3.1 Geology and Minerals

3.1.1 Affected Environment

This section addresses the geology, mineralization, and geologic hazards associated with the Phoenix Project. The geologic conditions discussed below also provide the background information for characterizing the hydrogeologic conditions, which are discussed in Section 3.2, Water Resources and Geochemistry.

3.1.1.1 Physiographic and Topographic Setting

The topography and physiographic features of the regional study area for geology and minerals are shown in ***Figure 1-2***. The Phoenix Project is located in the southern portion of the Battle Mountain range, which trends north-south and is approximately 18 miles long and 12 miles wide. The highest peak is North Peak at 8,550 feet above mean sea level (amsl). The Battle Mountain range is flanked by the Buffalo Valley to the west, the Reese River Valley to the east, and the Humboldt River to the north and northeast. Buffalo Valley is a closed basin with a valley floor elevation of approximately 4,600 feet amsl. The Humboldt River near the town of Battle Mountain is situated at an approximate elevation of 4,500 feet amsl. The tributaries in Buffalo Valley drain toward a playa lake in Buffalo Valley; drainage into the Reese River Valley flows toward the Reese River, a tributary of the Humboldt River.

The project area is located within the Great Basin region of the Basin and Range physiographic province and is characterized by a series of generally north-trending mountain ranges separated by broad basins. The Basin and Range physiography has developed from normal faulting that began approximately 17 million years ago and continues to the present (Stewart 1980). The extensional block faulting uplifted the mountains, which consist of Precambrian to Tertiary age bedrock units. The basins are filled with thick accumulations of unconsolidated-consolidated sediments derived from erosion off of the adjacent mountain ranges. These sediments form alluvial fans that surround the Battle Mountain range and form gradual slopes down to the valley bottom rivers.

3.1.1.2 Regional Geologic Setting

The regional geologic conditions are presented in ***Figure 3.1-1***, and the regional geologic cross sections are shown in ***Figure 3.1-2***. The major geologic units, from oldest to youngest, include the Late Cambrian Harmony Formation, Middle and Early Ordovician Valmy Formation, Devonian Scott Canyon Formation, Mississippian to Permian Havallah and Pumpernickel formations, and Pennsylvanian to Permian Antler Sequence. However, because of thrust faulting, these formations do not occur in stratigraphic order.

Paleozoic sedimentary rocks form the regional basement throughout the study area and have undergone a complex history of sedimentation and deformation. During the early Paleozoic Era, marine clastic and carbonate rocks were deposited in a shallow sea that represented the western continental margin of North America. The marine clastic rocks (Harmony, Valmy, and Scott Canyon formations) were deposited in the deep water to the west, while carbonate rocks were deposited in the shallow water to the east (Stewart 1980). During the Late Devonian and Early Mississippian periods, sedimentary deposition was interrupted, and the Paleozoic sediments were uplifted, folded, and thrust faulted by the Antler Orogeny. During the Antler Orogeny, thrusting occurred in several stages. The oldest thrust is the Roberts Mountain thrust, which moved the Scott Canyon Formation 90 miles eastward over the carbonate rocks (Roberts 1964; Stewart 1980; Baker Consultants, Inc. 1997a). This thrust and the carbonate rocks do not crop out in the study area (Roberts 1964), but probably occur at depths greater than 4,600 meters (Theodore and Roberts 1971). Subsidiary thrusts (Valmy and Dewitt thrusts) associated with the Antler Orogeny changed the stratigraphic sequence in the area (***Figure 3.1-3***).

The Antler Orogeny also created a highland that persisted from the Mississippian period to the Permian period (Stewart 1980). Erosion of the Antler highlands during the Pennsylvanian and Permian periods produced the Antler Sequence, which lies unconformably on top of the early Paleozoic rocks. The Antler Sequence (an in situ assemblage) consists of shallow marine siltstone, sandstone, conglomerate, and limestone (Doebrich 1995). The Battle Formation, Antler Peak Limestone, and the Edna Mountain Formation make up the Antler Sequence (***Figure 3.1-3***).

To the west of the Antler highlands, Mississippian to Permian Havallah and Pumpernickel formations were deposited (Murchey 1990). Both of these formations represent deep water sediments. The Pumpernickel Formation is composed of argillite, cherty siltstone, radiolarian chert interbedded with greenstone, sparse sandstone, and conglomerate (Theodore and Blake 1975; Baker Consultants, Inc. 1997a). The Havallah Formation is a complex assemblage of volcaniclastic greenstone, deep water clastic rocks, radiolarian chert, and basalt at the base (Doebrich 1995). Together, the Pumpernickel and Havallah formations make up the Havallah Sequence (Theodore and Blake 1975).

During the Late Permian to Early Triassic time, the Sonoma Orogeny thrust the Havallah Sequence 45 miles eastward over the Antler Sequence along the Golconda thrust (Siberling and Roberts 1962). The Havallah Formation was thrust over the Pumpernickel Formation by the Willow Creek thrust. In addition to the thrusting, the Sonoma Orogeny locally folded the Antler Sequence, which lies below the Golconda thrust.

Tectonism developed throughout the rest of the Mesozoic era, causing northwest-trending faults and broad open folds. Because of the deformation caused by faulting and folding, particularly in the late Cretaceous period, magmatism resulted in monzogranite stocks that contain mineable minerals (molybdenum, copper, silver, and gold) (Baker Consultants, Inc. 1997a).

Beginning in the late Cretaceous period, the area was block-faulted by a series of normal faults that created the basin and range topography that characterize the region. Broad valleys in the regional study area, such as Buffalo Valley and Reese River Valley, were formed as down-dropped blocks between uplifted mountain ranges. In Copper Canyon, north-south Tertiary normal faults also are important for localizing ore and for controlling emplacement of granodiorite (Theodore and Blake 1975). The major north-striking, west-dipping faults include the Virgin, Hayden, Monitor, Copper Canyon, and Plumas faults. Associated with the extensional block faulting, widespread igneous activity emplaced granodiorite stocks and dikes. During the middle Tertiary period, volcanic activity led to the deposition of ash-flow tuffs, which are hundreds to thousands of feet thick (Baker Consultants, Inc. 1997a).

