# Geology, Skarn Alteration, and Au-Cu-Ag Mineralization of the Phoenix Project, (Battle Mountain Mining District), Lander County, Nevada

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## ABSTRACT

The Phoenix project represents a re-birth of milling and leaching operations in the Copper Canyon area of the Battle Mountain Mining District, Lander County, Nevada. The year-end 1999 proven and probable reserve of 121.87 million tonnes of mill ore averaging 1.31 g/t Au, 9.88 g/t Ag and 0.16 percent Cu, and 14.85 million tonnes of leach ore averaging 1.15 g/t Au and 8.38 g/t Ag contains 176,633 kg Au, 1,328,854 kg Ag, and 213,000 tons of Cu. The Phoenix project will mine Au-Cu-Ag ore from five separate open pits; Phoenix, Greater Midas, Reona, Iron Canyon, and Sunshine.

Gold, Ag, and Cu skarn mineralization is associated with the 38-Ma Copper Canyon granodiorite stock, and is hosted in the Pennsylvanian and Permian Antler sequence, a fining upward package of ferruginous conglomerate, calcareous sandstone and siltstone, and limestone. The Cambrian(?) Harmony Formation, in the upper plate of the Roberts Mountains thrust, and the Mississippian, Pennsylvanian, and Permian Havallah sequence, in the upper plate of the Golconda thrust, are the respective footwall and hangingwall stratigraphic units. Gold mineralization is primarily hosted in pyrrhotite- and pyrite-bearing skarn consisting of pyroxene, epidote, and actinolite > garnet. Lesser amounts of Au mineralization is associated with quartz-rich veins, fault breccia (± clay), and retrograde skarn consisting of chlorite, quartz, actinolite, and epidote. Total sulfide content of mill ore averages from 1 to 25 percent by volume. Skarn mineralogy and Au-Cu-Ag mineralization are zoned about the stock and are controlled by (1) carbonate-rich lithologies, (2) distance from the stock, and (3) faults and lithologic contacts.

In the Phoenix deposit, skarn hosted by the Antler Peak Limestone is zoned from a proximal assemblage of andraditic garnet > diopsidic pyroxene adjacent to the stock (with Cu>Au), to an intermediate assemblage of hedenbergitic pyroxene > grandite garnet distal to the stock (with Au>>Cu). Skarn in the Greater Midas deposit is zoned from a proximal assemblage of pyroxene>garnet with strong retrograde alteration adjacent to the stock (with Cu>Au) that grades outward to a similar skarn assemblage with lesser retrograde alteration, and to distal assemblages containing actinolite with only minor pyroxene, and chlorite + biotite + clay, respectively (with Au>>Cu).

## INTRODUCTION

### LOCATION

Battle Mountain Gold's Phoenix project is located 19 kilometers southwest of the town of Battle Mountain, Nevada in the Copper Canyon area of the Battle Mountain Mining District (Fig. 1). Battle Mountain Gold, and its predecessor Duval Corporation, has produced Au and Cu ore in the Copper Canyon area of the district since 1967. Located on the Battle Mountain-Eureka mineral trend, the Phoenix project is about 25 kilometers north of the McCoy-Cove Mine and 15 to 20 kilometers southeast of the Marigold and Trenton Canyon complex of mines.

### PRODUCTION HISTORY

The Copper Canyon mining area has produced over 95,943 kilograms (3.1 million oz) Au, 495,707 kilograms (15.9 million oz) Ag, and 112,213 tons Cu from eleven open-pits and several small underground mines (Table 1 and Fig. 2). Gold was first discovered in the Copper Canyon area in 1909 in Philadelphia Canyon, near the present-day access to the Copper Canyon facilities. The Copper Canyon underground mine and the Copper Canyon placers produced over 4,670 kilograms Au in the 1930s. Bulk mining began with Duval Corporation's open-pit Cu operations, with the East and West pits at Copper Canyon producing moderate Au and Ag as by-products from 1967 to 1978. Gold production began at Copper Canyon in 1978 with development of the Tomboy and Minnie deposits, followed by the Northeast Extension, Upper Fortitude, and Lower Fortitude deposits in the early 1980s. The Reona heap-leach project, which exploited oxide Au in the upper levels of the Greater Midas pit, represents the most recent phase of Au mining and was discontinued in January 1998.

## REGIONAL GEOLOGIC SETTING

The geology of the Battle Mountain Mining District has been the focus of a substantial amount of geologic investigation over the last 50 years, and includes studies by Roberts (1964), Doebrich (1994; 1995), and Doebrich and Theodore (1996). The district consists of three Paleozoic rock assemblages that have been intruded by Cretaceous and Tertiary intrusive rocks (Fig. 1) and are locally overlain by Cenozoic volcanic rocks and alluvium. Two of the Paleozoic assemblages, the Ordovician, Silurian, and Devonian siliceous sequence and the Mississippian, Pennsylvanian, and Permian Havallah sequence are part of the Roberts Mountains and Golconda allochthons, respectively. The third assemblage, the overlap assemblage of the Antler orogeny, is autochthonous and is represented in the district by the Pennsylvanian and Permian Antler sequence (Roberts, 1964; Doebrich, 1995) (Fig. 3).

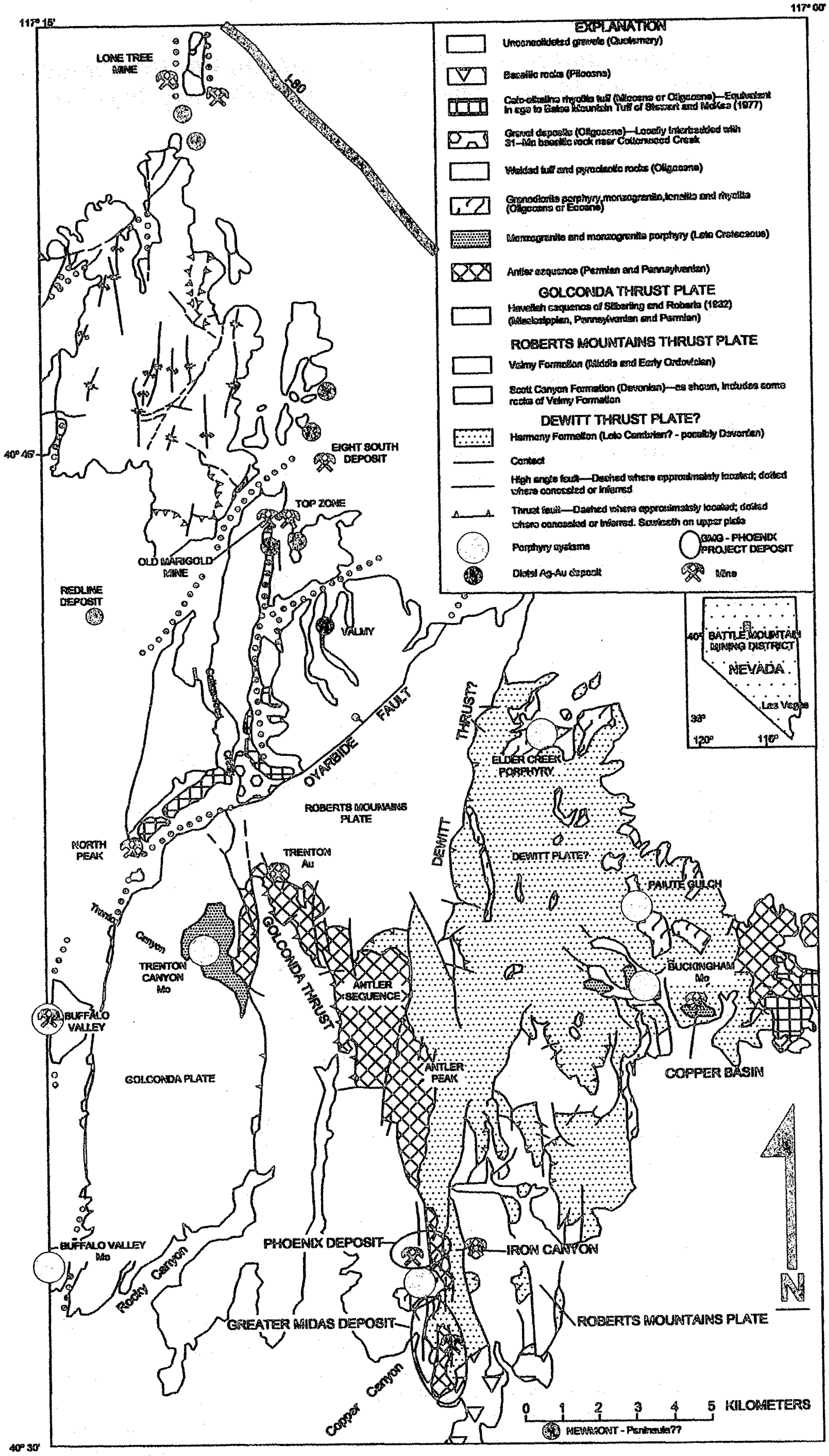


**FIGURE 1. Geology of the Battle Mountain Mining District, Nevada. (modified from Roberts, 1964; Theodore, 1991; and Doebrich et al., 1995).**

**TABLE 1. Historic Au-Cu-Ag production from the Copper Canyon area of the Battle Mountain Mining District, Nevada.**

| Deposit | | Years Operated | Mined Tonnes | Au (kg) | Au Grade (recovered (g/t) | Ag (kg) | Ag Grade (g/t) | Cu (short tons) | Cu Grade (%) |
|---|---|---|---|---|---|---|---|---|---|
| Pre-1961 Production | | < 1961 | n.a. | ~2643 | n.a. | n.a | n.a | n.a. | n.a. |
| Copper Canyon Underground | | 1871 to 1954* | 596,839 | 1,501 | 2.503 | 26,855 | 44.91 | 4,811 | 0.73 |
| *production from 1929 to 1954 | | | | | | | | | |
| East & West Pits | | 1966 to 1978 | | | | | | | |
| | Mill | | 13,482,583 | 5,527 | 0.411 | 123,630 | 9.26 | 74,837 | 0.50 |
| | Leach | | 43,407,895 | n.a. | n.a. | n.a. | n.a. | 32,565 | 0.07 |
| Tomboy | | 1978 to 1982 | | | | | | | |
| | Mill | | 2,661,681 | 6,406 | 2.400 | 10,951 | 4.11 | - | - |
| Minnie | | 1978 to 1981 | | | | | | | |
| | Mill | | 621,490 | 1,496 | 2.400 | 2,557 | 4.11 | - | - |
| NE Extension | | 1981 to 1989 | | | | | | | |
| | Mill | | 1,124,002 | 2,698 | 2.400 | 10,405 | 9.26 | - | - |
| Upper Fortitude | | 1982 to 1984 | | | | | | | |
| | Mill | | 2,572,777 | 7,020 | 2.743 | 73,277 | 28.46 | - | - |
| Lower Fortitude | | 1984 to 1993 | | | | | | | |
| | Mill | | 7,327,435 | 59,137 | 8.057 | 232,805 | 31.89 | - | - |
| Iron Canyon | | 1991 to 1993 | | | *in situ grade* | | | | |
| | Mill | | 180,412 | *786* | 4.354 | 3,155 | 17.49 | - | - |
| | Leach | | 689,292 | *794* | 1.166 | 12,074 | 17.49 | | |
| Reona Leach Project** | | 1994 to 1997 | | | *in situ grade* | | | | |
| Midas (P1, P2, P3) Pits | | | 20,614,251 | n.a. | 0.857 | n.a. | n.a. | - | - |
| Sunshine Pit | | | 1,690,567 | n.a. | 0.754 | n.a. | n.a. | | |
| **production to 9/1/99 | | | | 7,935 | | n.a. | n.a. | - | - |
| COPPER CANYON TOTALS | | | 94,969,224 | 95,943 | 1.010 | 495,707 | 5.22 | 112,213 | - |

At the Phoenix project area, the siliceous assemblage of the Roberts Mountains allochthon is made up of the Cambrian Harmony and Devonian Scott Canyon Formation (Fig. 1). These units form the footwall to most known mineralization in the Phoenix project area. Recent work at the Hot Springs Range, located 75 kilometers to the northwest, suggests that the Harmony Formation may be Devonian (Jones, 1997). Low angle faults and tight folding in Scott Canyon and Harmony Formations are associated with deformation of Roberts Mountains allochthon during the middle and late Paleozoic Antler orogeny (Roberts, 1964). The main host rock for Au-Cu-Ag-bearing ore is the Antler sequence that is unconformably deposited on the Harmony Formation (Figs. 2 and 3). The Antler sequence may be subdivided into three formations, the Middle Pennsylvanian Battle Formation, the Late Pennsylvanian-Early Permian Antler Peak Formation, and the Permian Edna Mountain Formation. The Battle Formation may be further divided into lower, middle and upper units (Roberts, 1964). The Antler Peak Formation overlies the Battle Formation, and hosted 80 percent of the historic Au production in the Phoenix project area.

Structurally overlying the Antler sequence rocks are chert, argillite, and fine-grained clastic rocks of the Havallah sequence of the Golconda allochthon (Roberts, 1964). The local term "Pumpernickel" Formation (Roberts, 1964) is still in use at the mine site for these rocks. The Golconda thrust fault and tight folding in Havallah sequence are associated with deformation of the Golconda allochthon during the Late Paleozoic-Early Mesozoic Sonoma orogeny (Silberling and Roberts, 1962).

