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Geology of the Cove Gold-Silver Deposit

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Abstract

The Cove gold-silver deposit is located 50 km southwest of Battle Mountain, Nevada and 1.5 km northeast of the McCoy Mine. Total proven and probable reserves are 48.7 Mt (53.7 Mst) with an average grade of 1.85 g/t (0.054 oz/st) Au and 87.1 g/t (2.54 oz/st) Ag. Mineralization is hosted by Triassic carbonate and siliciclastic rocks in two separate orebodies. Oxide ore consists of disseminated gold and silver in clay-altered, manganese-flooded limestone. Sulfide ore is dominated by pyrite-sphalerite-galena veins in siliciclastic rocks and sandy dolomite. Gold and silver occur in the native state, associated with the base metal sulfides. Mineralization is interpreted to be the distal expression of a porphyry system. The McCoy gold (copper) deposit is interpreted to be the proximal expression of the same system.

Introduction

The Cove gold-silver deposit is located in Lander County, Nevada, about 50 km (30 mi) southwest of the town of Battle Mountain (Figure 1). The deposit is situated in the north-central Fish Creek Mountains, 1.6 km (1 mi) northeast of the McCoy gold-skarn deposit (Figure 2).

Gold was discovered in the central Fish Creek Mountains in 1914 by Joseph H. McCoy (Schrader, 1934). The first significant gold production was realized in 1928 from the Gold Dome Mine. Minor production from shallow underground workings continued through the early 1930's. Total gold production for the McCoy district from this period is estimated to be less than 311 kg (10,000 oz) (Stager, 1977).

The district remained inactive until the mid-1960's when exploration for copper, then gold, was undertaken by Bear Creek Mining, Summa Corp., Houston Oil & Minerals Corp., Gold Fields Mining Corp., and Tenneco Minerals Company. Tenneco decided to place the McCoy gold-skarn deposit into production in September, 1985.

A year later, in October 1986, Echo Bay Mines acquired Tenneco's precious metal properties. District exploration, initiated by Tenneco, and continued under Echo Bay's ownership, resulted in the discovery of the Cove deposit in January, 1987. Production from Cove oxide reserves began in February 1988. The McCoy and Cove mines are run as a common operation. On average, 6800 t/day (7,500 st/day) mill feed, and 11,300 t/day (12,500 st/day) heap leach ore are produced from the open-pit and underground mine complex. Pre-mining reserves at Cove total 48.7 mt with an average grade of 1.85 g/t Au and 87.1 g/t Ag (53.7 Mst, 0.054 oz/st Au and 2.54 oz/st Ag).

Stratigraphy

The north-central part of the Fish Creek Mountains is underlain by the Star Peak Group, a sequence of carbonate and terrigenous clastic rocks (Figure 2). The Star Peak Group is as much as 1,200 m (3,900 ft) thick and ranges in age from late Early to middle Late Triassic (Nichols and Silberling, 1977). Four formations comprise the Star Peak Group in the Fish Creek Mountains. In ascending order they are the Dixie Valley, Favret, Augusta Mountain, and Cane Spring Formations (Figure 3). Stratigraphic thicknesses for individual units are estimated, based on geologic maps and core logs.

The Dixie Valley Formation rests with angular unconformity on quartzites and conglomerates of the Pennsylvanian to Permian Havallah Formation. It crops out about 3 km (2 mi) north of the Cove deposit, and has been intersected in core in the area of the deposit. The unit is estimated to have a minimum thickness of 110 m (350 ft). The Dixie Valley Formation is composed of interbedded dolomite, calcareous siltstone and sandstone, sandy dolomite, with minor pebble conglomerate and pebbly sandstone.

The Favret Formation conformably overlies the Dixie Valley Formation and consists mainly of very dark gray to black limestone. Very fine-grained, disseminated pyrite is ubiquitous throughout the limestone. The limestone is overlain by 10-13 m (30-40 ft) of black, fissile, calcareous shale which marks the top of the Favret Formation in the Cove area (Parsley, 1989). The Favret Formation is conformably overlain by the Augusta Mountain Formation in the northern Fish Creek Mountains.

The Augusta Mountain Formation hosts most of the mineralization in the McCoy district. The Augusta Mountain is divided into three formally described members (Nichols and Silberling, 1977). The Home Station Member is the lowermost unit. At its type locality in the Augusta Mountains, the Home Station Member rests disconformably on the Favret Formation (Nichols and Silberling, 1977). The disconformity has not been recognized in the northern Fish Creek Mountains where the contact is gradational. The Home Station consists of massively bedded calcareous and dolomitic limestone. It commonly contains lenses or beds of sandstone and pebble conglomerate. The Home Station is a minor ore host at the Cove.

The Panther Canyon Member conformably overlies the Home Station Member. The contact between the two members is gradational, and is characterized by a subtle upward transition into massive dolomite. The contact is difficult to recognize in the northern Fish Creek Mountains. As a result, the two members were combined on geologic maps and drill hole logs. The massive dolomite of the Panther Canyon Member is approximately 25 m (80 ft) thick. In the Cove area, approximately 104 m (340 ft) of terriginous clastic deposits rest on the massive dolomite.

The clastic unit of the Panther Canyon Member is the primary host of sulfide mineralization at Cove. Typically, it can be divided into four sub-units, which exhibit a general coarsening upward progression. The lowermost sub-unit consists of approximately 23 m (75 ft) of calcareous siltstone and sandstone. The matrix can be either limy or dolomitic. The calcareous clastic rocks grade upward into 20 m (65 ft) of non-calcareous sandstone with lesser siltstone. The sandstone and siltstone are overlain by approximately 21 m (70 ft) of pebbly sandstone with interbeds of pebble conglomerate. The uppermost portion of the clastic unit consists of 40 m (130 ft) of pebble to cobble conglomerate with lesser sandstone. The conglomerate is massively bedded, and is composed of angular to sub-rounded pebbles and cobbles of chert and quartzite. Thickness and grain size distribution of the sub-units are typical, although local variations can be substantial.

The Panther Canyon Member is overlain by limestone of the Smelser Pass Member. The Smelser Pass is approximately 350 m (1,200 ft) thick in the northern Fish Creek Mountains. However, in the Cove area, erosion has removed the upper half of the member. It is composed of medium- to thick-bedded gray limestone with sparse, thin shale interbeds. The Smelser Pass Member is an important ore host in the district. The Cove oxide orebody is situated within the lower part of the member. Most of the gold-bearing skarn at the McCoy Mine is localized in the uppermost 60 m (200 ft) of the Smelser Pass Member.

Siliceous conglomerate and massive limestone of the Cane Spring Formation overlie the Augusta Mountain Formation elsewhere in the Fish Creek Mountains. The Cane Spring has been removed by erosion in the Cove area.

Triassic sedimentary rocks are overlain by Caetano Tuff along an angular unconformity. Two informal units comprise the Caetano Tuff in the northern Fish Creek Mountains. The lower unit consists of up to 90 m (300 ft) of weakly consolidated, sedimentary rocks. The unit is poorly sorted and consists of a diverse assemblage of waterlain tuffs, tuffaceous sandstone, and pebble to boulder conglomerate. The tuffaceous sedimentary rocks are overlain by gray to purplish crystal-rich welded tuff of quartz latite composition. On the basis of 12 radiometric ages (10 K-Ar and 2 fission track), the Caetano Tuff is considered to be Oligocene (32.6 Ma) (Stewart and McKee, 1977).

Intrusive Rocks

Triassic sedimentary rocks have been intruded by numerous dikes and sills. Intrusive rocks are weakly to intensely altered and determination of original mineralogy is thus difficult. The dikes and sills consist of phenocrysts of plagioclase + biotite $\pm$ quartz $\pm$ amphibole set in a fine grained matrix of quartz + plagioclase $\pm$ potassium feldspar (?). Accessory minerals include apatite $\pm$ zircon (J. Brooks, written comm., 1990). Dikes tend to occupy either northeast- or north-trending, high-angle, normal faults. Less commonly, the intrusive bodies have the form of sills (Figures 4 and 5). High-grade gold and silver mineralization is spatially associated with the sills.

Four K-Ar ages for intrusive rocks at the Cove average 39.8 Ma (Table 1). Age determinations were obtained from biotite separates. The dikes, from which these samples were collected, are weakly to intensely altered. Biotite from sample CV-1-4925B occurs as euhedral to subhedral, unaltered, phenocrysts which show good "bird's-eye maple" extinction. Biotite phenocrysts in sample CV-1-4925B have been partially replaced (up to 60%) by a mixture of calcite and illite. The K-Ar age for these intensely altered biotites is statistically indistinguishable from the ages for other biotites from Cove intrusive rocks. The correspondence in dates suggests that hydrothermal alteration of the biotites closely followed intrusion, and that biotite ages are a good estimate of the age of the intrusive rocks (Eng, 1990).

Structure

The sedimentary rocks in the immediate vicinity of the Cove deposit have been folded into a broad, gently southeast-plunging, anticline. The southern limb of the anticline is exposed in the open pit and in the underground workings. The bedding in this limb strikes N.80°W., and dips 20° to the southwest. The fold formed in response to horizontal compression oriented N.50°E. Joint sets related to the folding include extension and shear joints. The folding and associated joints predate the alteration and mineralization.

The sedimentary rocks are cut by three sets of normal faults (Figure 4). The earliest set strikes north, and dips on average 60° to the east. The second set strikes N.20°-40°W. and dips 60° to the northeast. The youngest set strikes northeast and dips 60° to the northwest. The northeast-striking faults are commonly occupied by dikes that are locally mineralized, and several of the faults can be traced along strike to the McCoy deposit. Age relationships among the fault sets are somewhat obscured by renewed movement on all the faults during Basin and Range extension.