During the late Tertiary and Quaternary time, uplift and subsequent erosion of the mountains created from the block-faulting have partially filled the basin with poorly consolidated to unconsolidated silt, sand, gravel, and boulders deposited primarily as a series of coalescing alluvial fans. The center of the valleys are dominated by river alluvium along the ephemeral rivers and playa lake deposits associated with the Buffalo Valley playa lake. As illustrated in ***Figure 3.1-2***, the thickness of these deposits ranges from a thin veneer on pediment slopes to a thousand feet or more near the central portions of the basins.

3.1.1.3 General Site Geology

The general site geology is illustrated in ***Figure 3.1-4***. Baker Consultants, Inc. (1997a) analyzed and compiled information on the local geology from geologic maps published by the Nevada Bureau of Mines and Geology and the U.S. Geological Survey, existing BMG reports, and exploration and hydrologic characterization data. In the vicinity of the project area, the stratigraphy is the same as that shown in ***Figure 3.1-3***, except the Battle Formation is divided into lower, middle, and upper units. The lower unit is a reddish-brown, calcareous, hematitic, poorly sorted, chert-pebble conglomerate that is up to 400 feet thick. The middle unit is a thinly bedded red and yellow shale and calcareous siltstone and sandstone that is 75 feet thick. The upper unit is an interbedded red, yellow, and tan siliceous siltstone, sandstone, and sandy chert-pebble conglomerate that is 200 feet thick (Roberts 1964; Baker Consultants, Inc. 1997a).

In Copper Canyon, the Paleozoic formations have been intruded by a Tertiary granodiorite, causing alteration to the sedimentary sequence near the intrusion. Important local structures include the Copper Canyon fault, Virgin fault, Golconda thrust, and Plumas fault. The Copper Canyon fault is highly brecciated with 600 feet of displacement (Theodore and Blake 1975) and exhibits post-mineralization movement (BMG 1994). The Virgin fault dips 65 degrees to the west with 400 feet of displacement in the north end and 1,000 feet of displacement near the south end of the fault. Erosion along the Virgin fault has resulted in exposure of the Golconda thrust. The Golconda thrust moved the Pumpernickel Formation over the Antler Sequence during the Sonoma orogeny (Baker Consultants, Inc. 1997a).

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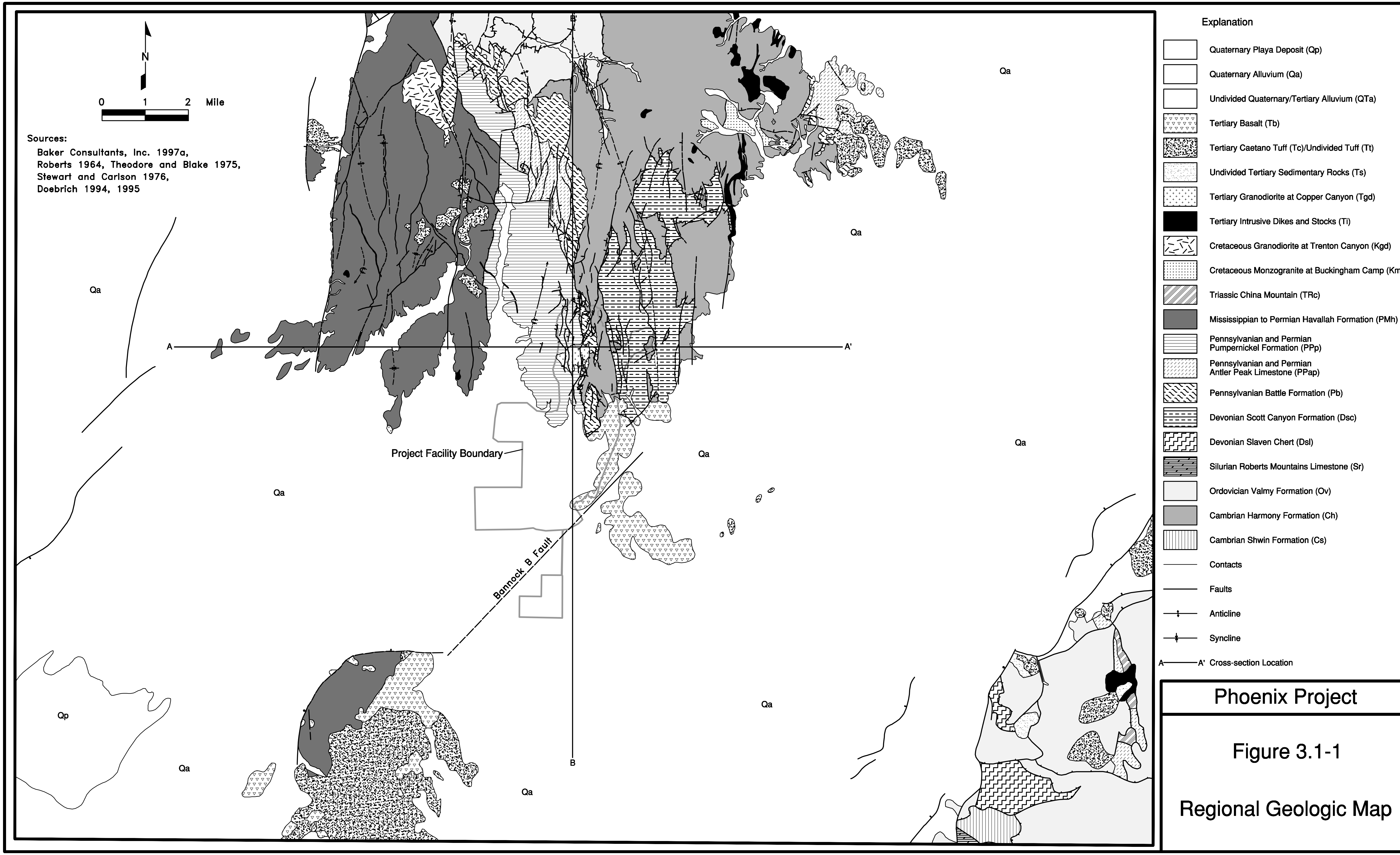
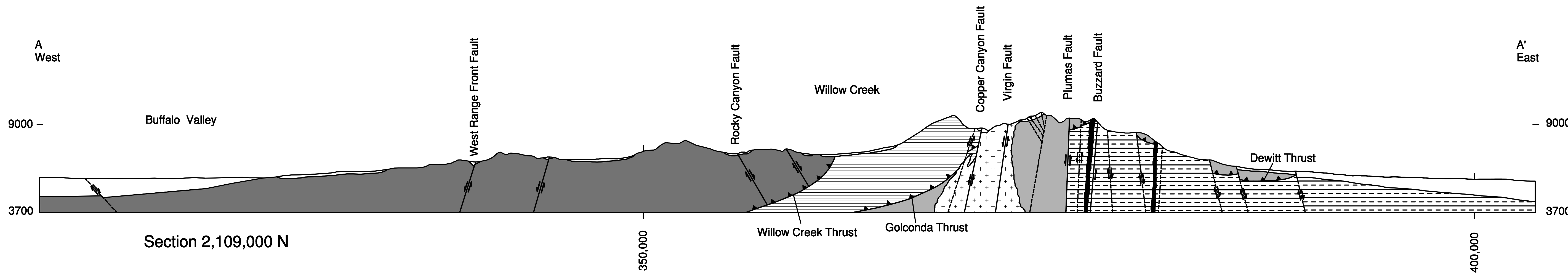
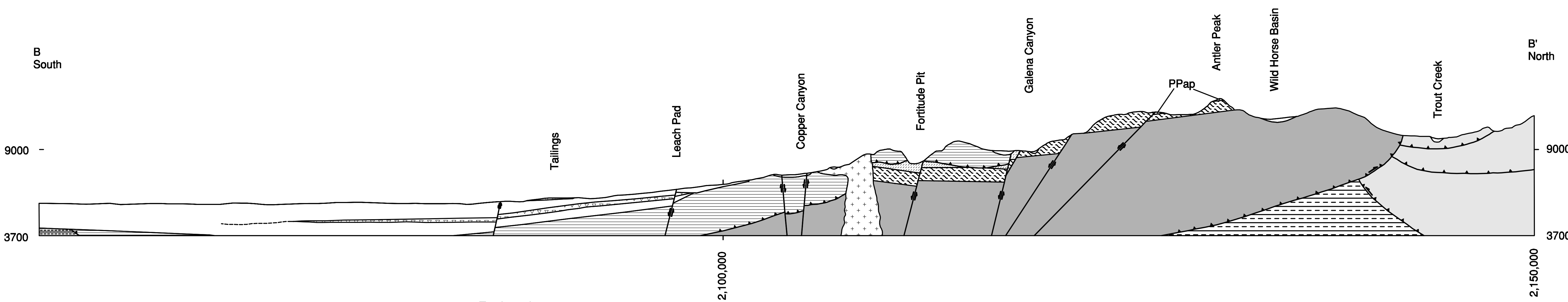


