrase-rich skarn in a crude zonation with increasing distance from the stock; (3) extensive retrograde alteration destroyed original skarn fabric producing chlorite, ± amphibole, ± epidote, ± chalcopyrite, ± pyrite, ± gold and clays; (4) quartz + pyrite ± adularia alteration (pyrite occurring as iron-oxide pseudomorphs) ± gold, ± chalcopyrite. It is not clear at this time if additional gold was introduced at this stage or just remobilized. The association of gold and secondary copper minerals suggests remobilization; and (5) supergene oxidation, which has altered adularia to clays, pyrite to hematite, and chalcopyrite to secondary copper minerals. Age dates on the adularia are contemporaneous with those of the Brown stock - 39.7 ± 1.6 m.y.b.p. This suggests there was no separate hydrothermal event at McCoy.

Skarn Classification

The McCoy deposit is a gold skarn according to the criteria of Orris and others (1987, p. 2). These criteria are: (1) an average grade of at least 1 g/t Au (.030 opt), and (2) mineralogy distinctive of the skarn environment. The McCoy deposit also has many of the characteristics of copper skarns as defined by Einaudi, Meinert, and Newberry (1981, p. 340 - 341). These characteristics include: (1) association with a hypabyssal barren granodiorite stock; (2) proximity of skarn to stock contacts; (3) high garnet to pyroxene ratios; and (4) oxidized mineral assemblages.

Controls on Mineralization

Mineralization is hosted in (1) gold-bearing calcic-exoskarn of the Augusta Mountain limestone and to a lesser extent in the Cane Spring Formation, (2) in endoskarn, (3) in iron-oxide, clay-rich fractures, shears, and bedding planes of the Augusta Mountain conglomerate, (4) in fractures and shears within the Brown stock, and (5) along faults in all rock types.

Original protolith and intensity of fracturing were the two most important controls on mineralization at McCoy. These two factors controlled the formation of skarn silicates and the degree to which infiltrational metasomatism could occur in the sedimentary rocks and in the Brown stock.

Skarn silicates probably played a role in controlling sulfide deposition (Wu, 1976, p. 26). This can be seen in poikilitic intergrowths of pyrite and calc-silicate gangue (R. Honea, 1987). Fractures and faults have localized and intensified the retrograde alteration, the cross-cutting quartz-adularia-pyrite alteration, and supergene oxidation.

SUMMARY

McCoy is a gold-bearing proximal calcic-skarn largely developed within the Triassic Augusta Mountain limestone as manto-shaped bodies at clastic-limestone contacts, as contact skarn haloing the periphery of a hypabyssal, barren Tertiary granodiorite stock and dike system, and as septa and pendants within the dike system. Gold is spatially and temporally associated with pyrite, and iron-oxide pseudomorphs after pyrite and was deposited initially during retrograde alteration and then re-introduced or remobilized during a later quartz-adularia-pyrite phase of alteration. Total mineable reserves are 13.2 million mt (14.5 million st) of ore grading 1.47 g/t Au (.043 opt) using a 0.55 g/t Au (.016 opt) cut-off.

ACKNOWLEDGEMENTS

I wish to thank my fellow geology staff members at McCoy, Bruce Kuyper, Paul Pettit, Bob Coyle, Dave Emmons, Ed Gates, and Leah Mach for their critical reviews and discussions of the deposit. Jeff Brooks provided microprobe data, the paragenetic sequence, details on skarn mineralogy, and photographic slides. Ted Paster did a paragenetic study and provided photographic slides; Russell Honea also did a petrographic and polished section study and provided slides. Sue Luescher made the graphic illustrations. I would also like to thank the management of Echo Bay for the opportunity to present this paper.

While I gratefully acknowledge the assistance and contributions of those just named, they are in no way responsible for any errors associated with this paper.