Tertiary intrusive rocks occur throughout the Phoenix project area. Most of the Au-Cu-Ag deposits occur adjacent to the Copper Canyon granodiorite porphyry stock which has been age dated at 38 Ma (Theodore et al., 1973) (Fig. 2). Within two kilometers of the Copper Canyon stock contact, pre-Tertiary strata have been pervasively recrystallized and form a distinctive aeromagnetic annulus with the stock occupying a central magnetic low (Fig. 4). The magnetic anomalies reflect variations in the abundance of pyrrhotite and lesser magnetite within skarn-altered rocks. Within this aureole, siliceous clastic rocks are largely converted to siliceous or biotite hornfels, whereas limestone and other calcareous rocks have been replaced by skarn and calc-silicate hornfels, respectively. The Wilson-Independence granodiorite porphyry stock occurs to the west of the Copper Canyon stock and is spatially associated with the Sunshine deposit (Fig. 2). In the Greater Midas deposit area, the Late Oligocene to Miocene volcanic rock and Quaternary alluvium unconformably overlie the pre-Tertiary rocks.

## TONNES AND GRADE

Development drilling programs from 1997 to the present coupled with new milling, mining, and metallurgy advances have added 117,530 kilograms (3.8 million oz.) of Au to the Phoenix project reserve. The Phoenix project will exploit Au, Cu and Ag ore from five open pits: Phoenix, Greater Midas, Reona, Iron Canyon, and Sunshine (Fig. 2). The Phoenix, Greater Midas, Iron Canyon and Sunshine pits will each

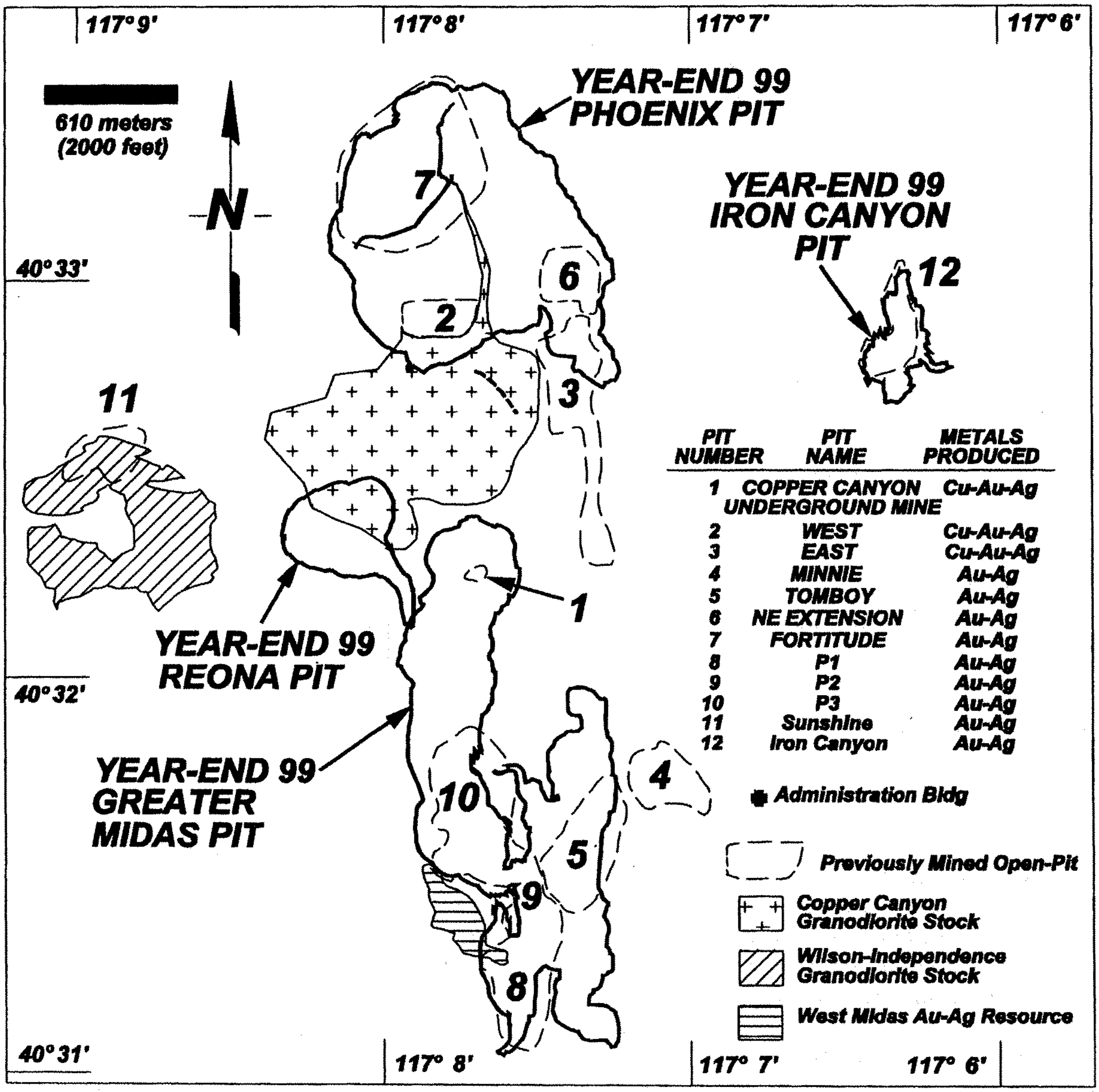


**FIGURE 2. Map of the Phoenix Project area showing major granodiorite stocks, previously mined open-pit deposits, and the year-end 1999 Phoenix, Greater Midas, Iron Canyon, and Reona pits.**

enlarge and deepen existing pits. Year-end 1999 proven and probable reserves include 121.868 million tonnes of mill ore averaging 1.31 g/t Au, 9.88 g/t Ag and 0.16 percent Cu, and 14.851 million tonnes of leach ore averaging 1.15 g/t Au and 8.38 g/t Ag. The reserve contains 176,633 kilograms Au, 1,328,854 kilograms Ag, and 213,300 tons of Cu (Table 2). An additional 83.20 million tonnes of sulfide mineralization grading 0.93 g/t Au, 7.46 g/t Ag, and 0.126 percent Cu, and 15.032 million tonnes of oxide mineralization grading 0.72 g/t Au and 5.68 g/t Ag, containing 2.83 million ounces of Au, are classified as "other mineralized material". The higher grade West Midas Au-Ag resource lies just outside the southwestern margin of Greater Midas pit and is not part of the 1999 year-end reserve due to a relatively high strip ratio. The proposed Phoenix project contains one of the largest known undeveloped Au resources hosted by skarn in North America and includes 176,633 kilograms (5.68 million oz.) of Au.

Year-end 1999 reserves for the Phoenix deposit are 74.4 million tonnes of mill ore at an average grade of 1.41 g/t Au, 9.92 g/t Ag and 0.15 percent Cu, and 2.3 million tonnes of leach ore at an average grade of 1.02 g/t Au and 7.81 g/t Ag (Table 2). The proposed Phoenix pit will encompass the Fortitude and Northeast Extension pits and parts of the East and West pits (Fig. 2). The East and West Cu deposits produced 5,527 kilograms (178,000 oz) Au and 123,630 kilograms (3.97 million oz) Ag from 13.48 million tonnes of mill ore (Table 1). The upper and lower Fortitude deposits produced 66,157 kilograms (2.1 million oz) Au and 306,082 kilograms (9.8 million oz) Ag from 9.9 million tonnes of mill ore; Cu was not recovered.

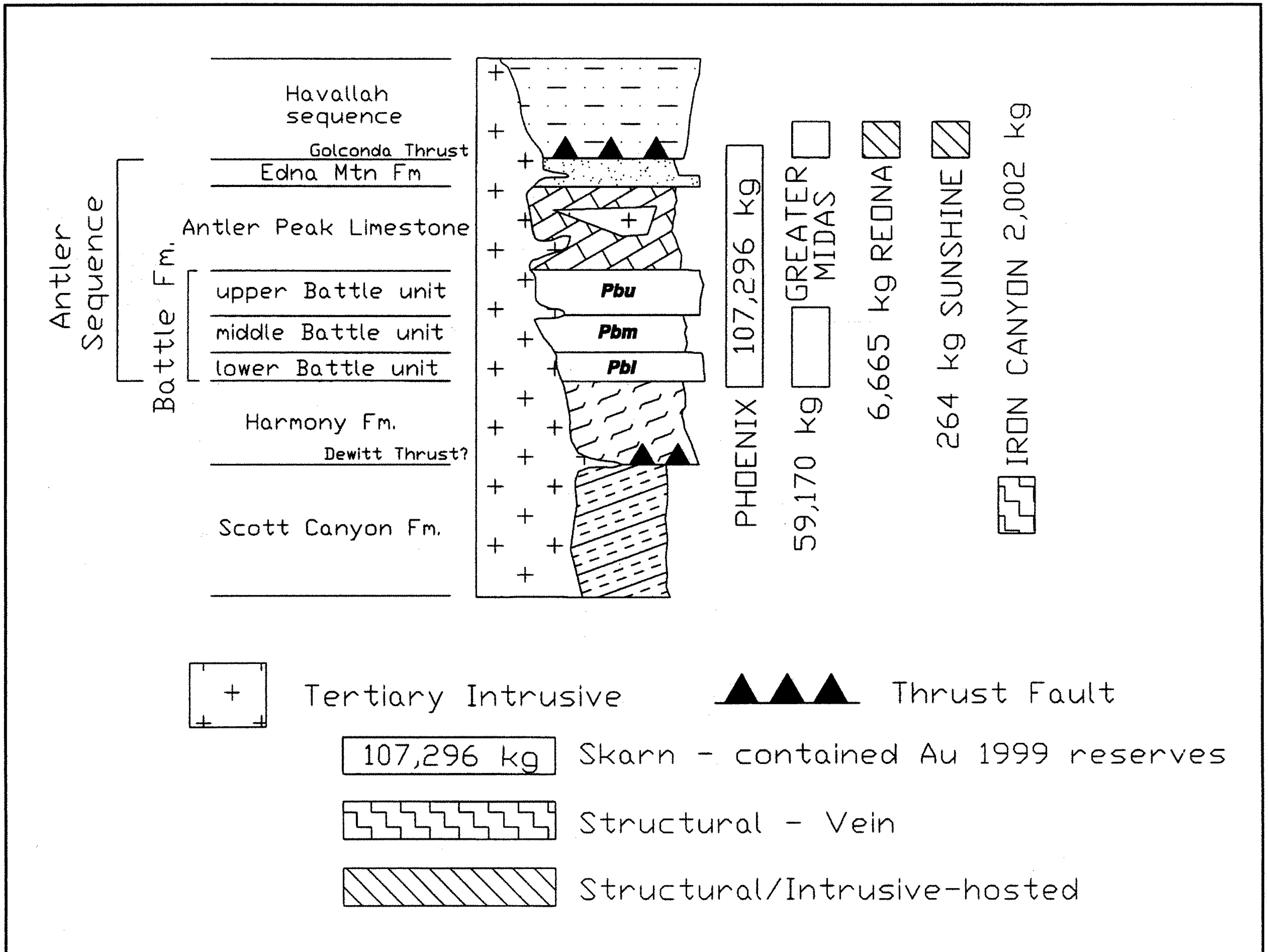


**FIGURE 3.** Stratigraphic section of the Phoenix project area. This figure schematically illustrates the dominant host rocks for each deposit along with dominant mineralization style and contained Au (in kg) based on the year-end 1999 proven and probable reserves (see Table 2).

**TABLE 3. Distribution of mill ore by formation for the Phoenix and Greater Midas deposits.**

| Formation | % Ore in the Phoenix Pit | % Ore in the Greater Midas Pit | % Total Mill Ore |
|---|---|---|---|
| Havallah sequence | 3.0 | 1.5 | 2.3 |
| Antler Peak Formation | 27.0 | 0.0 | 16.5 |
| Battle Formation | 44.0 | 76.0 | 52.7 |
| Harmony Formation | 9.0 | 22.0 | 13.0 |
| Granodiorite porphyry | 0.3 | 0.2 | 0.3 |
| Virgin Fault Zone | 17.0 | 0.0 | 10.4 |

Clasts are poorly sorted, angular to subrounded, and composed mainly of chert and sandstone. The clasts fine upward, with clasts > 15 centimeters in the lower section giving way to 2 to 8 centimeters clasts higher in the section. Conglomerate beds of the lower Battle Formation are red colored and highly ferruginous (hematite-bearing), and are well exposed immediately north of the Fortitude pit beyond skarn alteration (Theodore and Blake, 1975). The presence of hematite in this unit indicates relatively oxidizing wallrock conditions prior to skarn alteration. The basal conglomerate is the lower most favorable ore horizon; hosting most of the Au ore in the eastern half of both the Phoenix and Greater Midas deposits. West of the Virgin fault, significant Au ore is hosted along the contact in both the Phoenix and Greater Midas areas, and is not completely drilled off. The lower unit hosts 29 percent of the ore in the Phoenix pit, and 31 percent of the ore in the Greater Midas deposit. The lower unit of the Battle Formation varies in thickness. In the Phoenix pit east of the Virgin fault it is 100 to 130 meters thick, while west of the Virgin fault it varies from 68 to 91 meters in both the Phoenix and Greater Midas deposits. The upper contact with the middle unit is gradational for 9 to 15 meters in thickness and consists of medium- to thin-bedded, conglomerate, sandstone and siltstone with an increasing carbonate component.