Phoenix Project

Figure 3.1-1

Regional Geologic Map





Explanation

- Quaternary Alluvium (Qa)
- Undivided Quaternary/Tertiary Alluvium (QTa)
- Tertiary Basalt (Tb)
- Tertiary Caetano Tuff (Tc)/Undivided Tuff (Tt)
- Tertiary Granodiorite at Copper Canyon (Tgd)
- Tertiary Intrusive Dikes and Stocks (Ti)
- Mississippian to Permian Havallah Formation (PMh)
- Pennsylvanian and Permian Pumpernickel Formation (PPp)
- Pennsylvanian and Permian Antler Peak Limestone (PPap)
- Pennsylvanian Battle Formation (Pb)
- Devonian Scott Canyon Formation (Dsc)
- Ordovician Valmy Formation (Ov)
- Cambrian Harmony Formation (Ch)
- Contacts
- Faults

Horizontal Scale = Vertical Scale

0 5000 Feet

Source: Baker Consultants, Inc. 1997a

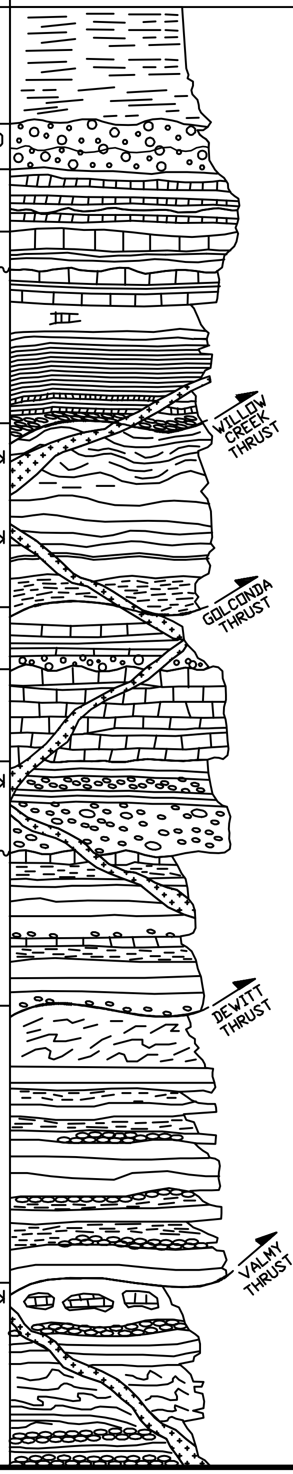
Phoenix Project

Figure 3.1-2

Regional Geologic Cross-Sections

	AGE	MAP UNIT	FORMATION	THICKNESS (FEET)	DESCRIPTION
	QUATERNARY	Qa	ALLUVIUM	0-600	GRAVEL, SAND, SILT AND CLAY IN ALLUVIAL FANS AND VALLEY BOTTOMS.
	TERTIARY (34 Ma)	Ta	VALLEY FILL DEPOSITS	100-1,000	TERTIARY VALLEY FILL DEPOSITS, COMPOSED OF ALLUVIUM, PYROCLASTIC AND DEBRIS-FLOW DEPOSITS, CRYSTALLINE AND VITRIC TUFFS AND BASALTS.
	TERTIARY (34 Ma)	Tb	BASALT FLOWS	30-400	BLACK OLIVINE-BEARING BASALT; FLOWS ARE VESICULAR AT BASE, DENSE IN CENTER, WITH HEMATITIC SCORIACEOUS FLOW TOPS. FLOWS MAY BE SEPARATED BY ALLUVIUM.
	TERTIARY (34 Ma)	Tc	CAETANO TUFF	30-350	PINKISH GRAY CRYSTAL-LITHIC WELDED ASH-FLOW TUFF WITH GLASSY QUARTZ PHENOCRYSTS; BASAL TUFF, MIDDLE VITROPHYRE, STONY QUARTZ LATITE WITH COLUMNAR JOINTING AT TOP.
HAVALLAH SEQUENCE	MISS.-PERMIAN	PMh	HAVALLAH	4,600	GRAYISH- GREEN RIBBON CHERT; INTERBEDDED BLACK, GRAY, GREEN, AND MAROON SILTY CHERT AND CALCAREOUS SILTSTONE, WITH MINOR DARK GREEN TO BLACK BASALT AND GABBRO WITH ORANGE CALCITE-FILLED AMYGDULES IN MIDDLE; AND INTERBEDDED GRAY LIMESTONE AND BLACK CHERT AT TOP. INTRUDED BY GRANODIORITE AT TRENTON CANYON.
HAVALLAH SEQUENCE	PENN.-PERMIAN	PPp	PUMPERNICKEL	Kgd 5,000 Tgd	GRAYISH-GREEN, MAROON, PURPLE AND BLACK ARGILLITE AND CHERTY SILTSTONE; BLACK AND MILKY-GRAY SPONGE-SPICULE AND RADIOLARIAN BEARING CHERT WITH MINOR GREEN AND BLACK ARGILLITE BEDS; AND INTERBEDDED GRAYISH GREEN, BLACK AND MAROON ARGILLITE AND BLACK AND GRAY SPONGE-SPICULE BEARING CHERT WITH SPARSE BROWN SANDSTONE INTERBEDS. INTRUDED BY GRANODIORITE AT COPPER CANYON.
ANTLER SEQUENCE	PERMIAN	Pem	EDNA MOUNTAIN	125	INTERBEDDED TAN TO BROWN CALCAREOUS, FELDSPATHIC, MICACEOUS SANDSTONE, WHITE TO LIGHT GRAY SANDY LIMESTONE, AND ROUNDED, WELL SORTED DRAB CHERT-PEBBLE CONGLOMERATES AT BASE.
ANTLER SEQUENCE	PENNSYLVANIAN	PPap	ANTLER PEAK LIMESTONE	600	LIGHT TO MEDIUM BLUISH-GRAY FOSSILIFEROUS LIMESTONE THAT IS LOCALLY SHALY, SANDY, AND PEBBLY, CONTAINS THIN DISCONTINUOUS CHERT BEDS AND NODULES.