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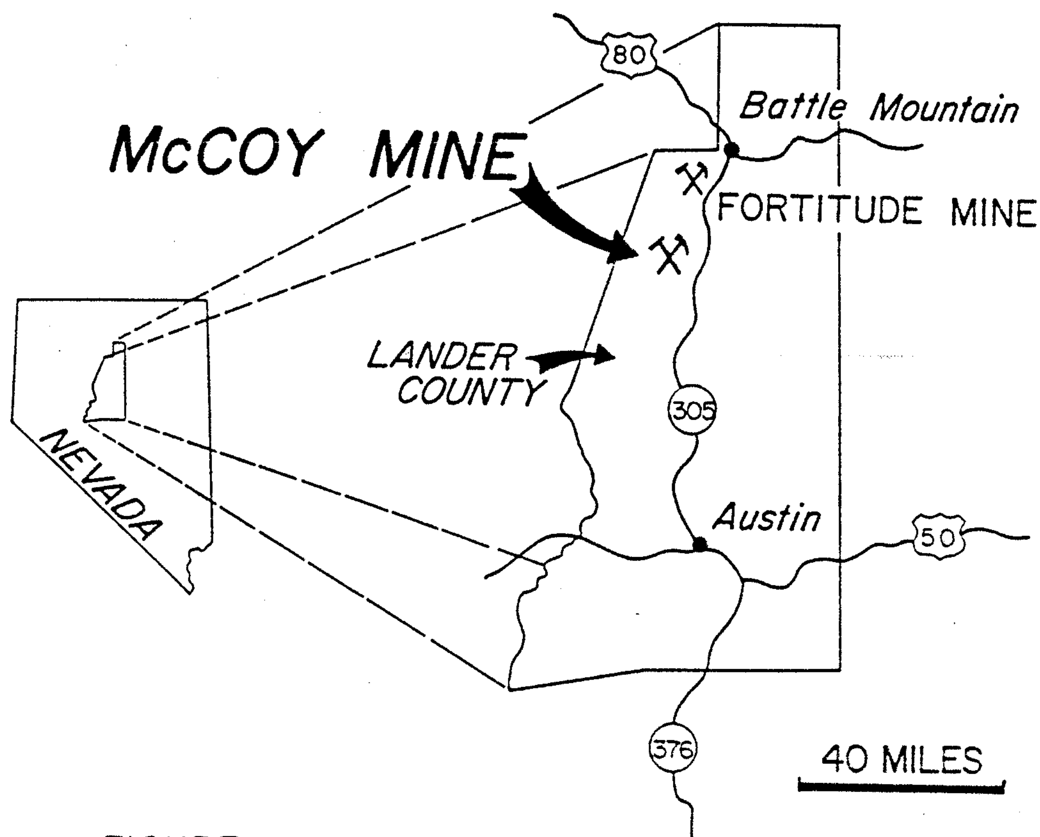
80
Battle Mountain
McCOY MINE
FORTITUDE MINE
LANDER
COUNTY
NEVADA
305
Austin
50
376
40 MILES

FIGURE 1

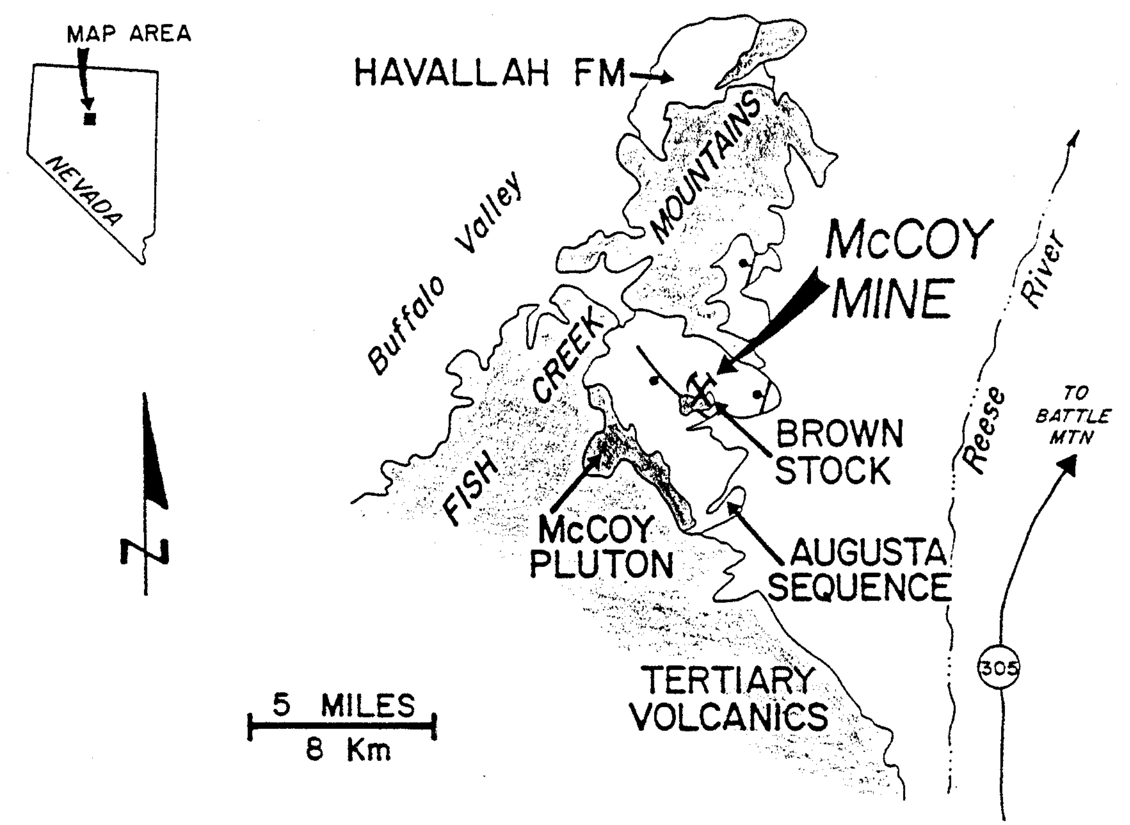
MAP AREA
NEVADA
HAVALLAH FM
MOUNTAINS
Buffalo Valley
McCOY MINE
CREEK
FISH
BROWN STOCK
McCOY PLUTON
AUGUSTA SEQUENCE
Reese River
TO BATTLE MTN
305
N
5 MILES
8 Km
TERTIARY VOLCANICS