The most prominent fault at the Cove is the Lighthouse Fault (Figure 4), a normal, dip-slip fault which has a maximum throw of about 150 m (500 ft). Both the oxide and sulfide orebodies have been cut by this fault. Manganese-rich oxide ore occurs primarily in the hanging wall; the footwall counterpart has presumably been eroded away. The main mass of sulfide ore lies in the footwall, with a minor portion of sulfide ore in the down-faulted block. The close spatial association of the Lighthouse Fault with high-grade mineralization suggests that the fault may have served as a conduit for mineralizing fluids (Figures 4 and 8). Northeast-trending faults appear to terminate against the Lighthouse Fault. Offset in the Caetano Tuff is approximately 30 m (100 ft), considerably less than the throw in the Triassic units, suggesting that most of the movement along the Lighthouse Fault occurred prior to 32 Ma.

High-grade sulfide ore, currently being mined underground, lies between two northeast-striking faults, the Bay and the Cay (Figures 4 and 5). The Cay Fault is occupied by an altered, granodioritic dike about 15 m (50 ft) wide, from which a sill extends into the clastic unit of the Panther Canyon Member. High-grade sulfide mineralization is spatially associated with this sill, although the sill itself does not constitute ore. Throw on the Cay Fault is less than 15 m (50 ft).

The Bay Fault is parallel to and approximately 245 m (800 ft) northwest of the Cay Fault. The Bay Fault is occupied by a discontinuous, altered, granodioritic dike. The dike is mineralized, and locally, constitutes ore. The sulfide orebody has been down-faulted to the northwest by the Bay Fault. Throw on the fault is approximately 60 m (200 ft).

Alteration & Mineralization

Hydrothermal activity at the Cove produced two separate orebodies which can be classified based on their relative position, and by the degree in which they have been affected by post-mineral oxidation (Emmons and Coyle, 1988). The upper Cove ore zone of Emmons and Coyle (1988) will be referred to as the oxide orebody (Figure 5). Their lower ore zone will be referred to as the sulfide orebody. Within each orebody there exist differing zones of mineralization which can be delimited on the basis of alteration assemblages, styles of mineralization, and lithologic associations.

Oxide Orebody:

The oxide orebody occurs in altered carbonate rocks of the Smelser Pass Member of the Augusta Mountain Formation. Four alteration styles have been tentatively identified:

1. Propylitic alteration
2. Clay alteration
3. Manganese alteration
4. Silicification

Alteration styles have been defined primarily on the basis of hand sample identification, with limited optical microscopy and x-ray diffraction studies.

Propylitic alteration: The propylitic alteration assemblage is characterized by the formation of chlorite and calcite ± pyrite. It has only been recognized in intrusive rocks. Chlorite occurs as fine-grained disseminations in the groundmass of porphyritic rocks, and it replaced amphibole and plagioclase phenocrysts. Calcite replaces plagioclase and biotite, and is also disseminated throughout the groundmass of porphyritic rocks. Disseminated, fine-grained pyrite is erratically distributed, but can locally constitute as much as 1% of the rock by volume. Propylitic alteration is typically observed as remnant islands or cores, surrounded by clay alteration. Propylitized intrusive rock is not generally not mineralized.

Clay alteration: Clay alteration is characterized by the mineral association illite ± mixed layer smectite/mica ± montmorillonite ± kaolinite (Baum, written comm., 1990). Clay alteration occurs primarily in carbonate rocks of the Smelser Pass Member, and to a lesser extent in intrusive rocks (Figure 6).

Intensity of alteration in Smelser Pass limestone varies from weak bleaching along fractures and bedding to zones of pervasive, intense alteration along fault zones and in shale interbeds. Intense clay alteration is characterized by compact yellow clay which lacks bedding, primary textures, and fossils. Oxidation of pyrite has resulted in the formation of goethite, limonite, and hematite. These oxidation products impart varying shades of brown and red to the clay altered rocks.

The distribution of clay-altered limestone about felsic dikes suggests that clay alteration was a result of hydrothermal activity. It is not clear whether the formation of illite and smectite/mica was the product of potassium metasomatism, or due to hydrothermal alteration of a terriginous component of the carbonate rocks.

Precious metal mineralization occurs within an envelope of clay-altered rock. Drill-hole samples of clay altered limestone average 0.34 g/t gold and 9.9 g/t silver (0.010 oz/st and 0.29 oz/st), no cut-off grade applied. Gold grades are higher along faults and at fault intersections. Grades of up to 10.00 g/t gold (0.300 oz/st) have been observed at structural intersections within clay altered limestone. Clay altered intrusive rocks are locally mineralized. Precious metal grades tend to vary directly with the iron-oxide content of clay-altered rock.

Manganese alteration: Manganese alteration is characterized by the formation of psilomelane-group minerals and pyrolusite (Schurer and Fuchs, 1988; Honea, 1988), usually in marble of the Smelser Pass Member. Manganese alteration is most intense in the hanging-wall block of the Lighthouse Fault, especially in the vicinity of the southeast intrusive (Figure 6). Manganese-altered limestone forms the high-grade core of the oxide orebody, within the aureole of clay alteration.

Manganese concentrations in excess of 1% have been observed in the most intensely altered rocks. The alteration imparts a pale brown color to clay altered limestone at the outer fringe. The most intensely altered areas have a brownish black color, and are cut by small, 1 mm to 3 mm (0.04 to 0.10 in) quartz and calcite veinlets. Intensity of manganese alteration diminishes away from the Lighthouse Fault.

High-grade mineralization (greater than 3.40 g/t gold and 170.0 g/t silver (0.100 oz/st and 5.00 oz/st respectively) coincides conspicuously with of intensely manganese-altered rock. Gold occurs in the native state as electrum (890 fine). Silver occurs with gold as electrum, as chlorargyrite (cerargyrite), and as argentiferous psilomelane (Honea, 1988). Sparse pyrite, sphalerite, galena, chalcopyrite, arsenopyrite, tetrahedrite, and pyrrhotite were recognized during reflected light petrographic studies of gravity concentrates recovered from manganese-oxide ore (Honea, 1990). The association of gold with iron-oxide minerals suggests that gold was originally deposited as inclusions in pyrite during hypogene mineralization, and was subsequently liberated during oxidation of the original sulfide assemblage (Honea, 1988, Theodore and Jones, 1990).

Silicification: Silicification consists of jasperoid in both clay-altered and manganese-altered carbonate rocks. Jasperoid occurs as irregularly shaped bodies up to 6 m (20 ft) across.

Jasperoid in clay altered rocks is erratically mineralized. As in clay-altered rocks, jasperoid which contains iron-oxide minerals tends to carry precious metal values. Jasperoid which lacks iron-oxide staining is typically unmineralized. Jasperoid in manganese-altered limestone is invariably mineralized. Gold grades in such jasperoid tend to be higher, and silver grades tend to be lower, than gold and silver grades in the surrounding, unsilicified, manganese-altered rocks.

The paragenesis of the alteration styles is poorly understood. Propylitic alteration is clearly overprinted by clay alteration. Less clear is the timing of manganese alteration. Rocks which display both manganese and clay alteration are typically dark colored, and lack the bleaching usually associated with clay alteration. This lack of bleaching suggests that manganese alteration postdates clay alteration. Rare cross-cutting textures indicate that silicification probably occurred late in the paragenetic sequence.

Sulfide Orebody

The sulfide orebody is hosted by clastic and carbonate rocks of the Panther Canyon Member and the Home Station Member (Figures 5 and 7). Mineralization has been observed in the Favret Formation and Dixie Valley Formation but does not constitute ore at this time. Sulfide mineralization can be divided into an upper high-grade zone, and a lower high-grade zone.

Two alteration styles are associated with sulfide mineralization:

1. Propylitic alteration
2. Sericitic alteration

Propylitic alteration: Propylitic alteration of intrusive rocks associated with sulfide mineralization is similar to propylitic alteration associated with oxide mineralization. It is characterized by the mineral association of chlorite and calcite ± pyrite. It is generally observed as remnant cores surrounded by sericitically altered rock.

Sericitic alteration: Sericitic alteration is represented by the mineral assemblage sericite ± quartz ± pyrite ± chlorite. In the clastic unit of the Panther Canyon Member, mineralization is intimately associated with sericitic alteration. During exploration drilling of the Cove, what is now recognized as sericitic alteration was logged as clay alteration. As a consequence, sericitic alteration is shown as clay alteration on Figure 7.

The distribution of sericite is generally restricted to the zone of base and precious metal mineralization. Within this zone, sericite is pervasive. Intensity of sericitization within dikes and sills increases from core to contact. Within the clastic unit, sericite is most abundant in the more silty units where intense sericitization imparts a bleached appearance to the rocks. The occurrence of sericite in carbonate lithologies below the clastic unit is poorly understood.

Silica, in the form of quartz, rims clasts and occurs as microveinlets in the Panther Canyon Member. Quartz in the microveinlets is rarely accompanied by sericite and pyrite (Schurer and Fuchs, 1988).

Pyrite, like sericite, is ubiquitous at Cove. Veinlets of pyrite are associated with base and precious metal mineralization, and form a halo which extends 15 m (45 ft) beyond the mineralization. Pyrite occurs as euhedral to anhedral grains which occupy vugs, and rim clasts in the clastic unit. Pyrite is disseminated in carbonate lithologies.

Chlorite is widely distributed in the deeper parts of the Cove system. It is commonly found intergrown with sericite with or without quartz (J. Brooks, pers. comm., 1990).