The middle unit of the Battle Formation consists of thin-bedded siltstone, sandstone, and shale with a significant calcareous component. The thickness of the middle unit varies from 12 to 38 meters, and its contact with the upper unit is a coarsening upward sequence of interbedded siltstone, sandstone, and pebble conglomerate similar to the lower contact. The middle unit is a significant ore host. In the Phoenix deposit, the middle unit hosts 12 percent of the ore in both the footwall and hangingwall of the Virgin fault, and the upper and lower transitional contacts are also highly favorable for sulfide-rich skarn alteration and Au mineralization. In the Greater Midas deposit, the middle unit hosts 42 percent of the ore, and as in the Phoenix deposit the transitional contacts are very favorable ore hosts.

The composition of the upper unit of the Battle Formation is highly variably, consisting of siliceous pebble conglomerate and quartz sandstone in the Phoenix deposit, and bedded siltstone in the Greater Midas deposit. The conglomerate is clast-supported with smaller, sub-rounded clasts and little or no original matrix carbonate. The upper unit siltstone is siliceous and thin- to medium-bedded, and is very similar to the overlying clastic rocks of the Havallah sequence in the Greater Midas deposit. Both rock types are poor hosts, with the upper unit contributing only 4 percent of the ore tonnes in both pits. The upper unit is 38 to 68 meters thick.

The Antler Peak Limestone at Copper Canyon is pervasively recrystallized and metasomitized to marble or skarn. The unit consists of medium-bedded limestone with shale and conglomerate interbeds near the base, and conglomerate interbeds and scattered chert nodules near the upper contact. The unit varies considerably in thickness from as much as 55 to 61 meters thick in the Phoenix deposit west of the Virgin fault to completely absent east of the Virgin fault. While it is completely absent from the Greater Midas deposit west of the Virgin fault, it crops out in the footwall of the Virgin fault south of the deposit. Fossils are rarely preserved, with fusilinids present in outcrop south of the Greater Midas deposit, and coral present in float on the northern margin of the Phoenix deposit. The Antler Peak Limestone is the most prolific host rock in the Copper Canyon area, containing 90 percent of the historic production in the Phoenix pit area (Lower Fortitude, West Cu), and 27 percent of the Phoenix deposit.

The Edna Mountain Formation consists of chert-pebble conglomerate, calcareous sandstone, and siltstone that varies in thickness from 7 to 76 meters. Its contact with the overlying Havallah sequence is commonly difficult to log in drill chips when the distinctive coarse clastic and (or) calcareous lithologies are not present. The Edna Mountain Formation is grouped with the Antler Peak Limestone in the generalized plan maps and cross sections (Figs. 5 and 6). The Edna Mountain Formation is not present in the Greater Midas deposit.

The Havallah sequence consists of thin-bedded siltstone, sandstone, and argillite as well as lesser chert and chert-pebble conglomerate in the upper plate of the Golconda allocthon. The fine-grained clastics are locally calcareous near the base of the unit. The Havallah hosts small amounts of structurally controlled Au ore in the Phoenix (3%) and Greater Midas (2%) deposits, and a significant portion of the Reona deposit (Table 3).

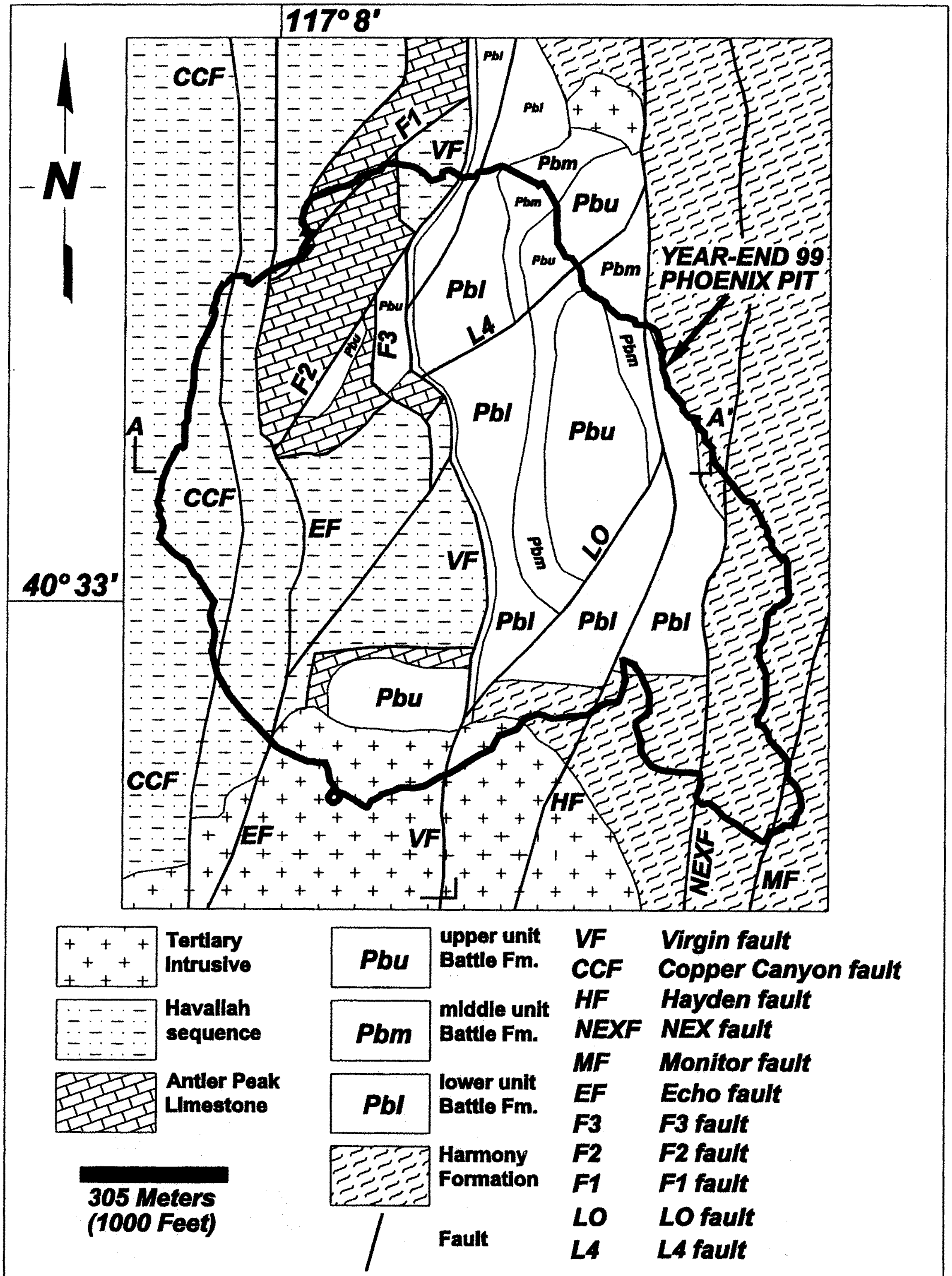


**FIGURE 5.** General geology of the Phoenix deposit area north of the Copper Canyon stock showing cross-section A-A′.

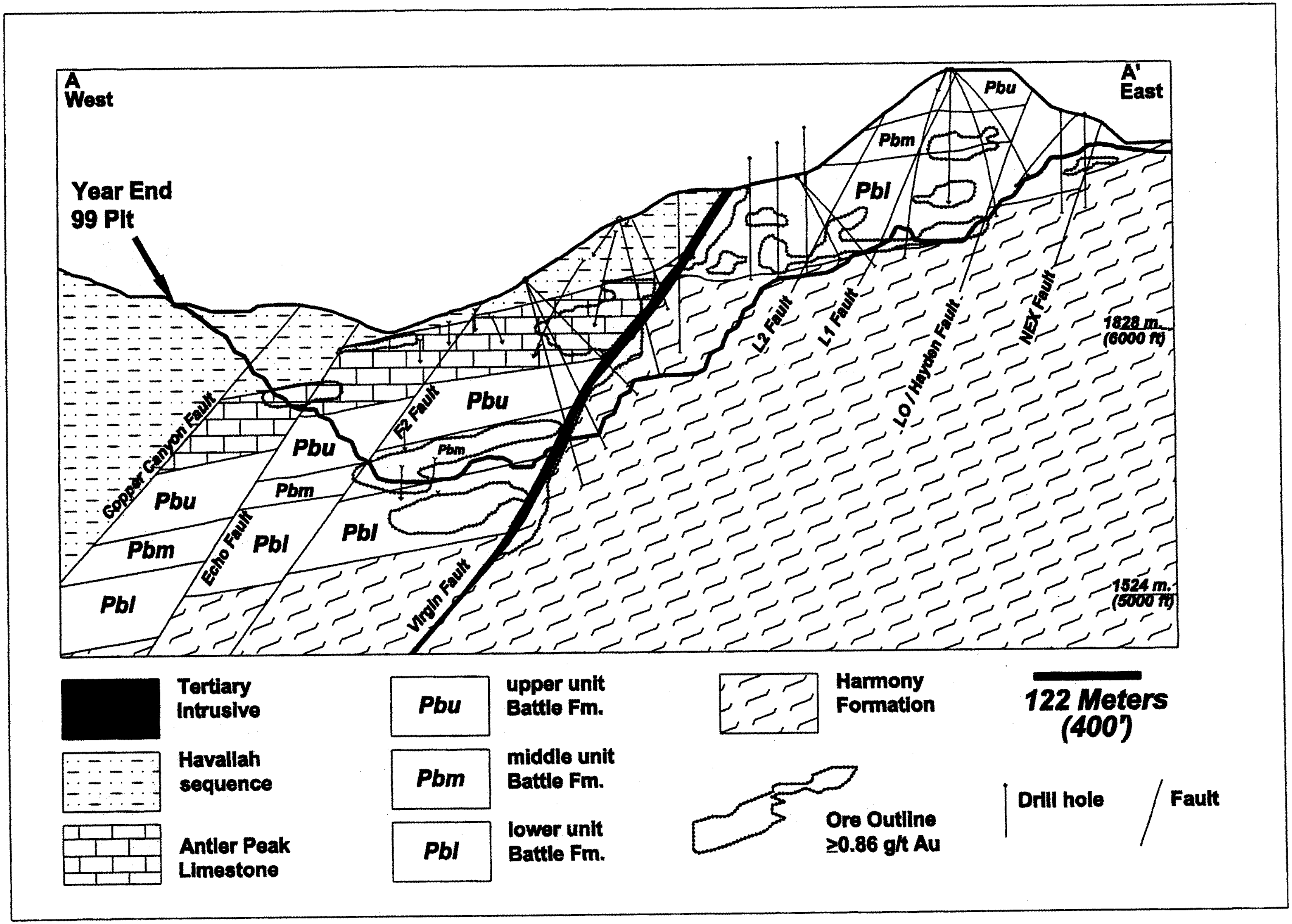


FIGURE 6. East-west cross-section A-A′ through the Phoenix deposit showing geology and Au mineralization >0.86 g/t.

The 38-Ma Copper Canyon granodiorite (Theodore et al., 1973) stock crops out in the center of the Phoenix project area (Fig. 2). The main intrusive body is weakly porphyritic and biotite and hornblende bearing. North of the stock in the eastern highwall of the Fortitude pit, a strongly porphyritic granodiorite dike (Tag) fills the Virgin fault along its entire strike length (Fig. 5). The rock contains phenocrysts of rounded quartz, feldspar and minor biotite and hornblende in a fine-grained groundmass of quartz, feldspar, and biotite. The granodiorite dike ranges from 1 to 30 meters in thickness and structurally-controlled Au mineralization is hosted in the immediate footwall of the dike throughout its strike length. South of the stock, there is no dike fill in the Virgin fault (Fig. 7). The granodiorite hosts only a minor amount of ore (<0.3%) in the Phoenix and Greater Midas pits, but is the main ore host in the Reona deposit. North-trending porphyritic quartz monzonite and granodiorite dikes are also present in the Iron Canyon deposit (Figs. 12 and 13) and correspond to the "Tgp" unit mapped by Doebrich (1994). The dikes are similar in appearance and age to the intrusives in the Copper Canyon area. One of the dikes at Iron Canyon was dated at 38.6 ± 1.2 Ma (Theodore, 1999). Phenocryst minerals include plagioclase, quartz, and locally K-feldspar. The groundmass is fine-grained and includes feldspar, quartz, biotite, and minor hornblende. Dikes with dioritic compositions are present at Iron Canyon, and small stocks with quartz monzonite and quartz diorite composition crop out northeast of the Phoenix pit, and in the Glory Hole area (Fig. 5). These intrusives are interpreted to be mid-Tertiary in age (Theodore and Blake, 1975). At Iron Canyon, the diorite and quartz diorite dikes are relatively fresh and have small (<2mm) plagioclase phenocrysts set in a fine-grained, gray groundmass containing magnetite.

## STRUCTURE

The Phoenix and Greater Midas pits are localized by the intersection of three significant faults and numerous associated secondary structures (Figs. 5 and 7). Fault intersections are important in localizing mineralization on both the deposit and bench scale. The oldest structure exposed is the Golconda thrust fault that places the Havallah sequence on some age-equivalent rocks of the Antler sequence (Roberts, 1964). In the Greater Midas deposit, the Golconda fault separates the Havallah sequence from the underlying Battle Formation in the hanging wall of the Virgin fault and generally forms the contact between oxide and sulfide ore. The fault is exposed in the middle part of the Greater Midas deposit on the northern highwall of the P3 pit (Fig. 7). In the Phoenix deposit, the Havallah sequence overlies the Edna Mountain Formation and locally the Antler Peak Limestone in the hangingwall of the Virgin fault. The fault is exposed in the northern and southern margins of the Fortitude pit (Fig. 5). These are the easternmost exposures of the Golconda fault in the Battle Mountain Mining District.