ANTLER SEQUENCE	PENNSYLVANIAN	Pbu Pbm Pbl	BATTLE	Tgd 700	REDDISH-BROWN CALCAREOUS, HEMATITIC CHERT-PEBBLE CONGLOMERATE WITH ANGULAR PEBBLES OF CHERT, QUARTZITE, AND GREENSTONE AT BASE; THINLY BEDDED RED AND YELLOW SHALE AND CALCAREOUS SILTSTONE AND SANDSTONE IN MIDDLE; AND RED, YELLOW, AND TAN SILICEOUS SILTSTONE, SANDSTONE, AND SANDY CHERT-PEBBLE CONGLOMERATE AT TOP.
	CAMBRIAN	Ch	HARMONY	3,000	INTERBEDDED GREENISH-BROWN, MEDIUM TO COARSE-GRAINED, MICACEOUS, QUARTZOSE AND FELDSPATHIC SANDSTONE; AND PEBBLY SANDSTONE; MINOR GREEN, BROWN, BLACK AND RED CALCAREOUS SHALE; AND TAN TO DARK GRAY LIMESTONE, INTRUDED BY GRANODIORITE AT COPPER CANYON.
	ORDOVICIAN	Ov	VALMY	8,000	THICK-BEDDED TO MASSIVE, LIGHT GRAY TO BROWN VITREOUS QUARTZITE AND INTERBEDDED DARK GRAY, GREEN AND BLACK CHERT AND GRAPTOLITIC SHALE, ARGILLITE AND GREENSTONE. INTERBEDDED CHERT AND SHALE HAS BEEN COMPLEXLY FOLDED AND SHEARED AT THE TOP.
	DEVONIAN	Dsc	SCOTT CANYON	Tgd Km 5,000	DARK TO PALE GREEN GREENSTONE WITH MINOR THIN GRAY TO BLACK QUARTZITE BEDS; INTERBEDDED BLACK, GRAY AND MILKY GRAYISH BROWN RADIOLARIAN CHERT AND BLACK TO GRAY CARBONACEOUS, SHALE AND ARGILLITE. IN PLACES, LARGE BLOCKS OF LIMESTONE, QUARTZITE, AND CHERT ARE PRESENT IN A TUFFACEOUS GREENSTONE MATRIX. INTRUDED BY GRANODIORITE TO QUARTZ MONZONITE LOCALLY.

LITHOLOGY



Source: Baker Consultants, Inc. 1997a

Phoenix Project

Figure 3.1-3

Stratigraphic Column

3.1.1.4 Mineralization and Pit Geology

The Phoenix Project lies at the north end of the northwest-trending Eureka mineral belt. Mineral development is related to a Tertiary granodiorite that has intruded the Paleozoic sedimentary rocks (Theodore et al. 1990). Hydrothermal fluids associated with the intrusion caused the mineralization and are associated with the local normal faults that acted as conduits. The Golconda thrust sheet capped the hydrothermal fluids, allowing them to react with the units of the Antler Sequence (Exponent 2000a).

Existing Pits

The geology of the existing pits (from north to south) is summarized below.

Fortitude Pit. Mining was completed in the Fortitude Pit in early 1993 (Baker Consultants, Inc. 1997). The Fortitude deposit is a gold-silver skarn deposit in the Antler Sequence that developed north of the 38 to 41 million year old granodiorite intrusion (Theodore et al. 1973). The mine contains upper and lower ore zones that are separated by the north-striking, west-dipping Virgin fault (***Figure 3.1-5***). The upper ore zone is discontinuous because of structural control along faults or at fault intersections and is selective sulfide replacement in calcareous siltstone (Doebrich 1995). The lower ore zone formed as massive sulfide replacement of the limestone and constitutes the bulk of the deposit (Wortruba et al. 1987).