FIGURE 2

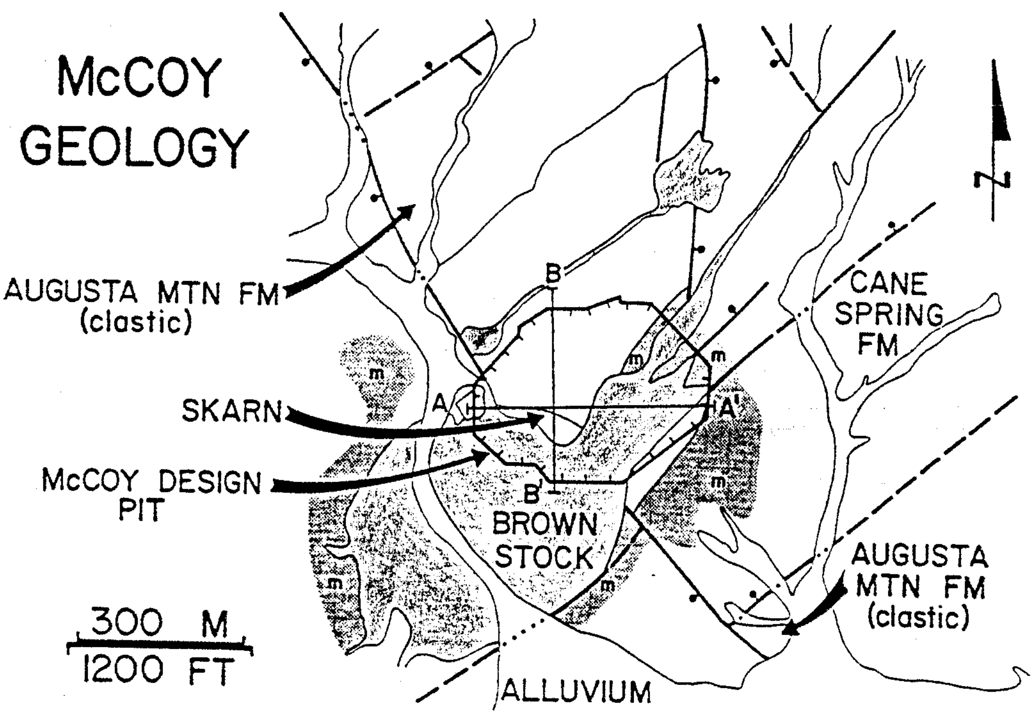
McCOY
GEOLOGY
AUGUSTA MTN FM
(clastic)
SKARN
McCOY DESIGN
PIT
B
A
A'
B'
BROWN
STOCK
CANE
SPRING
FM
AUGUSTA
MTN FM
(clastic)
ALLUVIUM
300 M
1200 FT
N

FIGURE 3

McCOY CROSS SECTION A-A'