Upper high grade zone: The upper high-grade zone is hosted by siltstone, sandstone and chert-pebble conglomerate of the Panther Canyon Member. The upper high-grade zone is a tabular body, roughly elliptical in plan view (Figure 8). It is 670 m (2,200 ft) long, 245 m (800 ft) wide, and is, on average, 21 m (70 ft) thick. The zone is fault bounded to the east and northeast by the Lighthouse fault. It thins, or pinches out to the southwest. It is localized primarily along the footwall of a felsic sill. The sill strikes N.70° to 80°W. and dips 20°-30° to the west and is roughly conformable to bedding in the clastic unit.

The sill predates sulfide mineralization but is typically unmineralized. The sill is cut by normal, dip-slip faulting, and has been successively down-dropped to the northeast. It appears to have acted as a barrier to upward migrating hydrothermal fluids, so that the bulk of the orebody lies below the sill. Pre-mineral faulting allowed some leakage of hydrothermal fluids into the overlying sediments, which produced erratic high-grade mineralization above the sill.

Pre-main stage sulfide mineralization is characterized by near vertical, 0.25 to 1.00 mm (0.01 to 0.04 in) veinlets consisting of subhedral to euhedral pyrite without appreciable gangue. Pre-main stage veins have a characteristic alteration envelope which ranges in width from 1.0 to 5.0 mm (0.04 to 0.20 in). The alteration envelope consists of an inner, bleached, sericitic zone and an outer, dark grey, disseminated pyrite zone. These veins fill steeply dipping fractures which cut all rock types of the Panther Canyon Member, and are commonly offset a few centimeters by later, main stage sulfide veins. Pre-main stage mineralization also occurs as fault fillings and localized crackle breccias. Pre-main sulfide mineralization was not accompanied by precious metal deposition.

Main stage mineralization occurs as a stockwork or sheeted vein system. Individual sulfide veins range from 3 mm to 20 cm (0.12 to 8.0 in) in thickness. The veins occur as a conjugate set: one set conformable to the bedding, strikes N.80°W. and dips 20° to the southwest, the second set strikes N.59°W. and dips 18° to the east (Figure 9). The stockwork or sheeted vein system plunges concordantly with bedding to the southwest. The vein density within the orebody varies from two veins per meter to more than 15 veins per meter.

Vein size and density of stockwork veinlets tends to be a function of grain size within the clastic unit. Larger veins, and more intense stockworks typically occur in siltstone and sandstone. Conglomerate contains significantly fewer large veins, and stockworks in conglomerate are rare or poorly developed. Veins tend to be best developed at contacts where sandstone or siltstone is overlain by conglomerate. The distribution of veins and precious metal concentrations along these contacts suggests that conglomeratic units were more competent and did not readily fracture, hence effectively concentrating the mineralizing fluids in underlying sandstone or siltstone.

Mineralogically, the veins and stockworks consist of a complex intergrowth of sulfides and sulfosalts without appreciable gangue. Gangue, where observed, consists of sericite $\pm$ clay $\pm$ quartz. Rarely, some late drusy quartz or sparse manganocalcite infills vugs or cavities in the veins. Individual veins typically assay greater than 34 g/t gold and 6,800 g/t silver (1 oz/st gold and 200 oz/st silver). The clastic host rock, between veins, contains low precious metal values.

The most abundant sulfides are pyrite, sphalerite, marcasite and galena. Pyrite is the most common sulfide, found both in veins and as disseminations throughout the Augusta Mountain Formation. Disseminated pyrite consists of subhedral to euhedral cubes from 0.25 to 1.5 mm across. It forms a broad halo around the main sulfide orebody but in the absence of stockwork veins does not host significant precious metal mineralization.

Pyrite also occurs as massive open space fillings in the main sulfide orebody. Pyrite can locally constitute 90% of the vein sulfide mineralogy, but it typically makes up 5 to 8% of the ore. It occurs as anhedral to euhedral masses and intergrowths with other sulfides. Vein pyrite is the single most important host of visible electrum in the sulfide orebody (Schurer and Fuchs, 1988). Metallurgical studies have demonstrated that approximately 55% of the gold contained in sulfide ore reports to a pyrite flotation concentrate.

Sphalerite is the next most abundant sulfide, occurring as open space fillings in veins within the main sulfide orebody. It averages 0.5% or less of the orebody but comprises 20% of individual veins. Iron content of the sphalerite ranges from 1.9% to 12.7% (Schurer and Fuchs, 1988). Virtually all of the sphalerite with low iron content has a correspondingly higher manganese content, up to 3.7%. Sphalerite occurs as anhedral ,or occasionally subhedral, grains up to 3 mm across. It typically contains abundant exsolution blebs of chalcopyrite. Occasionally, sphalerite is cracked and filled with later galena.

Marcasite is the next most abundant sulfide. It is generally only present when large amounts of pyrite (> 30%) are present. However, some massive pyrite contains no marcasite. It commonly occurs as intimate anhedral intergrowths with pyrite.

Some marcasite and pyrite contains distinct dark, patchy domains. These domains contain significant copper (1.0% to 20.8% Cu), silver (0.65% to 1.4% Ag) and occasionally zinc (2.1% to 6.3% Zn) or lead (6.3% to 9.5% pb). Microprobe data suggest that this material is a non-stoichiometric mixture of variable composition deposited under non-equilibrium conditions rather than separate mineral species (Schurer and Fuchs, 1988).

Galena is generally anhedral to subhedral and usually associated with pyrite and sphalerite. It is argentiferous, carrying up to 1.4% Ag (Schurer and Fuchs, 1988) and it also contains significant concentrations of gold. Galena occurs as patches and blebs in pyrite or sphalerite; as rims or fracture fillings in pyrite; as microveinlets with pyrite; or as scattered, megascopic subhedral grains in sulfide veins.

In addition to these major constituents of the Cove sulfide ore, numerous minor, though widely distributed sulfides and sulfosalts also occur in the deposit. Table 2 presents a list of the Cove sulfide deposit ore minerals.

Stannite is a minor component of the sulfide assemblage, but is widely distributed throughout the sulfide orebody. It typically occurs as olive gray blebs or inclusions in pyrite, and rarely as inclusions in sphalerite and galena. Typical grain size range for stannite is 5 to 30 microns.

Stannite relatives, including stannite III, kesterite, and non-stoichiometric stannite, are rare but widely distributed. They typically occur as small grains (2 to 30 microns) associated with sphalerite, galena, and occasionally, pyrite. The stannite relatives are characterized by the substitution of zinc for some or all of the iron in stannite (Ramdohr, 1980; Schurer and Fuchs, 1988).

Canfieldite has only been observed in the Lighthouse fault area. It typically occurs as small grains associated with sphalerite and stannite.

Cassiterite is rarely observed in Cove sulfide ores. It occurs characteristically as small (6 to 20 microns) grains associated with stannite.

Lower high-grade zone: Mineralization, beneath the upper high-grade zone, occurs in carbonate dominated lithologies of the Panther Canyon Member, and in the clastic unit of the Panther Canyon Member in the hanging wall of the Lighthouse Fault (Figure 5). This deeper mineralization is informally referred to as the lower high-grade zone. The lower high-grade zone differs from the upper high-grade zone in size and intensity of veins. The stockworks and sheeted veins observed in the clastic unit do not continue into carbonate lithologies. Although fewer veins occur in carbonate rocks, the veins tend to be larger. Veins up to 0.3 m (1 ft) thick have been observed in core. Base and precious metal mineralization also occurs along the contacts of sparse clastic interbeds, similar in occurrence to that described for the upper high-grade zone.

Vein mineralogy for the lower high-grade zone is similar to that described for the upper high-grade zone. Silver sulfosalts appear to occur more frequently in the lower high-grade zone, but this observation may be an artifact of the spatial distribution of lower high-grade zone samples chosen for the study.

Paragenesis: The paragenesis of vein minerals is poorly understood. Unambiguous paragenetic relationships are rarely observed. In many sections the evidence favors contemporaneous deposition of all the sulfides, sulfosalts, and precious metals in a single episode of short duration. Indirect evidence for this may be indicated by the existence of numerous non-stoichiometric sulfide phases which is an indication of chemical disequilibrium (Schurer and Fuchs, 1988).

At least some of the pyrite was deposited early, as evidenced by pre-main stage veins which are clearly cross-cut by main stage mineralization. Sphalerite is occasionally cut by veins of pyrite, marcasite, chalcopyrite, and galena which suggests that it is one of the earlier formed sulfide minerals.

Native silver is commonly observed in vugs and along fractures in sulfide veins. It typically occurs as wirey masses which grow into the vugs. Silver was clearly deposited late in the paragenetic sequence, and was probably deposited as a result of supergene alteration.

Discussion

The Cove deposit, with its association of Ag + Au + manganese oxides in the oxide orebody, and Ag + Au + base metal sulfides + sulfosalts + tin sulfides is a unique occurrence for the state of Nevada. The mineralogy of the Cove sulfide orebodies, and the tin-silver association, suggest that there may be an affinity between the Cove deposit and the polymetallic vein deposits of tin-silver province of central and southern Bolivia. However, we propose that the occurrence of base and precious metals at the Cove can best be explained within the context of a metal zoning model centered around the McCoy gold (copper) system.

The tin-polymetallic deposits of the southern part of the Bolivian tin belt have been described by numerous authors, in particular, Turneaure (1960, 1971). The ore deposits consist primarily of narrow veins and stringer lodes, but some sheeted zones, stockworks and breccia lenses have been productive (Turneaure, 1960). The veins occur in, or are associated with, porphyritic stocks which commonly range from quartz latite to dacite (Turneaure, 1971). Hydrothermal alteration of the stocks and enclosing volcanic rocks is characterized by the formation of chlorite, sericite and quartz. Mineralogy of the tin-silver veins consists of pyrite, cassiterite, stannite, chalcopyrite, tetrahedrite, andorite, lead sulfosalts, galena, sphalerite and ruby silver.