Northeast Extension Pit. The Northeast Extension Pit is located northeast of the East Copper Pit and is similar to the skarn of the East Copper Pit. The orebody of the East Copper Pit is a copper-gold-silver skarn deposit hosted in the Battle Formation (Baker Consultants, Inc. 1997a). The Northeast Extension Pit is mostly sulfide-bearing; minerals include pyrite and pyrrhotite, with minor amounts of chalcopyrite (Exponent 2000a).

Iron Canyon Pit. The lead-zinc-silver deposit associated with the Iron Canyon Pit is a massive sulfide replacement in the chert, shale, limestone, and greenstone of the Scott Canyon Formation. Sulfide minerals include pyrite and pyrrhotite, with minor amounts of chalcopyrite, sphalerite, and galena. Oxidation of the sulfide minerals causes hematite, jarosite, and minor chalcocite to be present (Baker Consultants, Inc. 1997a). The ore deposit occurs in north-south-trending asymmetrical antiform that is cut by sub-parallel, north-striking, high-angle faults that create a breccia zone up to approximately 120 feet wide. Most of the gold mineralization occurs within the breccia zone (Exponent 2000a).

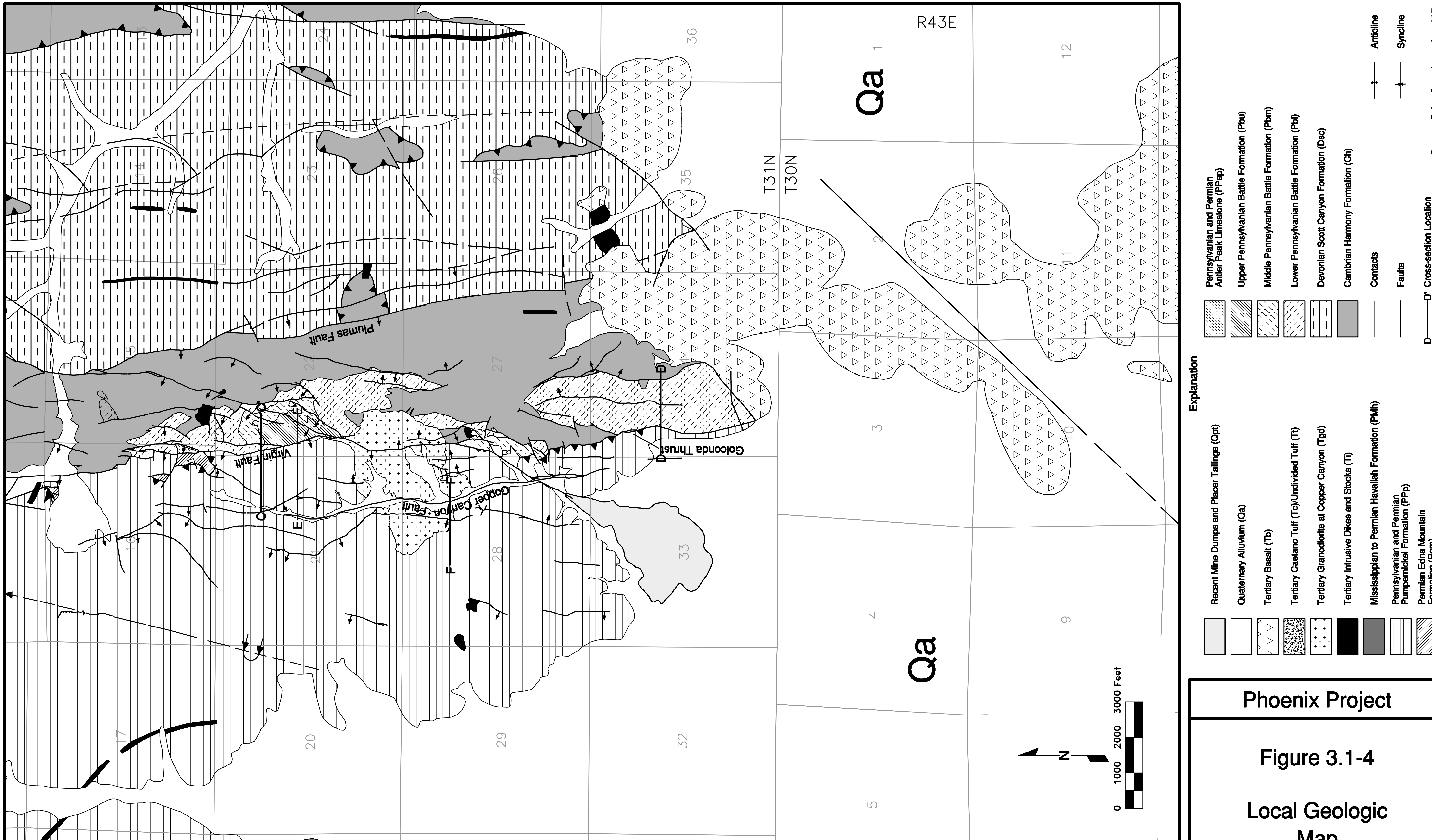
East Copper Pit. As mentioned previously, the East Copper Pit is a copper skarn deposit hosted in the Battle Formation. The bulk of the ore occurs between two north-striking, high-angle faults (Hayden and Monitor faults) that lie east of the Virgin fault. However, some of the deposit occurs outside the faults in the shattered rocks adjacent to the faults (Theodore and Blake 1975; Baker Consultants, Inc. 1997a). Hypogene sulfides include pyrite, chalcopyrite, pyrrhotite, and marcasite, with minor amounts of arsenopyrite, shalerite, molybdenite, galena, and native gold (Theodore and Blake 1975).

Sunshine Pit. The Sunshine Pit deposit is anoxide deposit located in a shear zone between the Havallah sequence and the granodiorite (Doebrich 1995).