The Virgin and Copper Canyon normal faults are the two major north-south trending faults in the Copper Canyon area. The faults dip 55° to 65° west with dip-slip displacements of ~275 and ~460 meters, respectively in the Phoenix deposit (Figs. 6 and 8). In the Greater Midas deposit, offset on the Virgin fault varies from 152 meters in the Glory Hole area to 182 meters farther south in the P1 pit. The Virgin fault typically separates the Battle Formation to the west in the hangingwall from the Harmony Formation to the east in the footwall in the Greater Midas deposit. In the Phoenix deposit, the Havallah sequence and Antler Peak Limestone are exposed in the hangingwall and the Battle Formation is present in the footwall of the Virgin fault (Figs. 7, 8, 9, and 10). Both structures predate emplacement of the Copper Canyon stock and subsequent mineralization, and also exhibit post-mineralization movement. Only the Virgin fault and closely associated sympathetic footwall structures in the Phoenix deposit host intrusive rock. The Virgin fault is the main ore controlling structure at Copper Canyon, with Au, Cu, and Ag mineralization in both the footwall and hangingwall over 5,500 meters of strike length. The Copper Canyon fault controls Au mineralization along a small portion of its strike length in the Reona and Greater Midas deposit areas.

Numerous subsidiary faults are developed in the vicinity of these main structures (Figs. 5 and 7). In the Phoenix deposit these include the north striking, west dipping Hayden, NEX and Monitor normal faults that are developed in the footwall of the Virgin fault. The faults have dip-slip displacements of 15 to 61 meters, and are continuous over long distances along strike. The faults appear to be en echelon in nature, with displacement progressively transferred to the north and west. The Hayden and NEX faults appear to merge with the Virgin fault along their southern extensions (Figs. 5 and 7). These structures are mineralized along their entire observed strike lengths, and localized Au-bearing fluids into sulfide-bearing, bedding controlled skarn alteration. West of the Virgin fault, are the north striking and west dipping Echo and F3 normal faults with 61 and 45 meters of dip-slip displacement, respectively. The F3 structure merges with the Virgin fault along strike and at depth. The Echo fault is probably the West Ridge fault defined by Theodore and Blake (1978) and it merges with the Copper Canyon fault along strike, and possibly at depth. Both of these faults are mineralized along their vertical extents, and the Echo fault was probably the structure that returned ore-grade assays from surface sampling above the Fortitude deposit. None of these structures host intrusive rock. In the Greater Midas deposit, the steeply west-dipping P3 fault separates siliceous siltstone and chert of the Havallah sequence to the west in the hangingwall from the variably calcareous Battle Formation to the east in the footwall (Figs. 7 and 8). The P3 fault is exposed in the northern highwall of the P3 pit and has down to the west displacement of 69 to 110 meters. Contour maps of blast hole Au assays from the P3 and Fortitude pits show a strong structural control on high grade Au mineralization in the Greater Midas and Phoenix deposits, respectively.

In contrast to the Phoenix deposit, several north-striking structures in the Greater Midas deposit are antithetic in

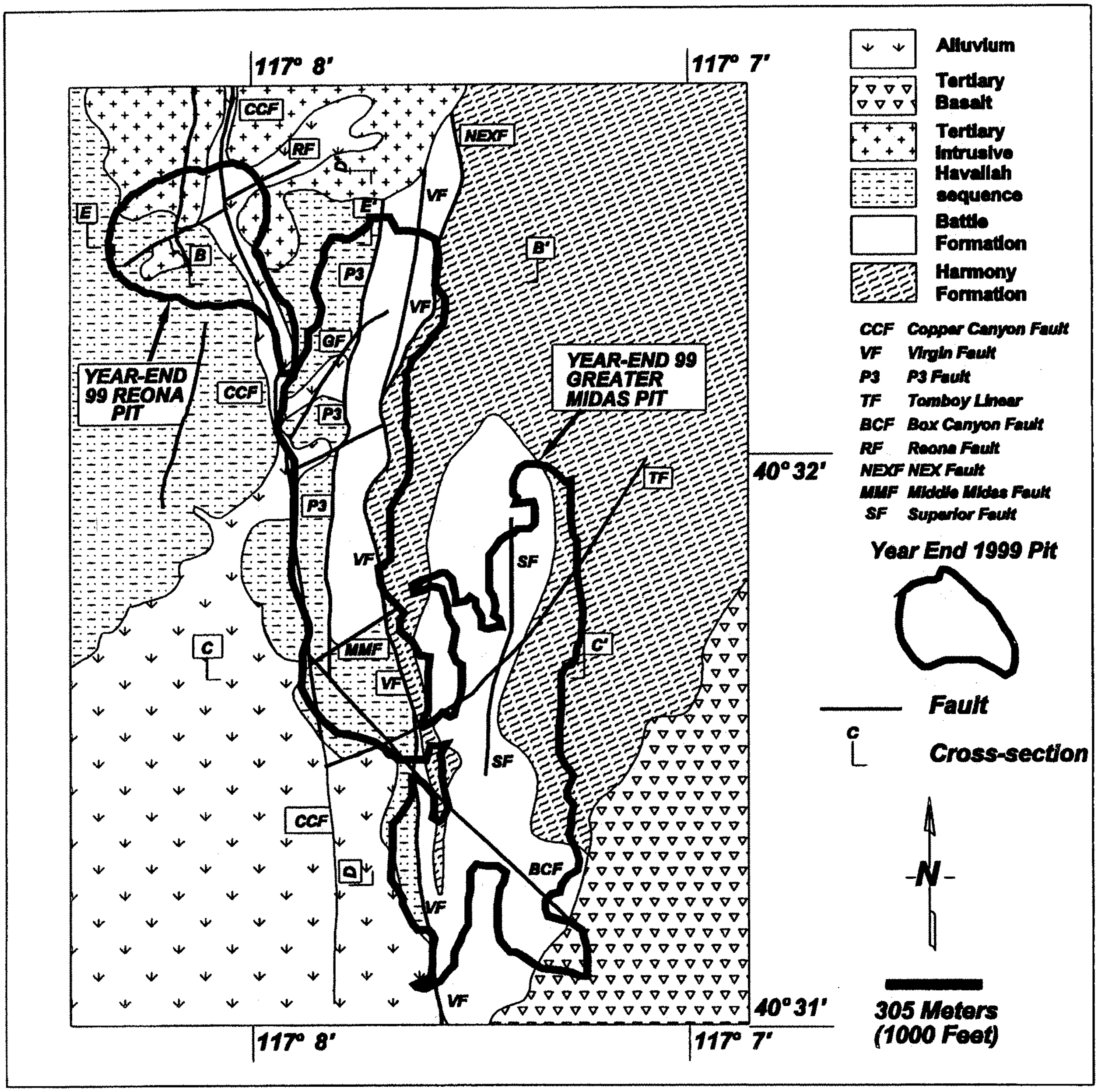


**FIGURE 7. General geology map of the Greater Midas and Reona deposits south of the Copper Canyon stock showing cross-sections B-B′, C-C′, D-D′, and E-E′.**

nature, dipping to the east. These east-dipping structures control Au mineralization in Havallah sequence rocks in the hangingwall of the Virgin fault, and are also important ore controlling structures on the east side of the Greater Midas deposit. The north-striking, east-dipping Superior fault (Figs. 7 and 9) has 9 to 12 meters of downward displacement to the east.

A prominent set of northeast-striking normal faults with mostly down to the northwest movement (Theodore and Blake, 1975) are present in the both the Greater Midas and Phoenix deposits, and are important ore controls (Figs. 5 and 7). In the Phoenix deposit, east of the Virgin fault the structures are referred to as "L" or "link" structures, whereas west of the Virgin fault they are referred to as "F" structures. Displacement on the "L" structures varies from 0 to 30 meters. Shallow, southwest-plunging slickensides, suggesting left-lateral displacement are common. None of these structures host intrusive rocks. The intersection of the "L" and "F" series structures with the Virgin fault and other north-south striking structures produces steeply plunging west-northwest trending "ore shoots" within the fault zone. The intersection of these shoots with favorable stratigraphy produces higher-grade, thicker ore zones in the Fortitude pit (e.g. 1784 meter bench). In the Greater Midas deposit, the Gulch, Middle Midas and Tomboy faults are the prominent northeast-striking faults (Fig. 7). The Gulch fault in the northern

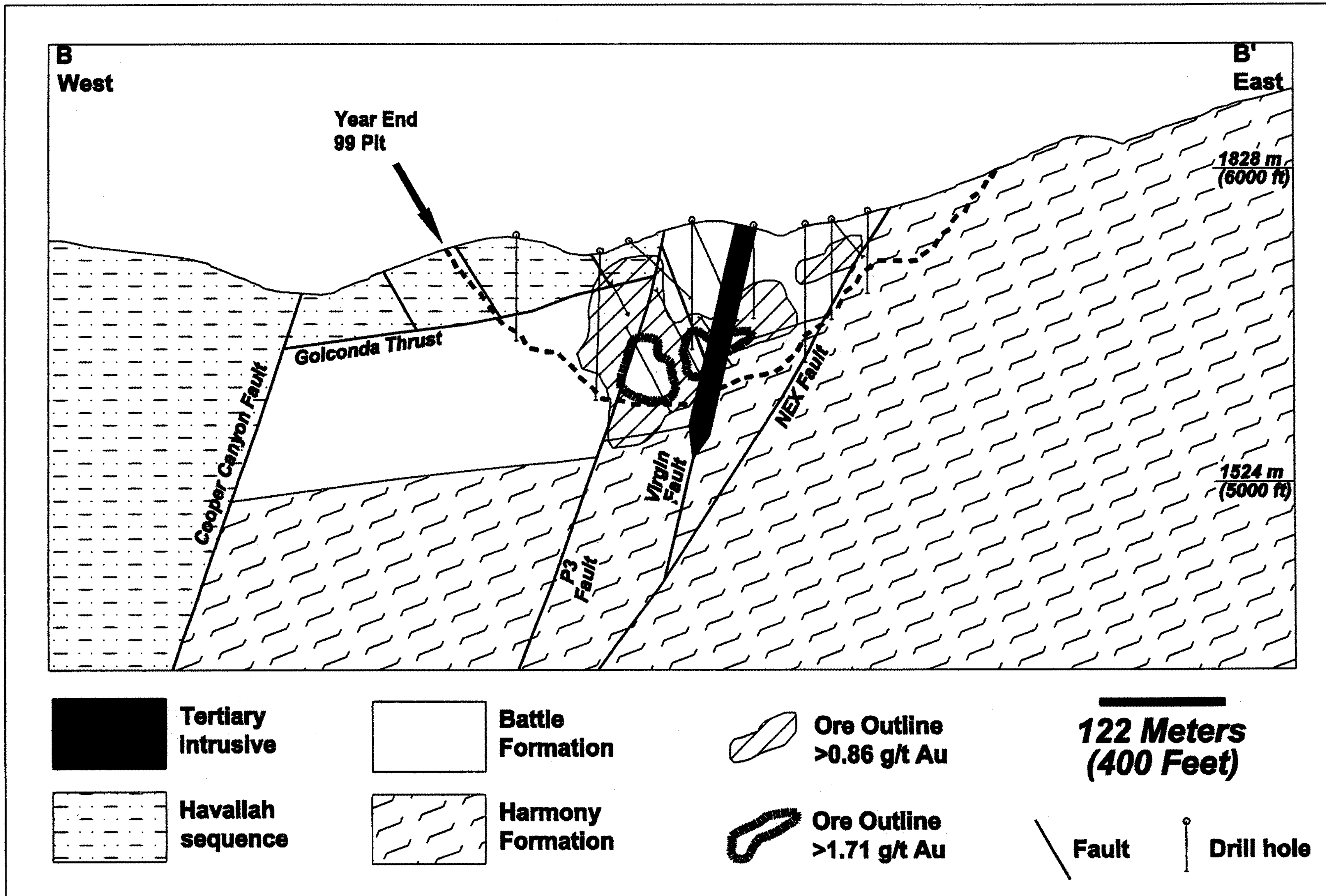


FIGURE 8. East-west cross-section B-B′ through the northern part of the Greater Midas deposit showing geology and Au mineralization >0.86 g/t.