The Cove deposit is similar to the Bolivian tin-polymetallic vein deposits in several respects. Mineralization occurs as veins and stockworks in brittlely deformed rocks. Hydrothermal alteration is characterized by the formation of quartz, sericite and chlorite. Vein mineralogy consists of a complex association of pyrite, base metal sulfides, tin-minerals, sulfosalts, and precious metals.

However, several differences should be noted. The tin-rich polymetallic vein deposits of Bolivia occur primarily in intrusive and volcanic rocks, whereas the mineralization at the Cove occurs almost exclusively in sedimentary rocks. The deposits in central and southern Bolivia produced tin-silver ores. This is in contrast to the Cove deposit which is being mined solely for its precious metal content. Although the sulfide orebody at Cove is markedly anomalous in lead, zinc, and tin (0.31%, 0.32%, 113 ppm respectively) only lead has the potential to be produced as a by-product. The paucity of cassiterite, high gold concentrations, and low base metal content of the ore sets Cove apart from the tin-polymetallic deposits of Bolivia.

The lack of ore-grade tin mineralization not withstanding, the association of gold and tin remains the single most distinctive aspect of Cove. Boyle (1979) notes that the gold content of typical tin deposits is very low, and that the reverse is also true, that gold deposits seldom contain much tin. The significance of the association of tin with high-grade gold mineralization at the Cove is not well understood. However, it does suggest that gold mineralization at the Cove may not be related to the silver-tin-base metal mineralization. The inference that gold mineralization occurred as a separate event is further supported by the observation that gold, while spatially associated with base metal sulfides in the sulfide orebody, is only weakly correlated with copper (Spearman's r = 0.505) and shows no correlation with silver, tin, lead, zinc, or arsenic (Kuyper et al., in prep.).

Based on our limited understanding of the alteration and mineralization, we interpret the Cove to be the distal expression of the McCoy gold-copper system. This interpretation is based on the occurrence of intrusive rocks of similar age and composition at both deposits; faults which structurally connect the deposits; and the position of the Cove with respect to McCoy.

K-Ar ages for intrusive rocks and alteration associated with skarn cluster around 40 Ma (Brooks et al., 1990). The ages for intrusive rocks and alteration at McCoy, are statistically indistinguishable from ages for intrusive rocks spatially associated with mineralization at Cove. Igneous rocks at both deposits are typically fine-grained, porphyritic, and contain phenocrysts of plagioclase, biotite, amphibole, and quartz. The igneous rocks are typically granodioritic in composition at both deposits. Based on similarity of ages and composition, the intrusive rocks are interpreted to represent apical stocks and dikes related to the emplacement of a larger intrusive body at depth.

Northeast-striking normal faults have been mapped at both McCoy and Cove (Figure 10). Due to poor exposure, the faults cannot be mapped as continuous features connecting the two orebodies. However, based on analysis of aerial photography, limited exposures, and stratigraphic offset, the faults are inferred to be continuous between the deposits. Northeast-striking faults are an important control for mineralization at McCoy, and are inferred to be the feeder structures at Cove. Northeast-striking faults could have served as conduits for mineralizing fluids from the McCoy deposit.

Concentric zones of metals associated with porphyry systems have long been recognized (Spurr, 1907; Emmons, 1933, 1937). More recent treatments of the subject include Jerome (1966), Einaudi (1982), and Jones and Leveille (1989).

Jerome (1966) describes two generalized zones of metals associated with porphyry copper deposits, a central copper zone, and a fringe zone. The major metals of the central copper zone include copper, molybdenum, gold, and silver. Lead, zinc, silver and manganese comprise the major metals of the fringe zone. Although Jerome (1966) interprets gold as being largely restricted to the central copper zone, he does note that gold may occur in veins at some distance from the main orebody.

Einaudi (1982), in his discussion of skarns associated with porphyry copper plutons, describes a lateral zone of pyrite, bornite, chalcopyrite, tennantite, sphalerite, and galena peripheral to lode type, porphyry-related copper deposits. Einaudi (1982) does not include gold in his discussion of lateral zoning. However, in his description of skarns in the Bingham District, he notes gold grades of 1.02 g/t to 1.70 g/t (0.03 to 0.05 oz/st) and silver grades of 136 g/t to 160 g/t (4.0 to 4.7 oz/st) in lead-zinc-silver replacement-fissure ores peripheral to the copper mineralization (Einaudi, 1982). Lead-zinc-silver fissure-replacements typically occur 500 m to 2,700 m (1,600 ft to 8,800 ft) laterally away from the porphyry contact.

Jones and Leveille (1989) specifically address the position of gold in metal zoning associated with gold-enriched porphyry systems. They have gold occurring in:

1. the center of the system associated with the highest copper grades;

2. peripheral to copper mineralization, frequently inside the lead-zinc silver zone, and;

3. distal to the lead-zinc-silver zone.

Although McCoy is not a gold enriched porphyry copper system in the strictest sense, gold and sub-economic copper mineralization are associated with a porphyritic stock. McCoy thus represents the central gold-copper zone of Jerome (1966) and Jones and Leveille (1989).

The association of gold and silver with manganese in the oxide orebody, and the association of lead-zinc-silver and gold in the sulfide orebody is typical of mineralization peripheral to gold enriched porphyry copper systems as described by Jerome (1966), Einaudi (1982) and Jones and Leveille (1989). The position of Cove with respect to McCoy (1,800 m, 6,000 ft laterally away) falls within the range tabulated by Einaudi (1982) for gold-rich base metal deposits in the Bingham district. Gold-rich base metal deposits, like those in the Bingham District and at Cove, probably represent late-stage overprint deposits as described by Jones and Leveille (1989).

Similar ages of intrusive rocks, structural framework of the district, trace element association and position of the Cove with respect to McCoy suggest that the deposits are related. Cove is interpreted to represent the distal part of the system, and McCoy is interpreted to occur as proximal mineralization. Intrusive rocks associated with the deposits are thought to be apical stocks and dikes related to larger intrusive body at depth.

Acknowledgements

We would like to thank the Management of Echo Bay Mines for permission to publish this paper. Discussions with David Emmons, Tony Eng, and the many other geologists who assisted with the exploration and development of the Cove have helped clarify our understanding of the deposit. We especially thank Jeffrey Brooks and David Boden for their thoughtful and constructive reviews of earlier drafts of this manuscript. Debbie Crabtree showed great patience during the typing of many drafts. Her assistance is greatly appreciated. John Brookhouser drew the figures which accompany this paper.

Table 1. K-Ar Ages for Intrusive Rocks, Cove Deposit

Sample No.	Material	K_2O%*	Age (Ma)	Comments
CVC-1-158-159	Biotite	6.703	39.5 ± 1.5	Biotite-feldspar porphyry, probably Cay Dike.
CV -1-4925B	Biotite	6.631	40.3 ± 1.2	Biotite-feldspar porphyry, Bay Dike, mod.-int. altered, up to 60%, by area, of biotite replaced by calcite and illite.
CV- 5-4895B	Biotite	6.572	39.4 ± 1.2	Felsic intrusive, Cay Dike, weakly altered, biotite fresh.
CV- 3-4865A	Biotite	7.181	40.0 ± 1.2	Biotite granodiorite boulder (?), weakly altered, biotite locally rimmed with calcite.

* Mean of two aliquots.
Sources: Eng (1990), Emmons (pers. comm.). All age determinations performed by Geochron Labs, Cambridge, MA.

Table 2: Cove Sulfide/Ore Mineralogy

Name & Nominal Chemical Composition	Abundance	Distribution
Acanthite Ag_2S	Trace	Rare
Anatase TiO_2	Minor	Ubiquitous
Arsenopyrite $FeAsS$	Minor	Widely Distributed
Bravoite $(Ni,Fe)S_2$	Trace	Rare
Canfieldite Ag_8SnS_6	Trace	Rare
Cassiterite SnO_2	Trace	Rare
Chalcocite Cu_2S	Trace	Rare
Chalcopyrite $CuFeS_2$	Minor	Ubiquitous
Chatkalite $Cu_6FeSn_2S_8$ (Tentative identification)		Trace Rare
Covellite CuS	Trace	Rare
Digenite Cu_9S_5	Trace	Rare
Electrum Au,Ag $(Ag \geq 20\%)$	Trace	Ubiquitous
Freibergite $(Ag,Cu,Fe)_{12}(Sb,As)_4S_{13}$ (var. of tetrahedrite)	Minor	Widely distributed
Galena PbS	Abundant	Ubiquitous
Gersdorffite $(Ni,Fe)AsS$	Trace	Rare
Goethite $(FeO(OH)$	Trace	Rare
Hematite Fe_2O_3	Trace	Rare
Kesterite $Cu(Zn,Fe)SnS_4$	Minor	Widely distributed
Kesterite-Stannite Mix $Cu_2(Fe,Zn)SnS_4$	Minor	Widely distributed
Marcasite FeS_2	Abundant	Widely distributed
Non-stoichiometric stannite	Trace	Widely distributed
Non-stoichiometric Cu-Fe sulfide	Trace	Rare
Pearceite-Polybasite $(Cu,Ag)_{16}(As,Sb)_2S_{11}$		Minor Rare
Pyrargyrite-Proustite Ag_3SbS_3-Ag_3AsS_3	Minor	Rare
Pyrite FeS_2	Abundant	Ubiquitous
Pyrrhotite $Fe_{1-x}S$	Minor	Ubiquitous
Rutile TiO_2	Minor	Ubiquitous
Shadlunite $(Pb,Cd)(Fe,Cu)_8S_8$ (Tentative identification)	Trace	Rare
Silver Ag	Minor	Ubiquitous
Sphalerite $(Zn,Fe)S$	Abundant	Ubiquitous
Stannite Cu_2FeSnS_4	Minor	Widely distributed
Stannite 3 $(Cu,Ag)_2(Fe,Zn)SnS_4$	Trace	Rare
Tetrahedrite-Tennantite $(Cu,Fe)_{12}(Sb,As)_4S_{13}$ distributed		Minor Widely

Note: Trace = 1 or 2 grains observed in polished section; Minor = <1% of vein mineralogy, occasionally visible in hand specimen; Abundant = >1% of vein mineralogy, commonly visible in hand specimen. Rare = only one occurrence noted; widely distributed = observed in 30% to 50% of sections studied. Ubiquitous = observed in over 50% of sections studied.