Midas Pit. Mineralization occurs in the brecciated zones along the Virgin fault in the Battle Formation with minor mineralization in the Pumpernickel and Harmony formations (***Figure 3.1-6***). Because of the fracturing and brecciation, the sulfide-bearing skarn is oxidized. The minerals in the sulfide oxidation zone include pyrite, pyrrhotite, and chalcopyrite, while chalococite and framboidal pyrite occur in the transitional zone (Exponent 2000a). Minerals in the oxidation zone include malachite, chrysocolla, siderite, limonite, and quartz (Doebrich 1995; Exponent 2000a).

Tomboy and Minnie Pits. Mineralization in the Tomboy and Minnie pits occurs in a gold-silver skarn deposit within the lower Battle Formation. Sulfide content in the ore zones ranges from 10 to greater than 50 percent by volume and is mostly pyrrhotite and pyrite (Theodore et al. 1990).

Canyon Placer. Placer gold deposits were discovered in the Copper Canyon alluvial fan in 1911. Workings occurred in a placer channel, lenticular sheets that were overlain by barren material; farther down the fan, the gold was concentrated in small isolated lens-shaped bodies filling channels. The gold-bearing layer of alluvium contained rocks derived from the Harmony and Battle formations, suggesting that the gold was derived locally (Doebrich 1995; Baker Consultants, Inc. 1997a).



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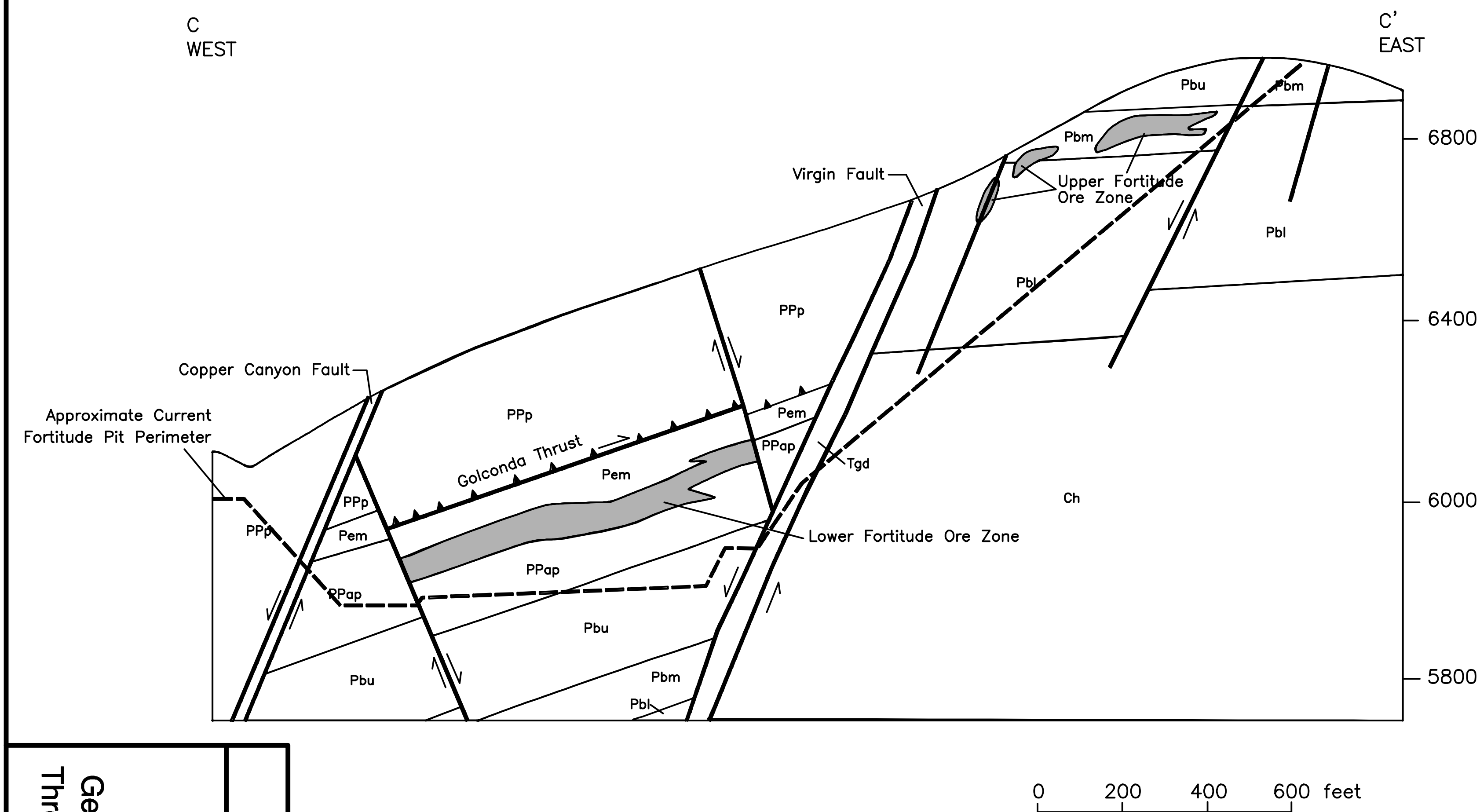
Phoenix Project