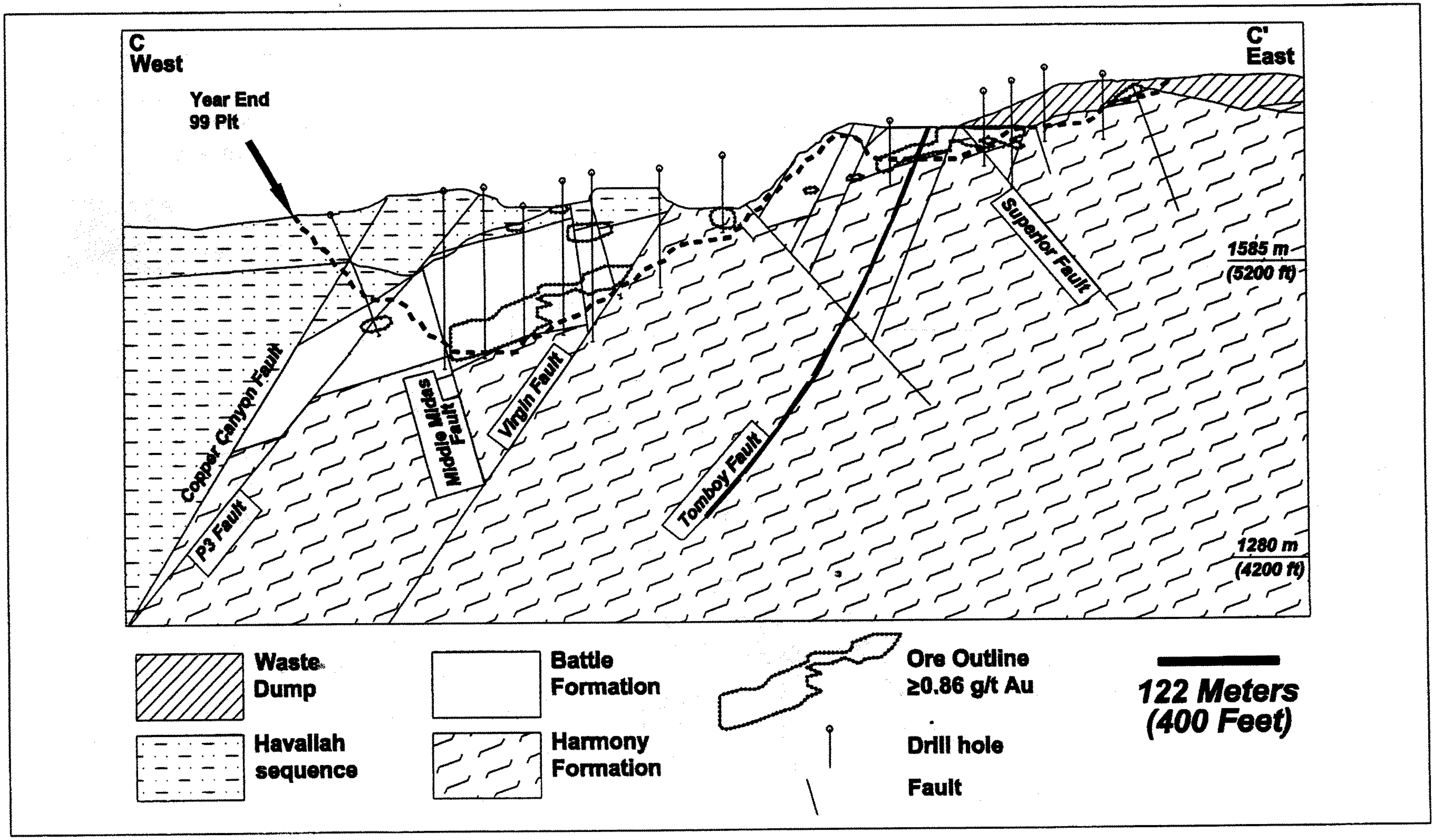


FIGURE 9. East-west cross-section C-C¢ through the middle part of the Greater Midas deposit showing geology and Au mineralization >0.86 g/t.

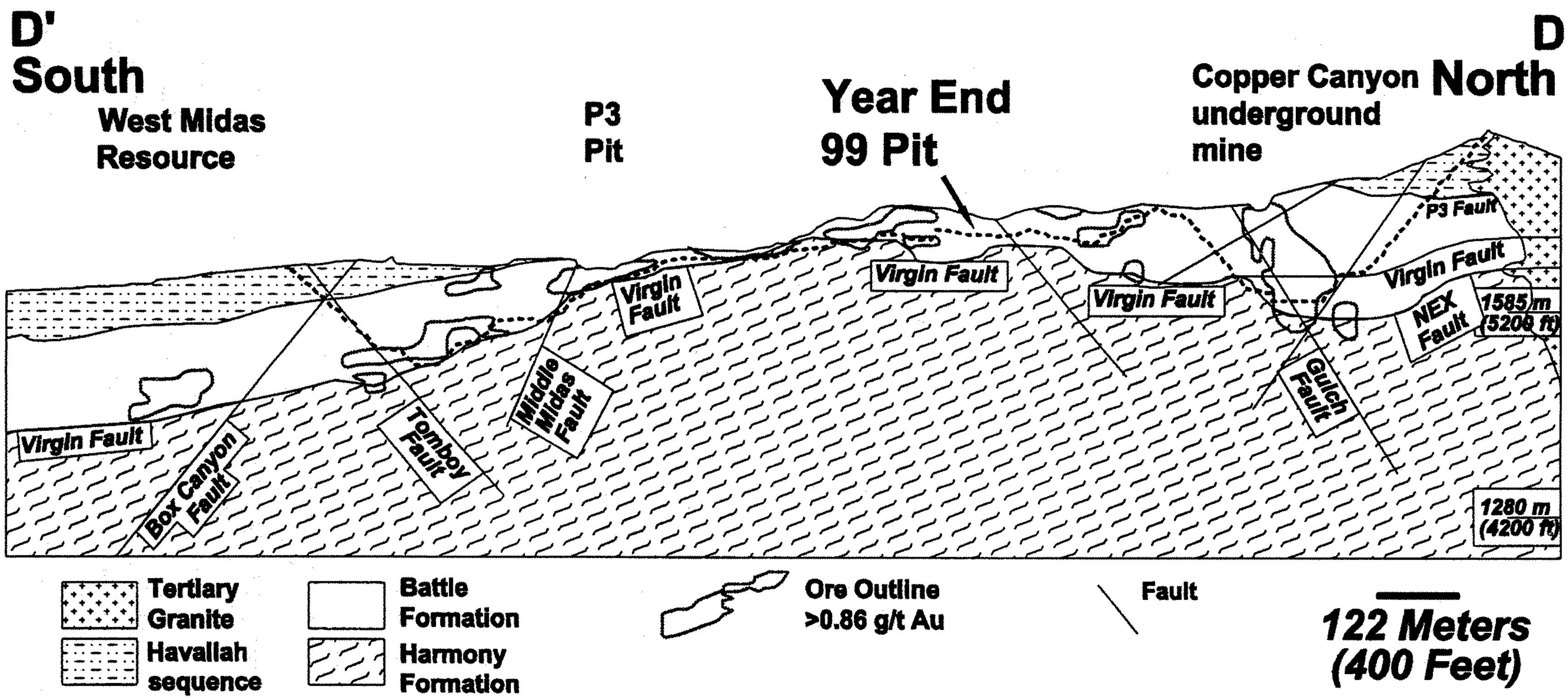


FIGURE 10. North-south cross-section D-D′ through the Greater Midas deposit showing geology and Au mineralization >0.86 g/t.

part of the Greater Midas deposit dips 70° to the northwest and is an important control to Au-Cu-Ag mineralization in the area of the Copper Canyon underground mine area. Farther south, the southeast-dipping Middle Midas fault localizes mineralization in the P3 pit, and the northwest-dipping Tomboy fault controls mineralization in the Minnie and Tomboy deposits east of the Virgin fault, and in the P2 pit west of the Virgin fault. The Tomboy fault zone is broadly defined as an aeromagnetic high, within the broad magnetic annulus developed on the periphery of the Copper Canyon stock. A follow-up ground magnetic survey refined these magnetic highs, and subsequent drill testing resulted in the discovery of the West Midas resource.

Similar northeast-trending faults also localize Au mineralization in the Reona and Iron Canyon deposits (Figs. 7, 11, 12, and 13). The northwest-dipping Reona fault controls both the emplacement of granodiorite porphyry and localizes Au ore in the Reona deposit. East of the Copper Canyon fault, Au-bearing ore is confined to the footwall of the Reona fault, while west of the fault rocks in the footwall and hanging wall of the Reona fault are mineralized.

## ALTERATION

Hydrothermal alteration in the Phoenix project area forms a halo centered about the Copper Canyon stock that includes up to 17 square kilometers of hornfels and skarn (Roberts and Arnold, 1965). The skarn alteration is hosted by all sedimentary rock units adjacent to the Copper Canyon granodiorite; however, the Edna Mountain Formation, Antler Peak Limestone, and Battle Formation host the bulk of the skarn alteration. The skarn mineralogy is controlled by the following factors: carbonate-rich lithologies or formations, distance from the Copper Canyon stock, and distance from other fluid conduits such as faults and lithologic contacts. Skarn alteration throughout the area is strongly developed along and at the intersections of three fault orientations: (1) north-striking faults (e.g. the Virgin fault and the low-angle Golconda thrust fault); (2) northwest-striking faults; and (3) northeast-striking faults.

The Antler Peak Limestone is the most carbonate-rich unit in the area and is commonly altered to coarse-grained (>1mm diameter) garnet and pyroxene skarn with minor quartz, and K-feldspar. Garnet is variable in color (light yellow, orange-brown, medium-brown, and dark red-brown), and exhibits a wide range in composition ($Ad_{25-100}$) from andradite to grossularite (Myers, 1990: 1994). Pyroxene is also compositionally zoned ($Hd_{2-100}$, $Jo_{<10}$) in the area with equigranular diopside and fibrous hedenbergite varieties (Myers, 1990; 1994). Retrograde skarn consisting of actinolite, quartz, epidote, calcite, prehnite, chlorite, siderite, and vivianite is weakly developed as fracture-controlled veins, commonly making up to 2 to 10 volume percent of the alteration, as an overprint to earlier-formed garnet-pyroxene skarn. The retrograde skarn is most abundant adjacent to the stock and near faults.

The Battle Formation contains significant calcareous siltstone, siltstone, and quartz-pebble conglomerate with a minor amount of carbonate minerals and is commonly altered to dark green, fine- to medium-grained calcic-amphibole (actinolite-tremolite)>chlorite+K-feldspar+biotite+quartz skarn and calc-silicate hornfels assemblages with local concentrations of pyroxene, epidote, and garnet that form adjacent to the stock at formational contacts and faults. Quartz-rich beds of the Battle Formation are altered to purple biotite-rich hornfels and/or quartz-rich hornfels with minor amounts of actinolite, biotite, and K-feldspar, or green chlorite + biotite hornfels. Clastic-rich sandstone and siltstone units of the Havallah sequence and the Harmony Formation are typically altered to a fine-grained, dark brown to purple biotite-rich hornfels outside of the deposit areas, and lesser chlorite hornfels with minor K-feldspar and quartz. Trace minerals in most skarn assemblages include sphene, apatite, ilmenite, and rutile. Biotite and siliceous hornfels alteration is crosscut by pyrite-quartz-chlorite-sericite alteration that is strongly structurally controlled. To date, Au mineralized rock in the Harmony is restricted to faults and adjacent stockwork fractures.

Alteration of the Copper Canyon granodiorite dike that occurs along the Virgin fault in the Phoenix deposit consists either of sericitic, argillic, or propylitic alteration. Sericitic alteration of the dike rock occurs adjacent to the Copper Canyon stock and consists of sericite replacing biotite with added quartz and pyrite in the groundmass. At higher levels in the skarn system (>1,997 m in elevation), the alteration has a greater clay component that is probably supergene in origin. Strong chalcopyrite ± Au and lesser sphalerite + galena ± Au mineralization are spatially associated with the Virgin fault within the sericitic zone. Lesser Au mineralization is associated with propylitic alteration of the dike rock distal to the Copper Canyon stock. Propylitic alteration is characterized by chlorite replacing biotite and hornblende phenocrysts with trace amounts of disseminated pyrite in the groundmass.

### MINERAL ZONING

The ores of the Phoenix project area are part of large, mineralogically and metallically zoned porphyry Au-Cu-Ag skarn system centered about the Copper Canyon stock (Roberts and Arnold, 1965; Kotlyar et al., 1998 and 1999; Myers, 1990 and 1994). For discussion purposes in the following paragraphs, both the Phoenix and Greater Midas deposits may be separated into proximal, intermediate, and distal zones with respect to lateral distance from the Copper Canyon stock, with each domain containing unique mineralogical and geochemical characteristics (Myers, 1990 and 1994; Johnson, 2000). Both deposits contain a low Au (<1.3 g/t) moderate Cu (>0.3%) zone adjacent to the stock which grades outwards to a distal zone enriched in Au (>2.0 g/t) with low Cu (<0.1%). An intermediate zone lies between the proximal and distal zones and forms a gradational metal zone between the two.