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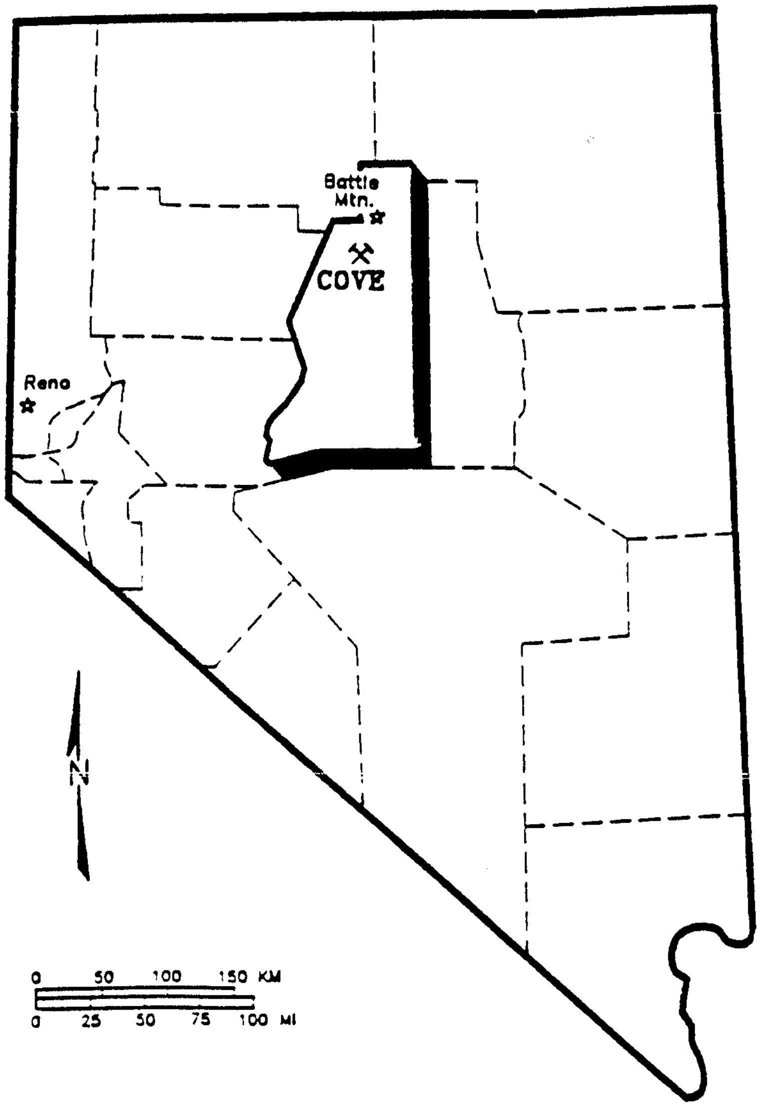

Figure 1 Location map fo the Cove deposit
Lander County, Nevada

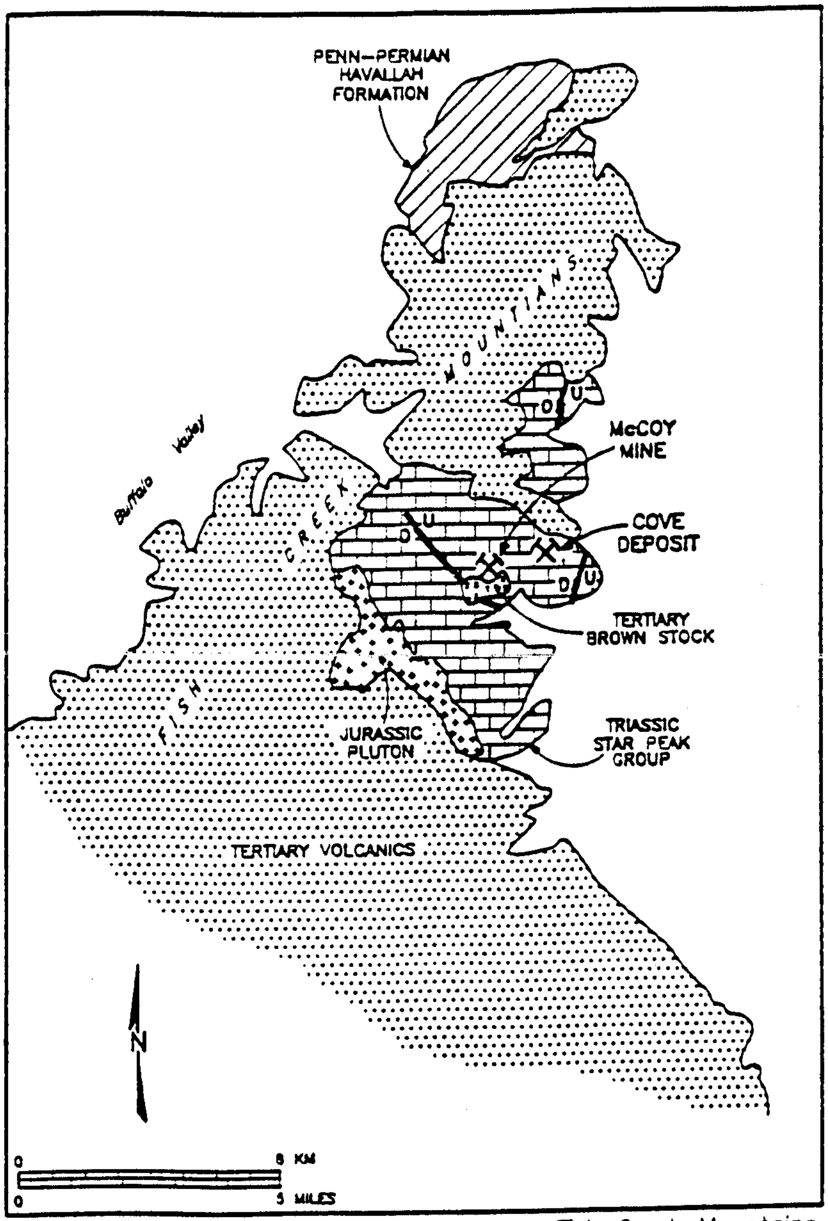

Figure 2 Geologic map of the Northern Fish Creek Mountains
(modified from Ferguson et. al., 1951, and Stewart and Mckee, 1977)