Figure 3.1-4

Local Geologic Map



Explanation

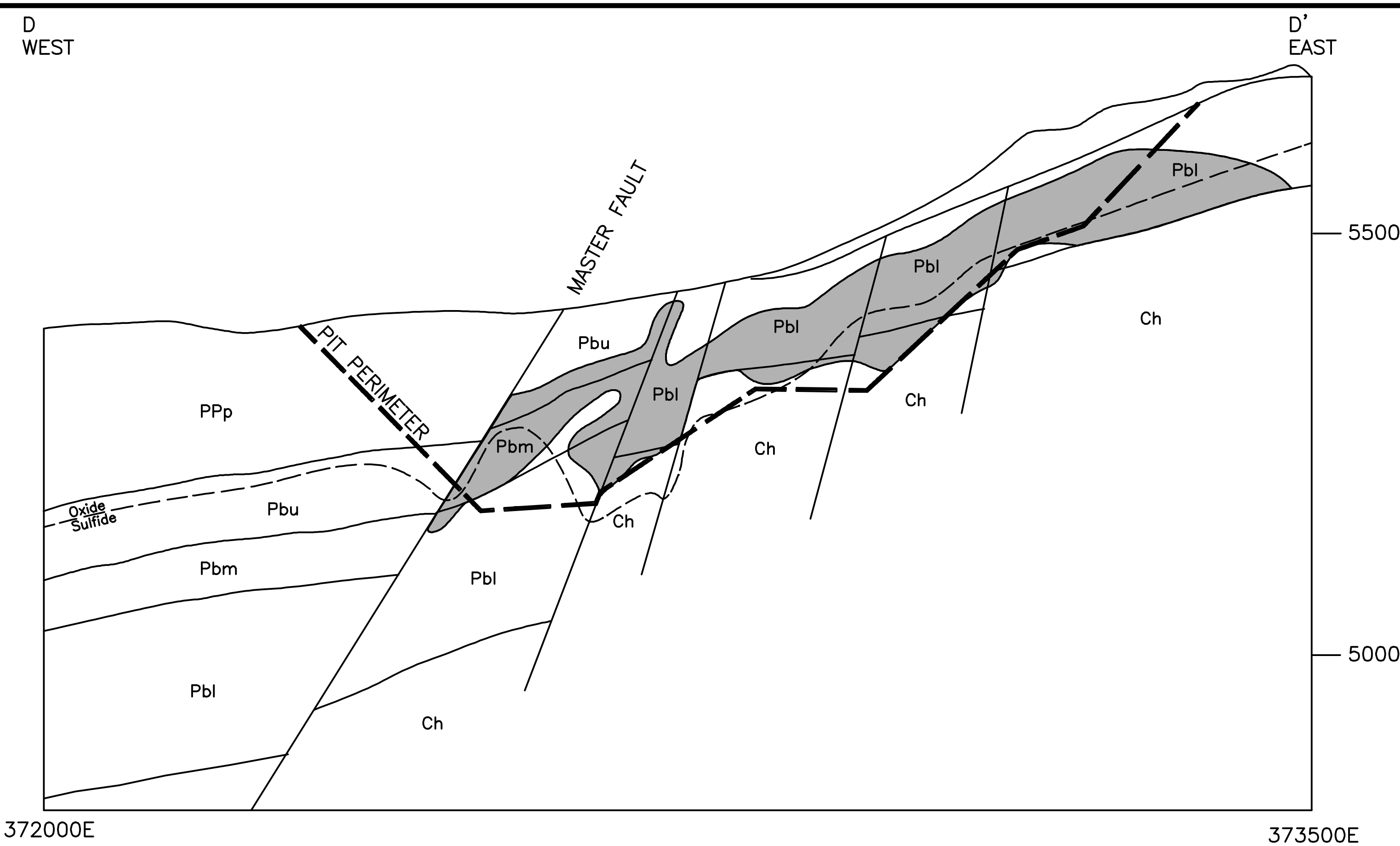
Tgd	Altered Copper Canyon Granodiorite
Pem	Edna Mountain Formation
PPap	Antler Peak Limestone
PPp	Pumpernickel Formation
Pb	Battle Formation (Pbu–upper, Pbm–middle, Pbl–lower)
Ch	Harmony Formation
(symbol)	Ore Zone

Source: Wortruba et al. 1988, Baker Consultants, Inc. 1997a

Phoenix Project

Figure 3.1-5

Geologic Cross-Section Through the Fortitude Pit



Explanation

PPp Pumpernickel Formation
Pbu Upper Battle Formation
Pbu Middle Battle Formation
Pbl Lower Battle Formation
Ch Harmony Formation
Ore Zone

Source: BMG 1994, Baker Consultants, Inc. 1997a

Phoenix Project

Figure 3.1-6

Geologic Cross-Section Through the Midas Pit

Proposed Pits

The Proposed Action would create the Phoenix Pit, which includes the existing Fortitude and Northeast Extension pit areas; Reona Pit; expansion of the Midas Pit, which includes existing Midas and Tomboy pit areas; and deepening of the existing Iron Canyon Pit. The mineralization and geology of the Midas and Iron Canyon pits are described above, while the Phoenix and Reona pit areas are described below.

Phoenix Pit. The Phoenix deposit is a gold-silver skarn in the Antler Sequence and is similar to the Fortitude deposit (Doebrich 1995). A dike similar to the composition of the granodiorite intrusion intruded along the Virgin fault altering the Antler Sequence (***Figure 3.1-7***). Alteration and mineralization is localized to a shear zone along the fault and as high-angle veins. Primary sulfides include pyrite and pyrrhotite, with minor chalcopyrite, marcasite, sphalerite, galena, and arsenopyrite (Baker Consultants, Inc. 1997a). Oxidation of the rock only occurs as a thin veneer at the surface; therefore, the deposit is considered to be mostly sulfide (Exponent 2000a).

Reona Pit. The deposit associated with the proposed Reona Pit is localized in a shear zone along the Copper Canyon fault (***Figure 3.1-8***) (Baker Consultants, Inc. 1997a). The Pumpernickel Formation is in fault contact with and intruded by the Copper Canyon granodiorite. Potassic alteration occurs in the Pumpernickel Formation and the granodiorite, while argillic and chloritic alteration occur in the shear zone (Baker Consultants, Inc. 1997a). Sulfides associated with the mineralization include pyrite, chalcopyrite, galena, arsenopyrite, and a trace of molybdenite. Oxidation ranges from 100 to 400 feet below ground surface, and the oxide mineralization is limited to chalcocite (Baker Consultants, Inc. 1997a; Exponent 2000a).