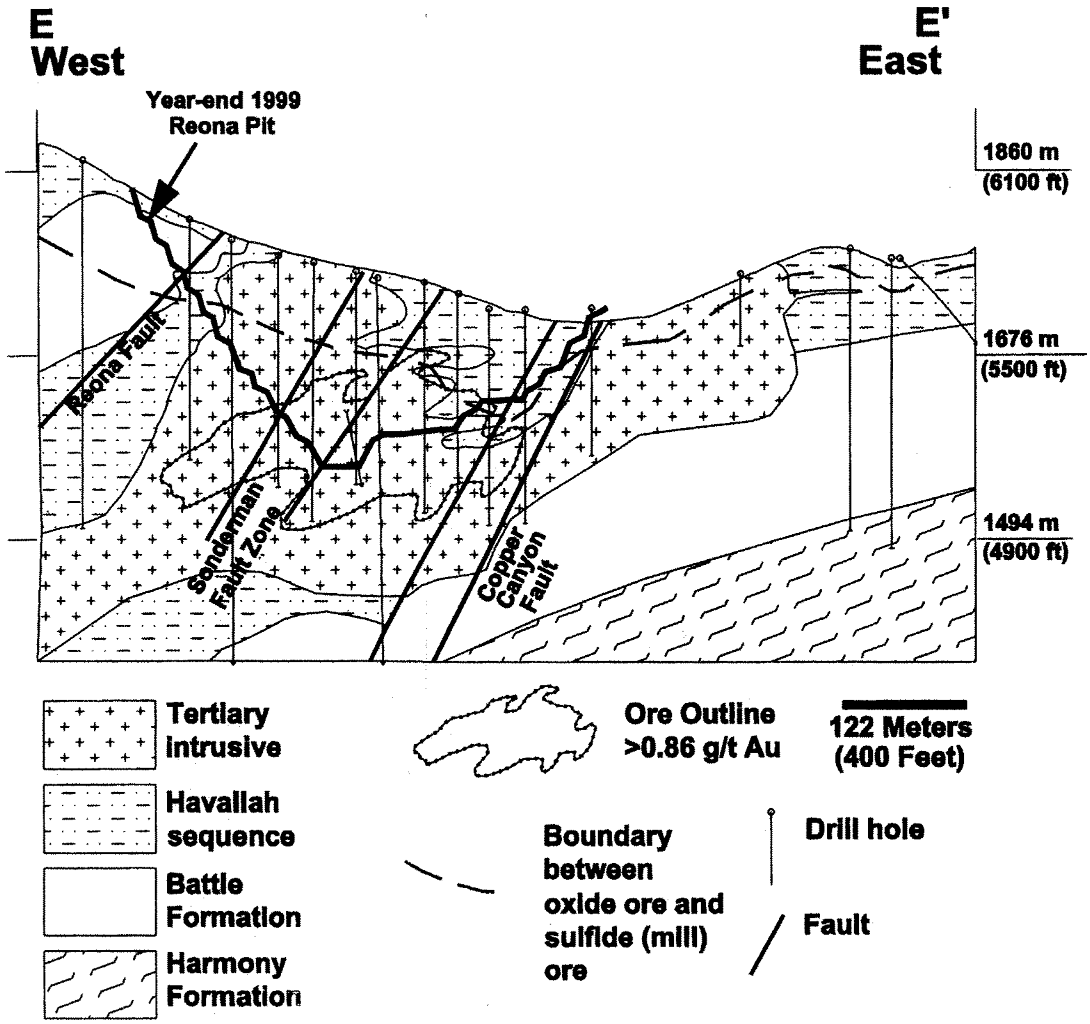


**FIGURE 11.** East-west cross-section E-E′ through the Reona deposit showing geology and Au mineralization >0.86 g/t.

### Phoenix Deposit

Myers (1990; 1994) documented a prograde-rich garnet+pyroxene skarn assemblage in the Antler Peak Formation that is zoned from a garnet-rich assemblage proximal to the stock (garnet:pyroxene ratio=2:1) at the West ore body to a pyroxene-rich assemblage (garnet:pyroxene ratio = 1:5) distal to the stock (>680 m away) in the Lower Fortitude ore body. Myers (1990 and 1994) also found garnet and pyroxene formed in the Antler Peak Limestone to be chemically zoned with more andraditic garnet ($Ad_{60-100}$) and diopsidic pyroxene ($Hd_{2-30}$) present adjacent to the stock, and grandite (Al-rich) garnet ($Ad_{25-50}$) and hedenbergite-rich pyroxene ($Hd_{30-100}$) distal to the stock. Skarn formed in the Antler Peak Limestone remaining in the proposed Phoenix pit area consists of a pyroxene ± garnet assemblage with an approximate garnet/pyroxene ratio of 1:3.

### Greater Midas Deposit

Mineral zoning in the Greater Midas deposit is most pronounced in the middle and lower Battle Formations. Mineral zoning within these two units grades from coarse-grained pyroxene>garnet assemblages adjacent to the Copper Canyon stock (0-1220 m away) to finer-grained assemblages away from the stock rich in actinolite ± epidote (1220-1890 m away) with only minor pyroxene, and chlorite + biotite + clay (1890-2400 m away), respectively (Johnson, 2000). Garnet-bearing skarn in the Greater Midas deposit occurs adjacent to the Copper Canyon stock and mainly forms where certain faults cut carbonate-rich protoliths. Orbicular textures within the middle unit of the Battle Formation, similar to those present at Carr Fork, Utah (Atkinson and Einaudi, 1978) and Beal, Montana (Wilke, 1996) are common in the intermediate actinolite-rich zone. Retrograde alteration of garnet, pyroxene, and actinolite to chlorite, biotite, quartz, and sulfide minerals is strongest adjacent to the Copper Canyon stock in the Copper Canyon underground mine area and gradually decreases in intensity away from the stock.

All of the aforementioned mineral zones host Au-Cu-Ag mineralization within the Greater Midas deposit and contain low to moderate sulfide content. Dark-purple biotite hornfels with less than three percent total sulfide content (by volume) occurs peripheral to the Au-bearing skarn assemblages described above and is dominantly hosted in siliceous rocks

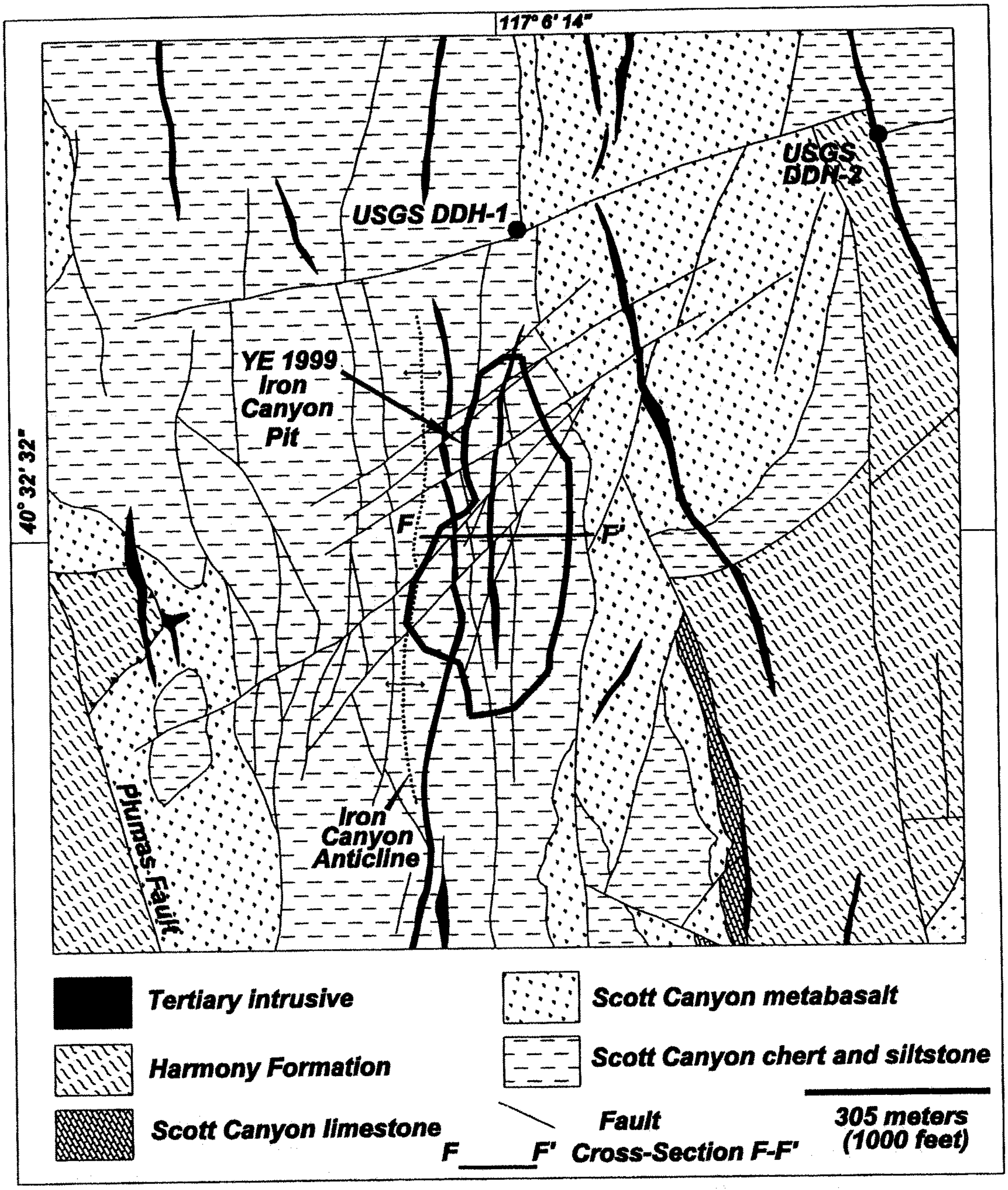


FIGURE 12. General geology map of the Iron Canyon deposit showing cross-section F-F′ (modified from Doebrich; 1994 and Theodore and Roberts; 1971).

of the Havallah sequence, and in the upper Battle and Harmony Formations.

## AU-CU-AG MINERALIZATION AND SULFIDE MINERALS

Mineralization within the Phoenix project can be classified as either being bedding or structurally controlled. The bedding type refers to the flat lying or gently-dipping tabular-shaped skarn that is dominantly controlled by carbonate-rich units and formation contacts. Faults are typically steeply-dipping to the west at ~60° and are controlled by the numerous fault sets and intersections that crosscut the sedimentary rocks. Bedding-controlled skarn is commonly present adjacent to mineralized faults, which implies structural control for the Au-bearing fluids. Table 3 lists the distribution of ore by formation in the Phoenix and Greater Midas deposits while Figure 3 schematically illustrates the dominant host rocks and mineralization style for each of the Phoenix project deposits. Minor amounts of Au-Cu-Ag mineralization (including the Reona, Sunshine, Iron Canyon, and Phoenix deposits) is hosted by Tertiary intrusive rocks primarily near the contact zones with sedimentary rocks (Fig. 3).

Three types of ore have been distinguished for the Phoenix project on the basis of supergene weathering and secondary Cu minerals: oxide, transitional, and sulfide. The three oxidation ore types typically exhibit sub-horizontal, layer-cake contact relationships with oxide on top (0 to 30 m thick), sulfide on the bottom, and transitional in between (1.5 to 23 m thick). Commonly, contacts among the three ore types may be steeply dipping where fault and fracture zones have extended the zone of oxidation to deep levels. Oxide material generally contains <1 percent total sulfide minerals and is dominated by Fe-oxide minerals. Transitional ore contains a mixture of sulfide and Fe-oxide minerals with ≥1 percent total sulfide minerals, and can have minor amounts of chalcocite, covellite, and Cu-oxide minerals. The Cu-oxide minerals that have been documented at Phoenix include: chalcanthite ($CuSO_{4.5}H_20$), malachite ($Cu_2(OH)_2CO_3$), chrysocolla ($CuSiO_{3.2}H_20$), and azurite ($Cu_3(CO_3)_2(OH)_2$. Sulfide ore contains ≤1 percent total Fe-oxide minerals and has variable amounts of sulfide minerals. The Phoenix deposit consists mostly of sulfide ore material, with minor transitional ore present in the Northeast Extension area. Oxide and transitional ores are most abundant in the northern half of the Greater Midas deposit and are not common in the southern half due to previous mining (P1, P2, and P3 phase open-pits of the Reona heap-leach project).

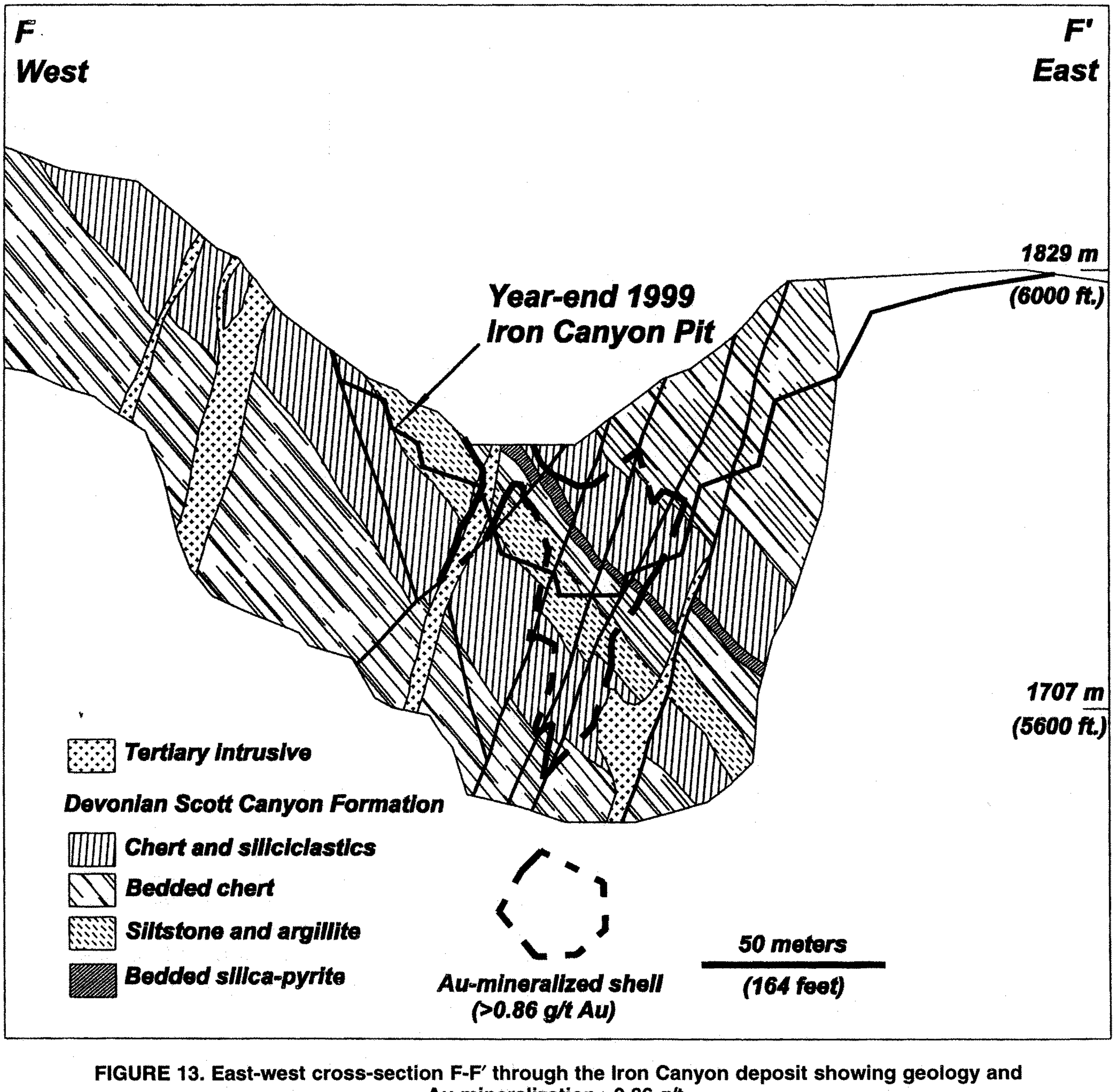


**FIGURE 13. East-west cross-section F-F′ through the Iron Canyon deposit showing geology and Au mineralization >0.86 g/t.**