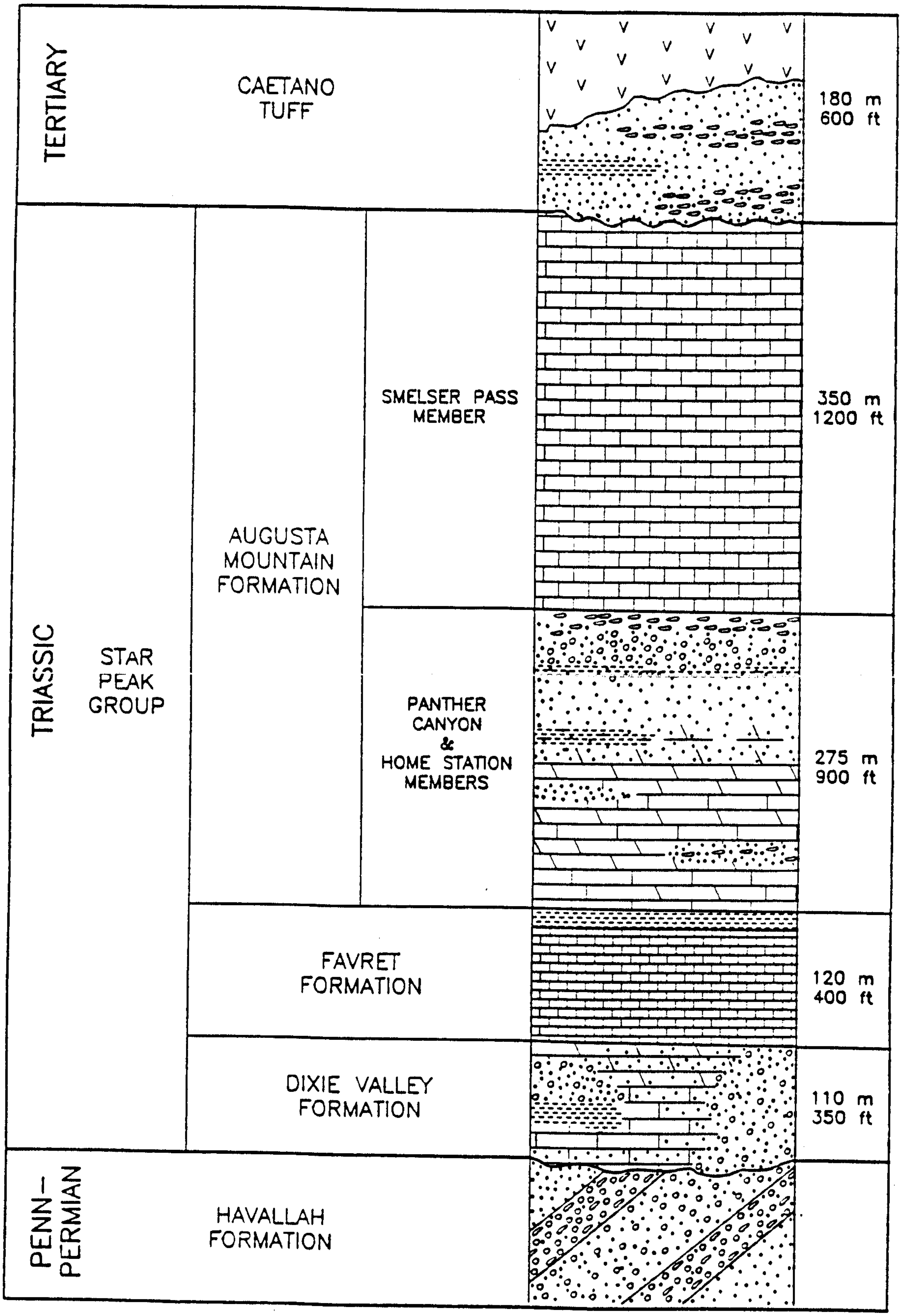

Figure 3 Generalized stratigraphic section for the Cove area

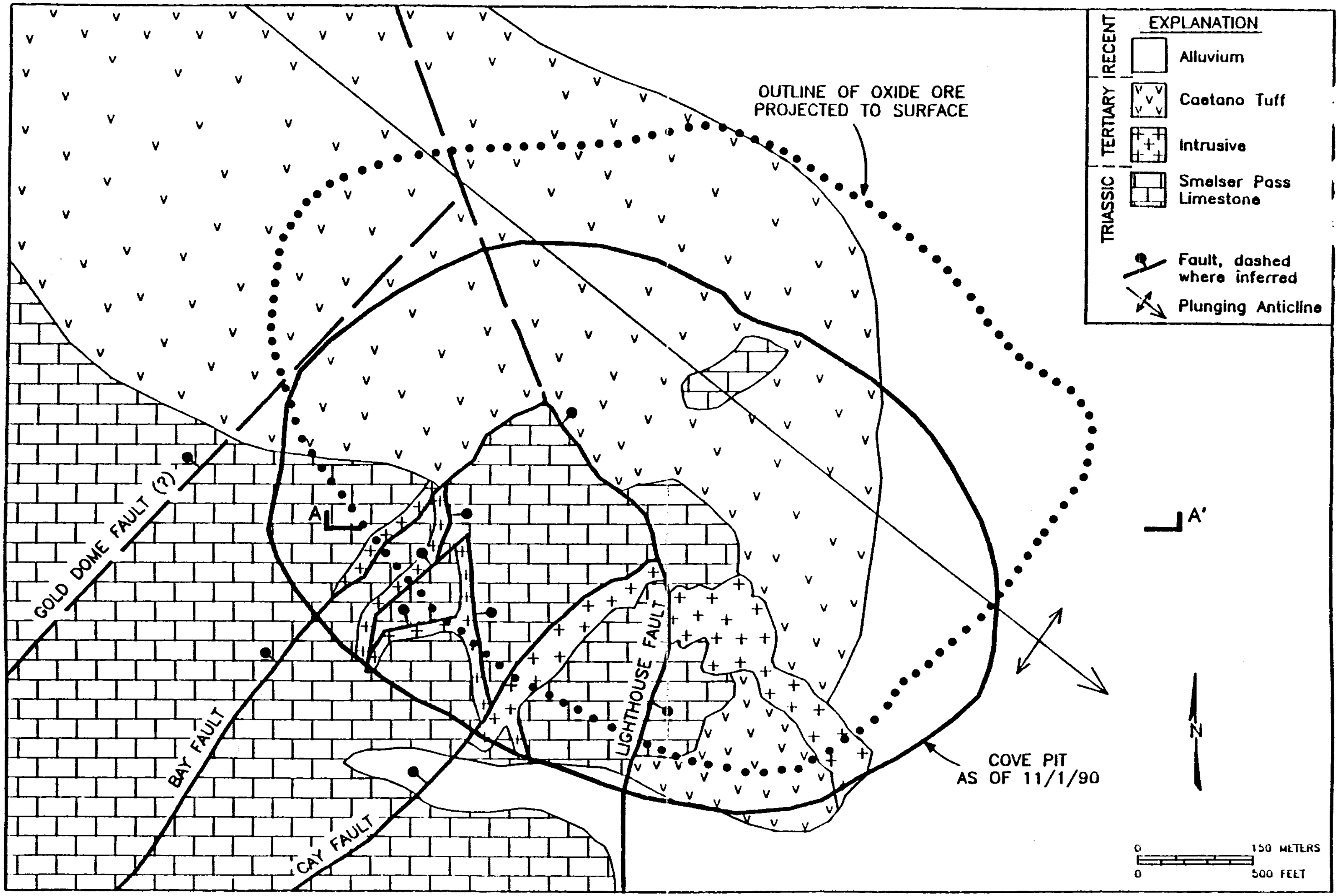

Figure 4 Geologic map of the Cove deposit

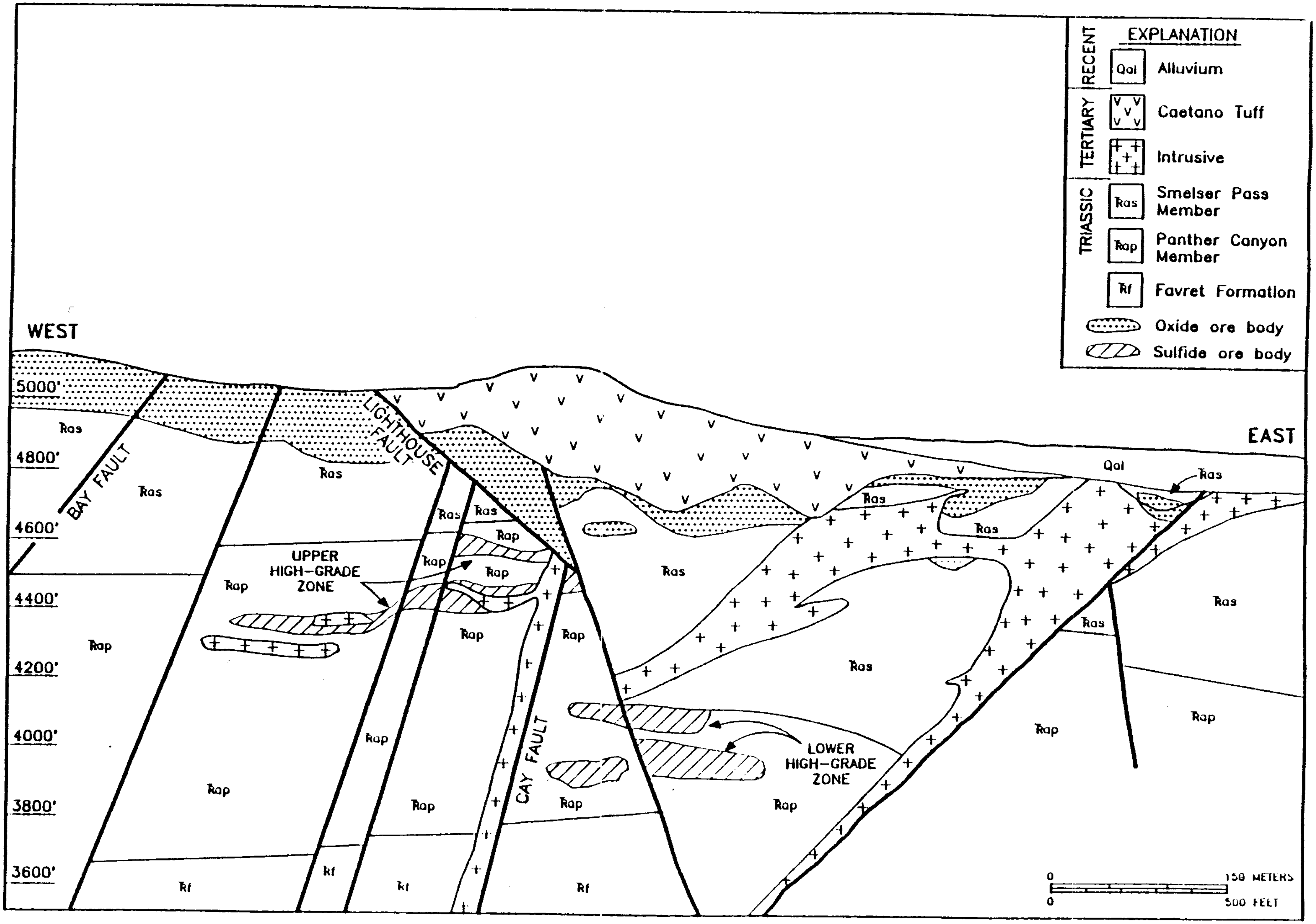

Figure 5 Cross section through the Cove deposit showing generalized ore zones