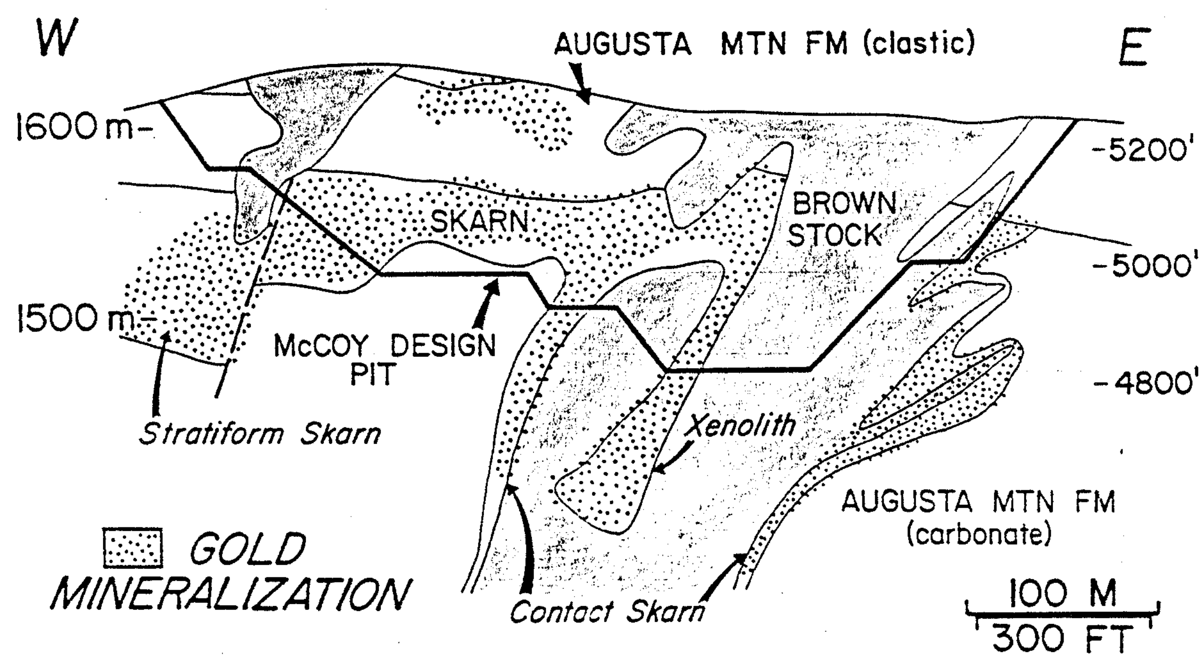

FIGURE 4

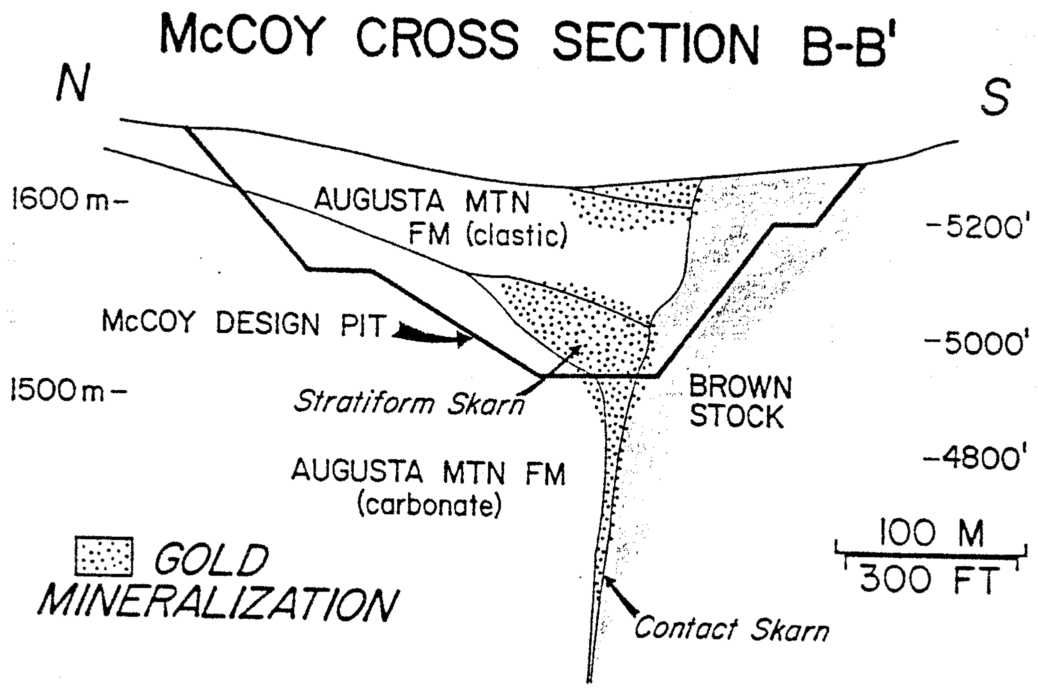
McCOY CROSS SECTION B-B'
N
S
1600 m-
AUGUSTA MTN
FM (clastic)
-5200'
McCOY DESIGN PIT
-5000'
1500 m-
Stratiform Skarn
BROWN
STOCK
-4800'
AUGUSTA MTN FM
(carbonate)
100 M
300 FT
GOLD
MINERALIZATION
Contact Skarn

FIGURE 5