Gold-bearing mineralization is mostly associated with sulfide-bearing prograde exoskarn. Moderate amounts of Au-bearing mineralization is also associated with biotite and quartz-rich hornfels, retrograde skarn, Fe-oxide-rich argillized fault breccia-gauge zones, or altered granodiorite porphyry. Stockwork quartz-rich veins within skarn, calc-silicate hornfels, or near fault zones host moderate amounts of Au, especially in the Greater Midas deposit. Petrographic studies of Au grains by one of the authors, Todd Johnson, from the Phoenix and Greater Midas deposits have determined that 64 percent of the observed Au grains are present as free Au at gangue-gangue grain boundaries and at sulfide-gangue grain boundaries. Gangue minerals in contact with native Au and electrum include quartz, pyroxene, epidote, and K-feldspar. The other 36 percent of the observed Au is present as inclusions totally encapsulated by sulfide minerals, that include pyrite and pyrrhotite, and lesser arsenopyrite, chalcopyrite, and sphalerite. This study also found the Au to be coarser grained at Phoenix relative to Greater Midas with an average Au grain size of 59 x 27 microns versus 29 x 16 microns, respectively.

Electron microprobe analyses of native Au and electrum grains from the Phoenix and Greater Midas deposits indicate a compositional range of $Au_{33\text{-}100}Ag_{0\text{-}68}$ (in weight %). Ion microprobe analyses of pyrite and arsenopyrite from the Greater Midas and Phoenix deposits show low to moderate concentrations of submicroscopic Au (<1 micron in diameter) in solid solution. Concentrations up to 0.73 g/t Au are present in arsenic-poor pyrite, whereas 2.4 to 13.3 g/t Au are locally present in arsenopyrite from the Copper Canyon underground mine area and the Virgin fault, respectively.

Total average sulfide content for Phoenix project ores range from one to 25 percent by volume. The sulfide minerals occur as disseminations within calc-silicate and silicate gangue, as massive replacements of carbonate-rich beds, as veins with abundant quartz, and as disseminations within clastic-rich lithologies and fault zones. The sulfide minerals are dominated by pyrrhotite and pyrite with minor marcasite, chalcopyrite, chalcocite, arsenopyrite, sphalerite, and galena. Sulfides that are present in trace amounts include: covellite, bornite, enargite, cubanite, molybdenite, and idaite. Other trace minerals identified by the electron microprobe include: tetrahedrite, electrum, native Au, electrum, native bismuth, tellurobismuthite ($Bi_2Te_3$), joseite ($Bi_3Te(Se,S)$), hessite ($Ag_2Te$), acanthite/argentite ($Ag_2S$), ikunolite/laitakarite ($Bi_4(S,Se)_3$), treasurite ($Ag_7Pb_6Bi_{15}S_{32}$), eskimoite ($Ag_7Pb_{10}Bi_{15}S_{36}$), vikingite ($Ag_5Pb_8Bi_{13}S_{30}$), petzite ($Ag_3AuTe_2$), tetradymite ($Bi_2Te_2S$), wehrlite (BiTe), bismuthite ($Bi_2S_3$), cosalite ($Pb_2Bi_2S_5$), native Cu, and emplectite ($CuBiS_2$).

## PHOENIX DEPOSIT

Mineralized rocks in the Phoenix pit may be classified by proximal and distal zones, as described earlier, or by domains that are identified by host rock and (or) mineralization style (bedding versus structural). Proximal mineralization in the Phoenix pit is typified by moderate Cu (≥0.5%) and low Au (0.86 g/t Au) and includes the previously mined West and East Cu > Au + Ag deposits. Distal mineralization is characterized by high-grade Au (>6.86 g/t) and low grade Cu (<0.1%) and includes the previously mined Lower Fortitude deposit. Gold-Cu-Ag-bearing ore from the Phoenix deposit lies mostly in the intermediate zone and will exploit the area between the West and Fortitude deposits, and the remaining ore in the Northeast Extension deposit. Total average sulfide content in the Phoenix deposit is moderately higher than other Phoenix project ores due to the presence of Antler Peak limestone and ranges from 5 to 25 percent by volume.

Three domains of Au-Cu-Ag mineralized rock were separately modeled in the proposed Phoenix pit development area: (1) a west zone; (2) an east zone; and (3) the Virgin fault zone which separates the first two domains. In the west zone, the Antler Peak Limestone hosts the bulk of the remaining mineralized skarn and is characterized by pyroxene ≥ garnet mineralogy with an approximate garnet/pyroxene ratio of 1:3. The bedding-controlled ore gently dips to the southwest 5° to 15°. Mineralized rock in the east zone is hosted by the Battle Formation and exhibits both lithological and structural controls. Stratabound ore typically is hosted in the lower Battle unit, immediately above the lower contact, while faults and other lithologic contacts also form important mineralized bodies in the east zone (Fig. 6).

The Virgin fault zone separates the previous two domains and defines a mineralized zone where structural control is much stronger than bedding control. The hangingwall is defined by the granodiorite dike along the Virgin fault, and the footwall is defined by a block of Battle Formation that is preserved in the fault zone. Mineralization is hosted in steeply dipping sulfide-rich stockwork veins and disseminations. The veins have a similar orientation to the Virgin fault, and the zone is 5 to 24 meters wide with a strike length > 760 meters. The zone is characterized by 5 to 25 percent sulfide minerals with pyrite > pyrrhotite ± arsenopyrite, and quartz-sericite-clay (illite, smectite, montmorillonite) in siliceous rocks (such as the Harmony Formation and the granodiorite dike); whereas chlorite and minor amphibole occurs in carbonate-rich units (such as the middle Battle Formation). Copper and total sulfide content in the Virgin fault zone are locally higher than adjacent mineralization in the east and west zones.

## GREATER MIDAS DEPOSIT

Similar to the Phoenix deposit, Au-Cu-Ag-bearing ore within the Greater Midas deposit may also be classified by bedding and structural mineralization styles. Mineralization adjacent to the Copper Canyon stock in the Greater Midas deposit is typified by moderate Cu (>0.3%) and low Au (1.22 g/t), including the historic Copper Canyon underground mine area. Mineralization that occurs distal to the stock is characterized by moderate Au (>2.0 g/t) and low Cu (<0.1%) and includes the West Midas Au-Ag resource area, and the southern part of the Greater Midas deposit.

Ore from the Greater Midas deposit lies mostly in the middle and northern half of the year-end 1999 pit and mining will exploit sulfide-bearing mineralized rock at the bottom of the P1, P2, and P3 pits, and remaining ore in the Copper Canyon underground mine area. Ore horizons in the Greater Midas deposit include the unconformable contact between the Harmony and Battle Formation, contacts between conglomerate and siltstone units of the Battle Formation, and the thrust contact between the Havallah sequence and Battle Formation. Total sulfide content of ore from the Greater Midas deposit ranges from one to 19 percent by volume and averages around 7 percent by volume.

Adjacent to the Copper Canyon stock in the Copper Canyon underground mine area, retrograde alteration to earlier-formed pyroxene and garnet skarn is strongly developed. Faults exert strong control to mineralization with iron-oxide-stained, clay-rich fault-breccia zones, wide veins of quartz + pyrite ± chlorite ± magnetite, and/or wide zones of moderate sulfide replacement characterized by 3 to 18 percent total sulfide minerals by volume. Intense faulting and pervasive skarn alteration prevents accurate identification of Battle Formation units in the underground mine area.

The distinctive fabric in the Greater Midas sulfide skarn ores, especially in the proximal and intermediate zones, is the presence of open-space that makes up a trace to as much as 10 volume percent of the rock where it is present in relict sulfide, and or coarse-grained, subhedral quartz and less abundant K-feldspar crystals. The open-space is thought to be related to (1) relict carbonate-rich zones that were common in the matrix of the quartz-pebble conglomerate, (2) local carbonate-rich clasts of the conglomerate, or (3) in fracture and fault zones, and/or in open-space veins. Wispy and rare planar-banded veins, making up less than 5 volume percent of the total rock, and consisting of banded pyrite + open-space siderite/ankerite + quartz + Fe-oxide minerals + chlorite ± K-feldspar crosscut the actinolite + epidote + K-feldspar-sulfide-bearing skarn ores. Veins rich in quartz adjacent to the stock (<1,780 m) typically contain high-grades of Au and Ag, while those veins rich in siderite/ankerite occur distal to the stock (>1,780 m) and typically contain no Au and Ag.

Oxide ores are prevalent in the northern portion of the Greater Midas deposit and are dominantly hosted in the Havallah sequence close to the Copper Canyon fault and, to a lesser extent, in the Battle Formation along footwall splays of the Virgin fault zone. Typical mineralogy of the oxide ore consists of orange to dark-brown iron-oxide, clay, purple biotite, and quartz. The bulk of the oxide ore in the southern part of the Greater Midas deposit has been previously mined.

## GEOCHEMISTRY

Table 4 lists representative geochemistry associated with Au ore (>0.5 g/t) from the Phoenix, Greater Midas, Reona, and Iron Canyon pits. The values in this table are averages for each deposit. Geochemistry, along with calc-silicate and silicate minerals, are zoned about the Copper Canyon stock (Theodore et al., 1986; Myers, 1990; Myers and Meinert,

**TABLE 4. Representative geochemistry from the Phoenix, Greater Midas, and Reona pits. The data represent average values from drillhole ore intervals (Au>0.5 g/t) throughout each pit and includes oxide, transitional, and sulfide ore types. The Au-Cu-Ag abundances are averages for the data that was analyzed and are not average grades for the three deposits. All data was analyzed by ACME Laboratory, Vancouver B.C. Canada, with Au-Cu-Ag analyses performed by American Assay Laboratory, Reno, NV and (or) by the Battle Mountain Gold's Copper Canyon Mine Laboratory. Pap = Antler Peak Formation; Pbm = middle Battle Formation; Pbl = lower Battle Formation; Tag = altered granodiorite; Dsc = Scott Canyon Formation; FZ = fault zone.**

| Pit Area<br># samples<br>Host Rocks used in averages | Phoenix Pit<br>n=31<br>Pap | Phoenix Pit<br>n=87<br>Pbm, Pbl | Phoenix Pit<br>n=29<br>Virgin FZ | Greater Midas Pit<br>n=113<br>Pbm, Pbl | Reona Pit<br>n=15<br>Tag | Iron Canyon Pit<br>n=36<br>Dsc |
|---|---|---|---|---|---|---|
| Au (g/t) | 1.20 | 1.58 | 3.56 | 2.29 | 1.37 | 2.64 |
| Cu (%) | 0.152 | 0.155 | 0.182 | 0.184 | 0.178 | 0.047 |
| Ag (g/t) | 13.14 | 45.66 | 30.86 | 24.37 | 7.30 | 37.89 |
| As (ppm) | 339 | 862 | 3748 | 474 | 490 | 3944 |
| Ba (ppm) | 17 | 61 | 41 | 43 | 91 | 95 |
| Bi (ppm) | 43 | 108 | 110 | 69 | 23 | 125 |
| Cd (ppm) | 4 | 17 | 13 | 60 | 11 | 166 |
| Co (ppm) | 18 | 26 | 23 | 26 | 15 | 12 |
| Cr (ppm) | 31 | 52 | 68 | 52 | 51 | 26 |
| Hg (ppb) | 161 | 204 | 131 | 51 | 23 | 19 |
| Mn (ppm) | 783 | 387 | 438 | 732 | 207 | 467 |
| Mo (ppm) | 4 | 9 | 23 | 24 | 10 | 3 |
| Ni (ppm) | 59 | 39 | 76 | 51 | 23 | 30 |
| Pb (ppm) | 67 | 430 | 1362 | 1290 | 86 | 451 |
| Sb (ppm) | 3 | 13 | 11 | 6 | 5 | 29 |
| Se (ppm) | 27 | 22 | 26 | 18 | 6 | 37 |
| Sn (ppm) | 14 | 5 | 6 | 12 | 2 | 4 |
| Te (ppm) | 12 | 12 | 10 | 11 | 5 | 6 |
| W (ppm) | 10 | 8 | 6 | 13 | <2 | 25 |
| Zn (ppm) | 190 | 233 | 725 | 2612 | 509 | 12423 |

1991; Kotlyar et al., 1998 and 1999; Johnson, 2000). Correlation coefficients of Au with other elements and metals along with metal ratios have been examined in the Fortitude deposit by Kotlyar et al. (1998; 1999) and Myers (1990) and in the Greater Midas area by Theodore et al. (1986) and Johnson (2000).