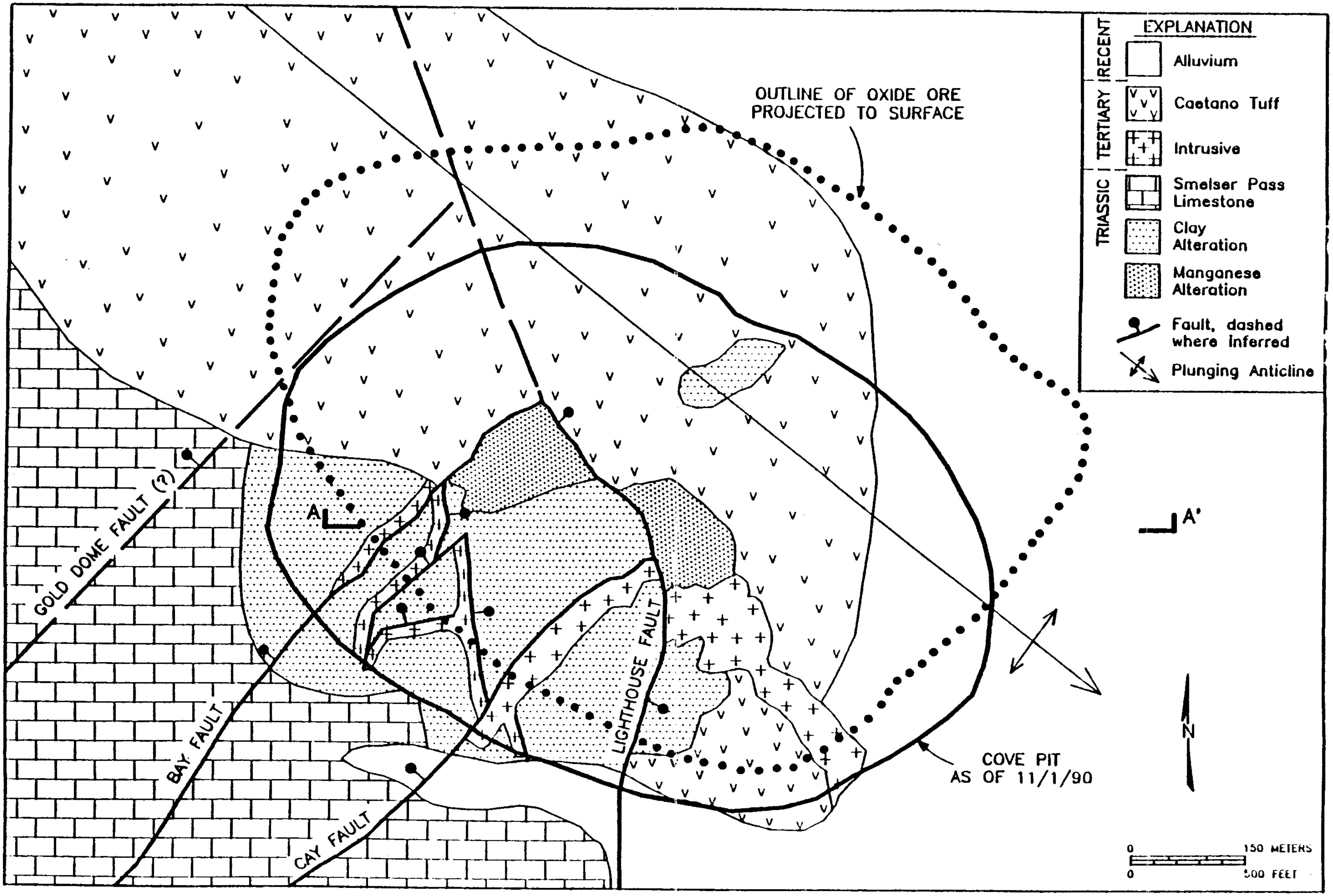

Figure 6 Geologic map of the Cove deposit showing alteration

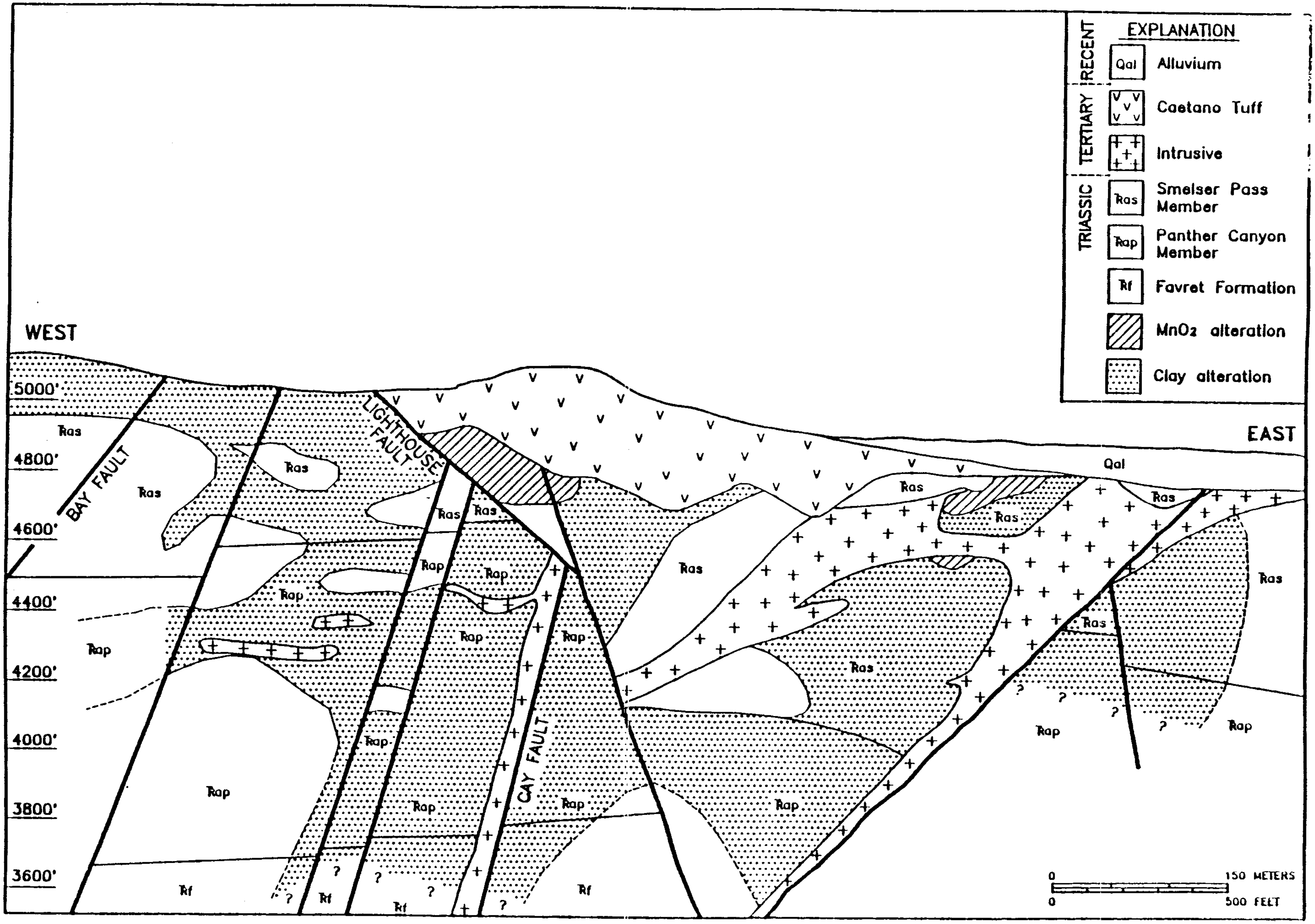

Figure 7 Cross section through the Cove deposit showing generalized distribution of alteration

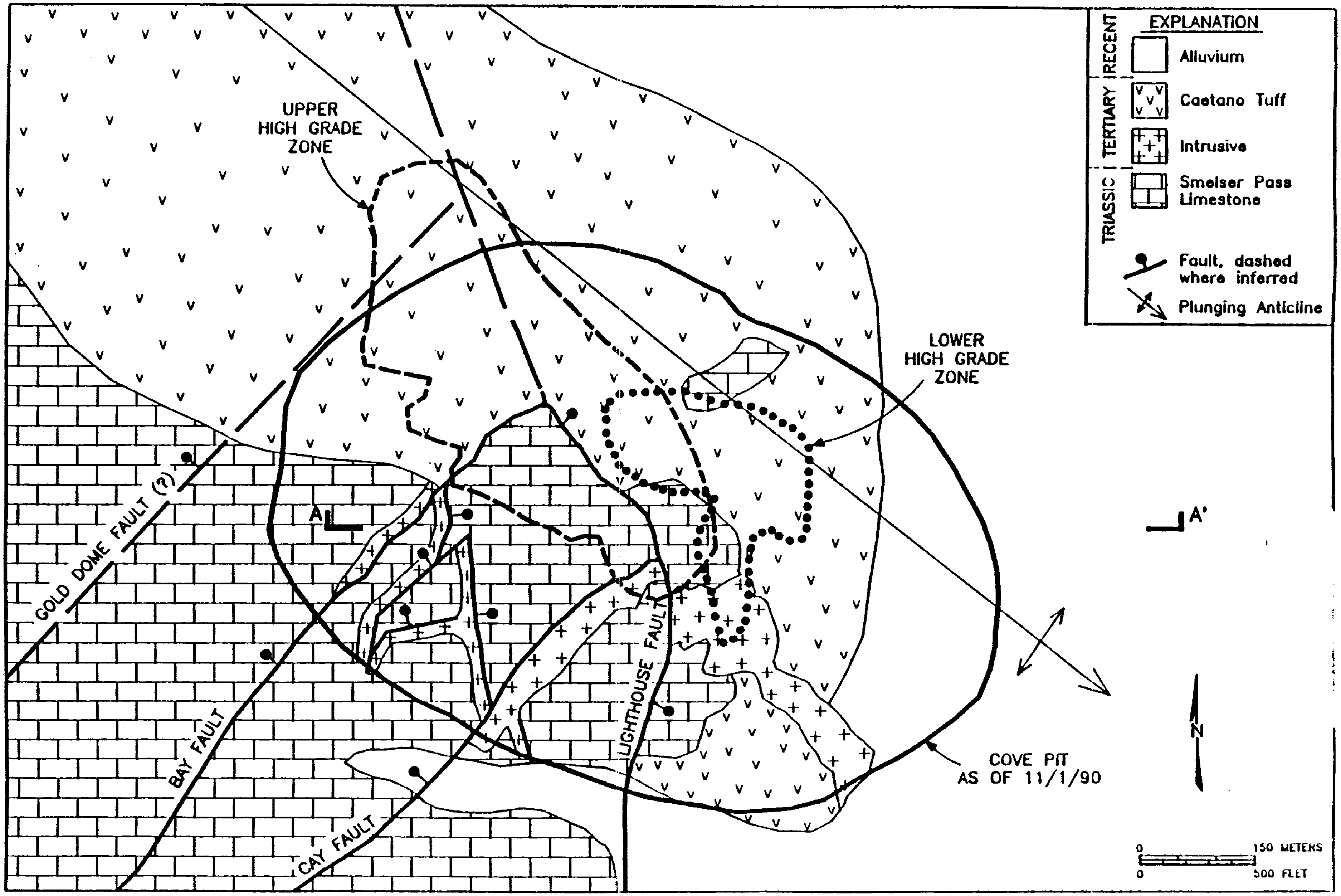

Figure 8 Geologic map of the Cove deposit showing outline of sulfide mineralization projected to surface

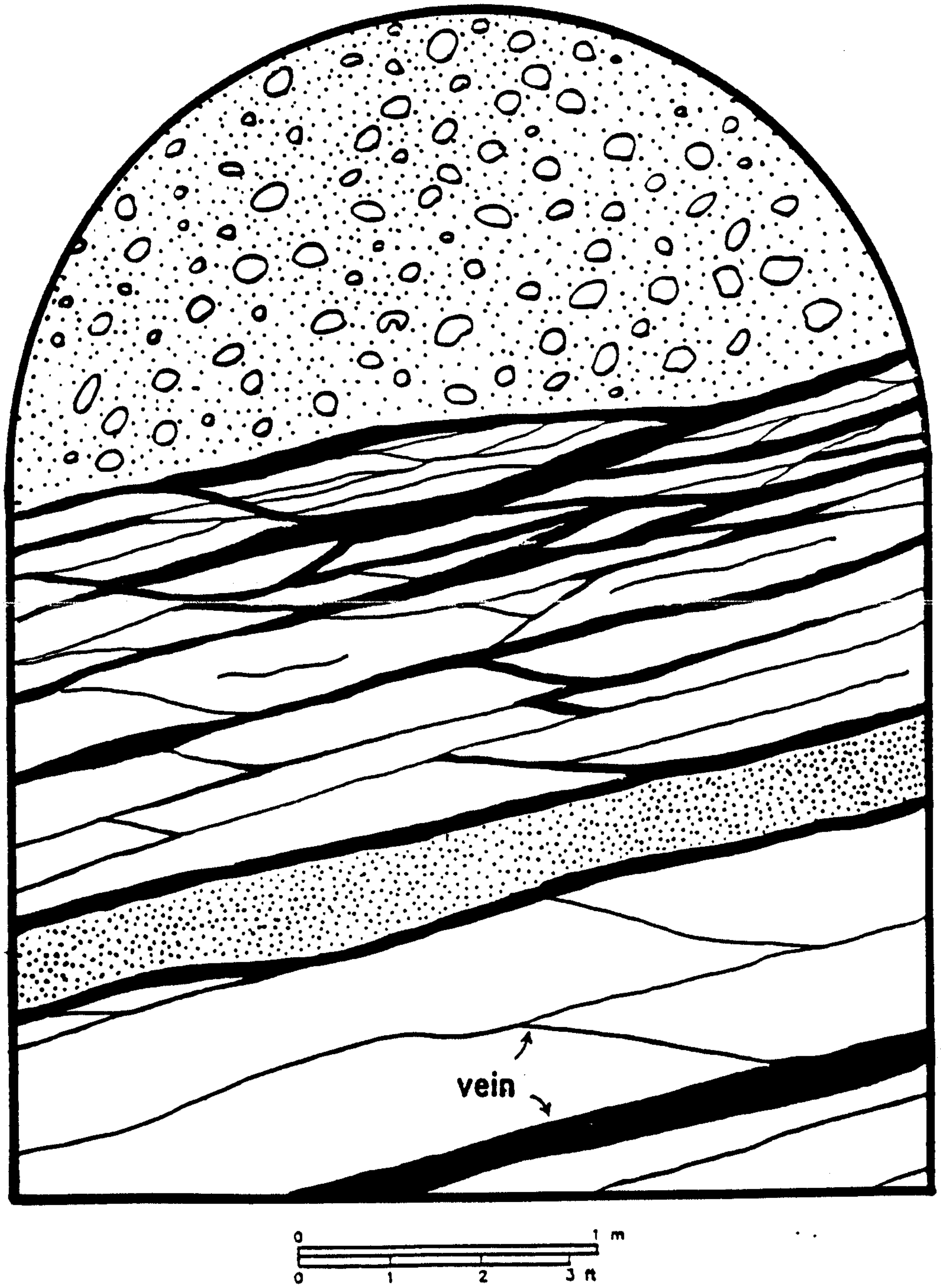

Figure 9 Sketch of the 4440-2 +32 ft. crosscut face showing joint and bedding control of sulfide veins

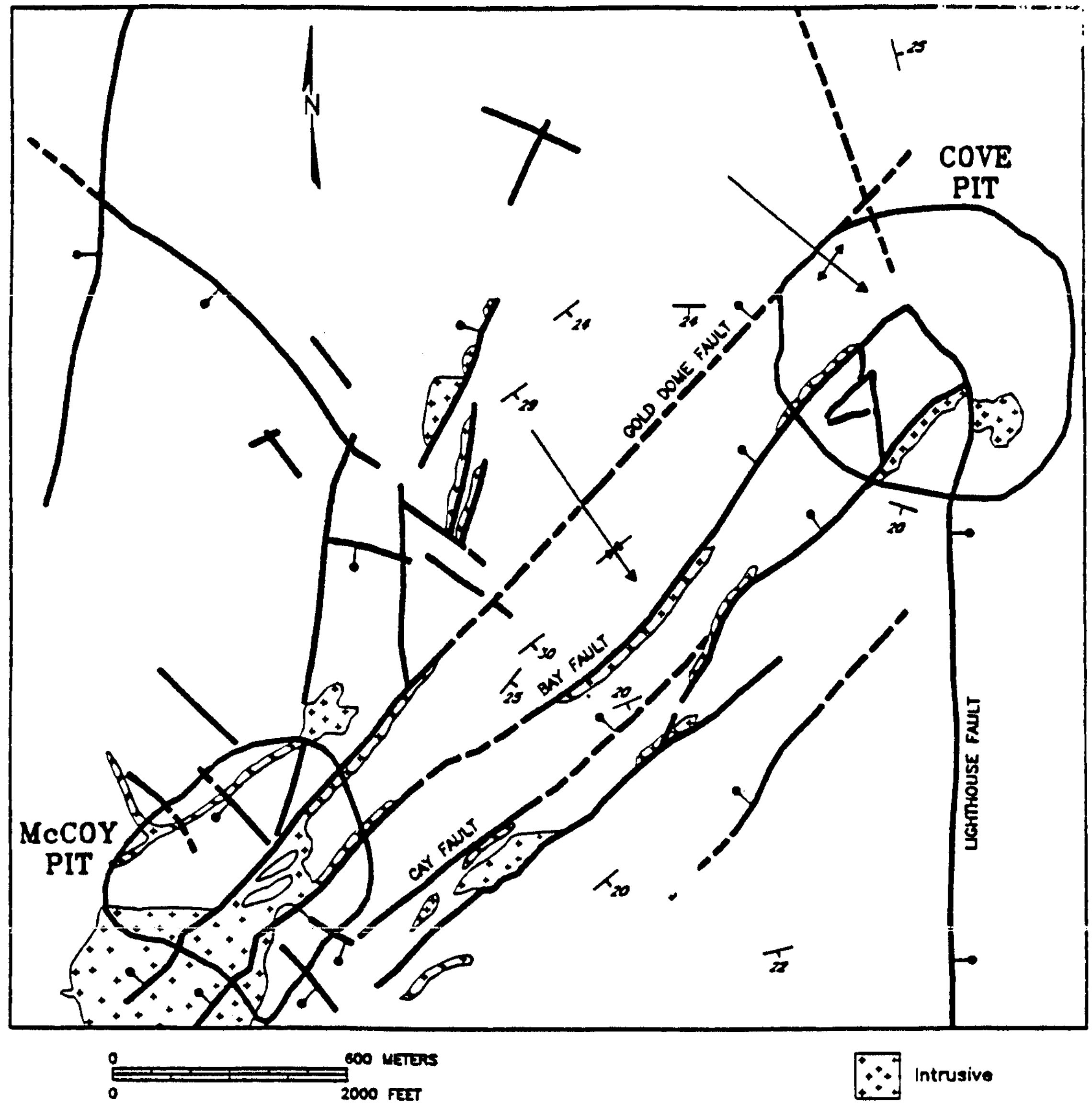

Figure 10 Simplified structure – McCoy district