Skarn ore geochemistry in the Phoenix deposit has been separated by host rock (Antler Peak Formation vs. Battle Formation) and/or by structural zone such as the Virgin fault zone. The remaining skarn ores in the Phoenix deposit hosted by the Antler Peak Limestone are predominantly from the intermediate area between the Fortitude and West deposits. Skarn ore hosted in the Antler Peak Limestone makes up approximately 27 percent of the Phoenix deposit and is geochemically anomalous in Au, Ag, As, Bi, Co, Cr, Cu, Ni, Se, and Te. For a comparison, the geochemistry and associated metal zoning of skarn formed in the Antler Peak Limestone within the Fortitude and West ore bodies were described by Myers and Meinert (1991). Skarn ore hosted by the middle and lower units of the Battle Formation makes up approximately 41 percent of the Phoenix deposit and is geochemically anomalous in the same elements described above for the Antler Peak Limestone hosted ores. Elevated Ag, As, Bi, and Pb are present in the middle and lower units of the Battle Formation relative to the overlying Antler Peak Limestone. Ores from the Virgin fault zone make up approximately 17 percent of the Phoenix deposit and contain elevated amounts of As, Bi, Cu, Pb, and Zn relative to the other sedimentary rock units listed in Table 4.

About 73 percent of the skarn ore in the Greater Midas deposit is hosted by the middle and lower units of the Battle Formation and is generally anomalous in Au, Ag, As, Bi, Cd, Co, Cr, Pb, Te, and Zn. The geochemistry of skarn ore in the Greater Midas area is zoned from a proximal area of Cu + Ag > Au with elevated Pb, Zn, Mn, Mo, As, and Cd to an intermediate and distal area containing elevated Au, Bi, Cu, and Cr, and Au + Bi, respectively (Johnson, 2000). Ore hosted by altered granodiorite from the Reona pit contains elevated Au, Ag, As, Bi, Cu, and Cr. Ore hosted in the Scott Canyon Formation at the Iron Canyon deposit is anomalous in Au, Ag, As, Bi, Cd, Co, Pb, Se, and Zn.

## CURRENT MINING, MILLING, AND PERMITTING PLANS

Mining at the Phoenix Au-Cu-Ag project will involve open-pit methods and include heap leaching of oxide ore and milling of transitional and sulfide ores. Leach pads previously constructed at the mine site as part of previous mining during the Reona project will be expanded for additional use for the Phoenix project.

The mill will contain several circuits to optimize recovery of Au-Cu-Ag, and includes in relative sequencing order: gravity concentration, bulk sulfide flotation, a regrind circuit, a secondary gravity circuit, and a final Cu cleaner flotation circuit (Fig. 14). Ore brought to the mill will be first ground to a $P_{80}$ of 74 microns before processing. The presence of relatively coarse free Au requires that the ground ore be passed initially through a gravity-separation circuit that will incorporate a series of at least four 48 inch Knelson concentrator units. The gravity concentrate will be tabled and smelted into a high-grade dore' at the mine site. The second circuit in the mill is a bulk sulfide flotation process. This is followed by regrinding the rougher concentrate, followed by a gravity circuit and three stages of Cu flotation upgrading to produce a saleable Cu concentrate. Total recoveries from the mill using the aforementioned flowsheet are estimated at 79 percent for Au, 81 percent for Cu, and 45 percent for Ag. Additional methods are being examined to optimize recovery of Au, Cu, and Ag and include cyanidation (CIL) of the cleaner flotation tailings, and SART (sulphidization, acidification, regeneration, and thickening) of the leached cleaner tails (MacPhail et al., 1998).

Mill throughput is targeting approximately 27,220 tonnes per day that will produce over 13,015 kilograms (400,000 oz.) Au per year over a mine life of 12 years. The strip ratio is currently estimated at 2.7:1. Multiple open pits will be active at any given time during the mine life of the Phoenix project. Production is being planned to begin in the northern part of the Greater Midas pit in the area of the Copper Canyon underground mine area, and also in the Iron Canyon deposit. Ore at the Copper Canyon underground mine area contains moderate Au with substantial Cu and Ag and has a relatively low strip ratio in comparison to other parts of the orebody. Iron Canyon ore will also help contribute high-grade Au ore early in the mine life. Mining of the Fortitude pit bottom is also planned to begin at the same time as mining of the Copper Canyon underground mine area in order to facilitate later backfilling of the pit with waste from other portions of the Phoenix deposit.

A feasibility study by Agra/Simons Incorporated, is currently underway for the Phoenix project and is scheduled to be completed in the late spring or early summer of 2000. A revised Plan of Operations was submitted to the Bureau of Land Management (BLM) in January of 1999. The project will be designed and permitted as a zero water discharge operation. Although dewatering of the proposed pit areas will occur, the Phoenix project plans to use all of the pumped water in its mining and milling operations. After all permits are received, Battle Mountain Gold hopes to start construction of a new mill and prestripping of overburden rock early in 2001. A total of 51,830 meters of additional development drilling throughout the Phoenix project area is planned for the year 2000.

## SUMMARY

The Phoenix project in Lander County, Nevada contains one of the largest known undeveloped Au resources hosted by skarn in North America. Total year-end 1999 reserves for the project include 176,633 kilograms (5.68 million oz.) of Au, 1,328,854 kilograms (42.7 million oz) Ag, and 213,364 tons

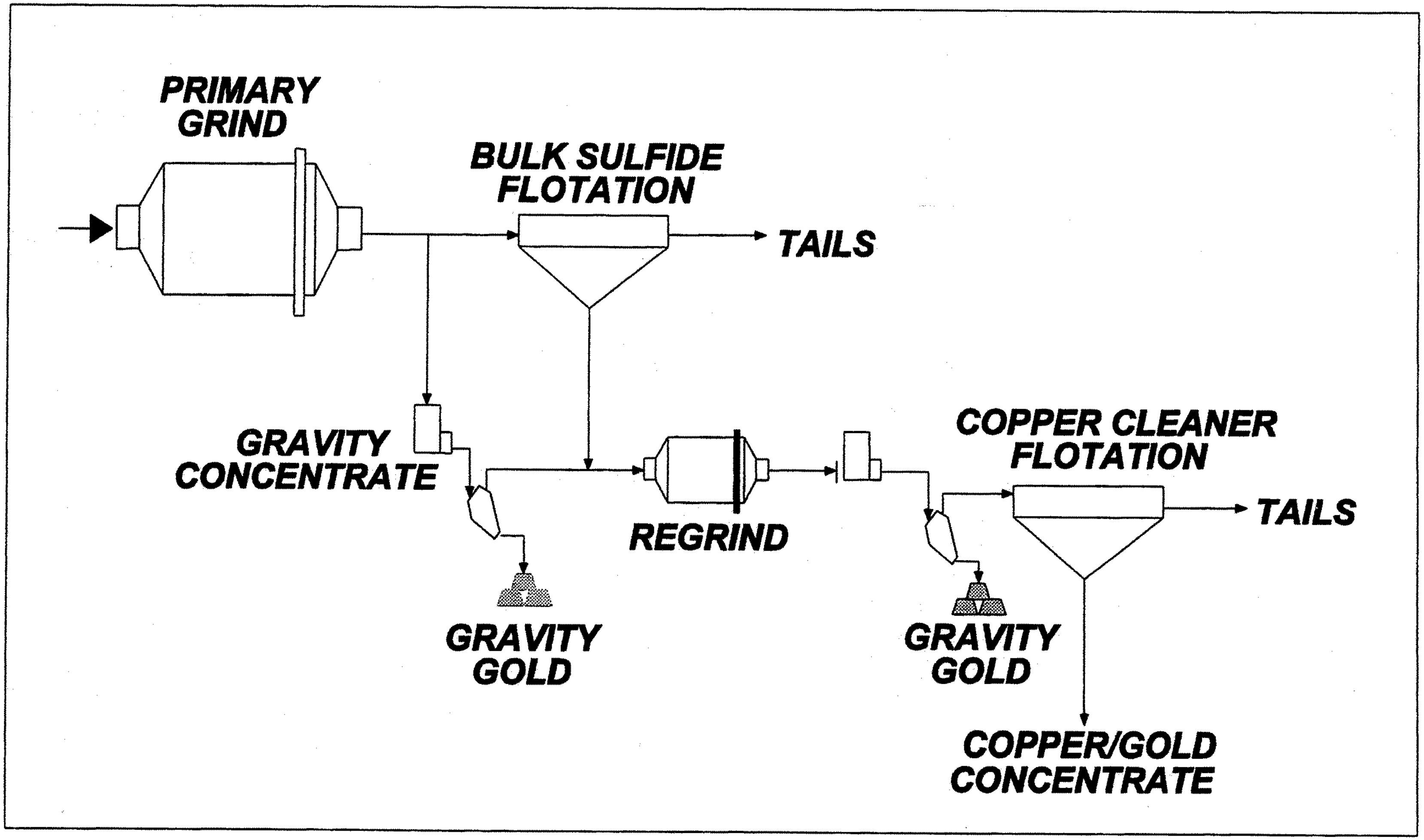


FIGURE 14. Proposed mill flowsheet for the Phoenix Project.

of Cu. The Au reserves of the Phoenix project combined with past Au production from the Copper Canyon area (including Fortitude, Minnie, Tomboy, and the Reona heap-leach project) totals 268,000 kilograms (8.76 million oz.). The Phoenix Au-Cu-Ag project will involve open-pit mining in five areas: Phoenix, Greater Midas, Reona, Iron Canyon, and Sunshine. Processing of the ores will include heap-leaching of oxide ore (with <1% total sulfide by volume) and milling of transitional and sulfide ores (with ≤1% total Fe-oxide minerals). The mill will include (in relative sequencing order): gravity concentration, bulk sulfide flotation, a regrind circuit, a secondary gravity circuit, and a final Cu cleaner flotation circuit. The high recoveries for Au, Cu, and Ag using this mill circuit design allowed the drilling of high-Cu domains in the Phoenix project area which significantly added to the total reserve base.

Gold-Cu-Ag-bearing mineralization within the Phoenix project can be classified as either being bedding or structurally controlled which are either strata-bound or high-angled in nature, respectively. The strata-bound skarn mineralization is hosted predominantly by carbonate-rich sedimentary rocks of the Antler sequence and includes the Antler Peak Formation, the Edna Mountain Formation, and the Battle Formation. High-angle normal faults that typically strike in a northerly direction and dip steeply to the west act as another important control to mineralization which helped concentrate Au-Cu-Ag in more clastic- and siliceous-rich units such as the Harmony Formation, the granodiorite dike within the Virgin fault zone, and the Havallah sequence. Intrusive-rock hosted Au-Cu-Ag mineralization in Phoenix project ores are less common and mainly occur in the Reona and Sunshine deposits with certain dikes hosting small amounts of mineralization in the Iron Canyon and Phoenix deposits.

The ores of the Phoenix project area are part of large, mineralogically and metallically zoned porphyry Au-Cu-Ag skarn system centered about the 38-Ma Copper Canyon granodiorite stock. The Phoenix and Greater Midas deposits to the north and south of the stock, respectively, host 94 percent of the total Phoenix project ores (by tonnes) and contain a low Au (<1.3 g/t) moderate Cu (>0.3%) zone adjacent to the stock which grades outwards to a distal zone enriched in Au (>2.0 g/t) with low Cu (<0.1%). Gold mineralization is primarily hosted in pyrrhotite- and pyrite-bearing skarn consisting of pyroxene, epidote, and actinolite > garnet. Lesser amounts of Au mineralization is associated with quartz-rich veins, fault breccia (± clay), and retrograde skarn consisting of chlorite, quartz, actinolite, and epidote. Total sulfide content of mill ore averages from 1 to 25 percent by volume and is generally higher in the Phoenix deposit due to the presence of the Antler Peak limestone unit.

Skarn mineralogy and Au-Cu-Ag mineralization are zoned about the stock and are controlled by (1) carbonate-rich lithologies, (2) distance from the stock, and (3) faults and lithologic contacts. In the Phoenix deposit, skarn hosted by the Antler Peak Limestone is zoned from a proximal assemblage of andraditic garnet > diopsidic pyroxene adjacent to the stock (with Cu>Au), to a distal assemblage of hedenbergitic pyroxene > grandite garnet distal to the stock (with Au>>Cu). Skarn in the Greater Midas deposit is zoned from a proximal assemblage of pyroxene>garnet with strong retrograde alteration adjacent to the stock (with Cu>Au) that grades outward to a similar skarn assemblage with lesser retrograde alteration, and to distal assemblages containing actinolite with only minor pyroxene, and chlorite + biotite + clay, respectively (with Au>>Cu).

A feasibility study on the Phoenix project is scheduled for completion in late spring or early summer of 2000. After all permits are received, Battle Mountain Gold hopes to start construction of a new mill and prestripping of overburden rock early in 2001.

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