3.1.1.5 Faulting and Seismicity

Faulting

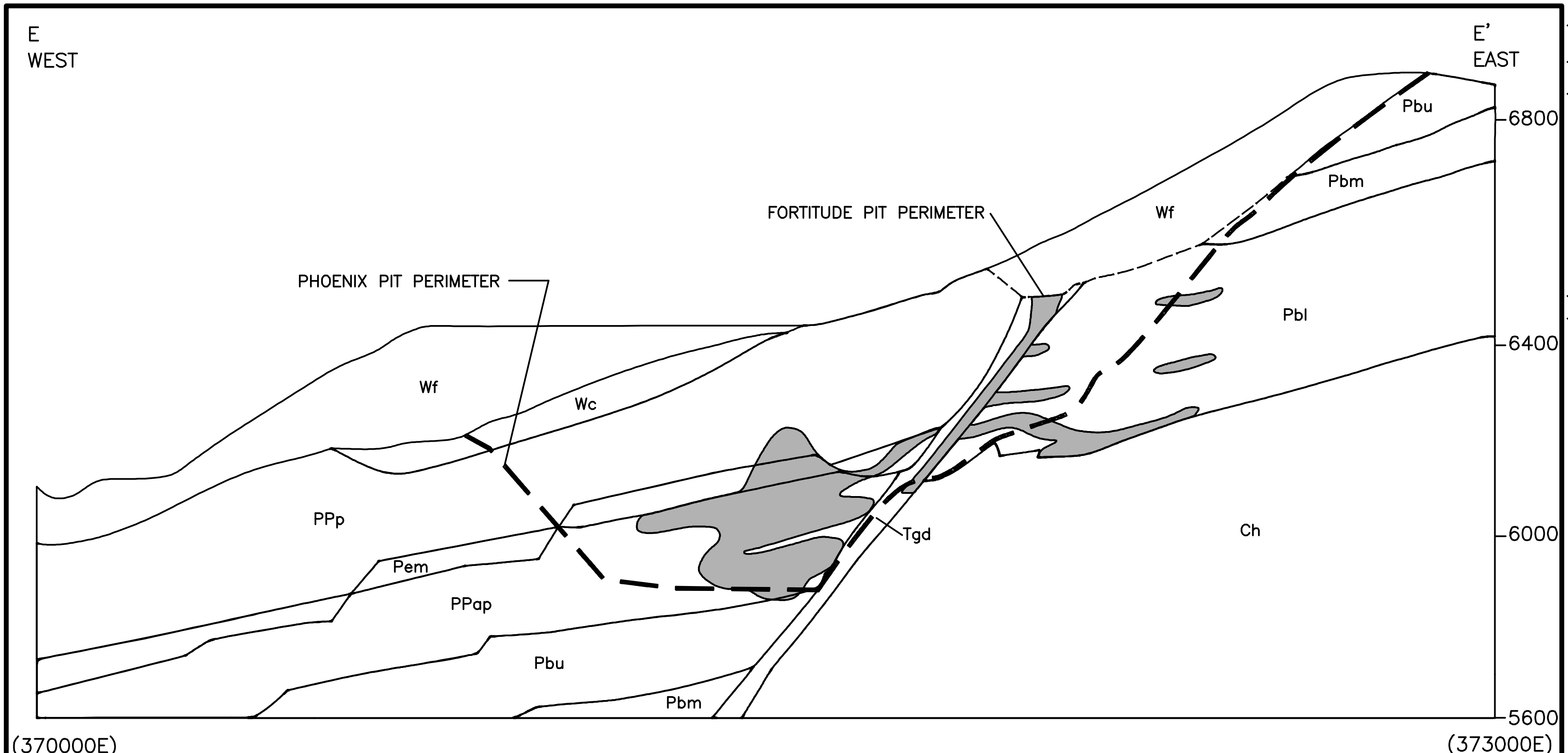
The project site is located in a region that is characterized by active and potentially active faults and a relatively high level of historic seismicity. An active fault is one that shows evidence of displacement during the Holocene period (last 10,000 years), and a potentially active fault is a fault that shows evidence of surface displacement during the late Quaternary period (last 150,000 years). Historically, surface displacement along faults occurred in Nevada during major earthquakes in 1869, 1903, 1915, 1932, and three events in 1954 (Stewart 1980). All of these events occurred along a north-trending zone called the Nevada Seismic Belt located west of the project site (***Figure 3.1-9***). The closest historic surface displacement to the Phoenix Project was in 1915 along the China Mountain Scarp in the Tobin Range approximately 20 miles to the west-northwest of the project site (***Figure 3.1-9***). Surface fault rupture typically occurs along active fault traces. A review of maps of potentially active faults (Dohrenwend and Moring 1991) indicates that there are no known active faults in the immediate vicinity of the project area. The nearest mapped potentially active faults are located approximately 4 miles southwest of the project site. The northern Reese River Valley scarps are located approximately 13 miles east of the project site, while the Buffalo Valley scarps are located approximately 13 miles west of the project site. The Reese River Valley scarps also continue south of the project site (***Figure 3.1-9***).

Seismicity

The project site is located in a region that has experienced considerable seismic activity in historic time. Earthquake records indicate that 202 earthquake events greater than or equal to 4.0 Richter Magnitude have been recorded (U.S. Geological Survey 1997) within a 100-mile radius of the Phoenix Project between 1872 and February 11, 1997. ***Figure 3.1-10*** shows approximate locations and estimated magnitudes of the recorded seismic events relative to the Phoenix Project. It is important to note that all 202 seismic events do not appear on ***Figure 3.1-10*** because several events occurred in the same location, and only the largest event is shown. For example, from August 8 to August 31, 1954, 25 events occurred in the same location; however, only one event appears on the figure. As shown in ***Table 3.1-1***, the largest recorded earthquake to affect the region was a 7.8 Richter Magnitude event located approximately 20 miles west of the Phoenix Project within the Nevada Seismic Belt. The closest recorded earthquake of magnitude 5.0 or greater occurred in 1946, was located approximately 6 miles from the site, and measured 5.1 Richter Magnitude.

Design Earthquakes

Golder Associates (1999a,d) conducted site-specific seismic evaluations in support of stability analyses for the proposed waste rock and tailings



Explanation

Qa	Quaternary Gravel	Pbl	Battle Formation – Lower
Tgd	Tertiary Granodiorite	Ch	Harmony Formation
PPp	Pumpernickel Formation	Wc	Copper Waste Dump
Pem	Edna Mountain Formation	Wf	Fortitude Waste Dump
PPap	Antler Peak Limestone	(shaded)	Ore Zone
Pbu	Battle Formation – Upper		
Pbm	Battle Formation – Middle		

Source: BMG 1994, Baker Consultants, Inc. 1997a

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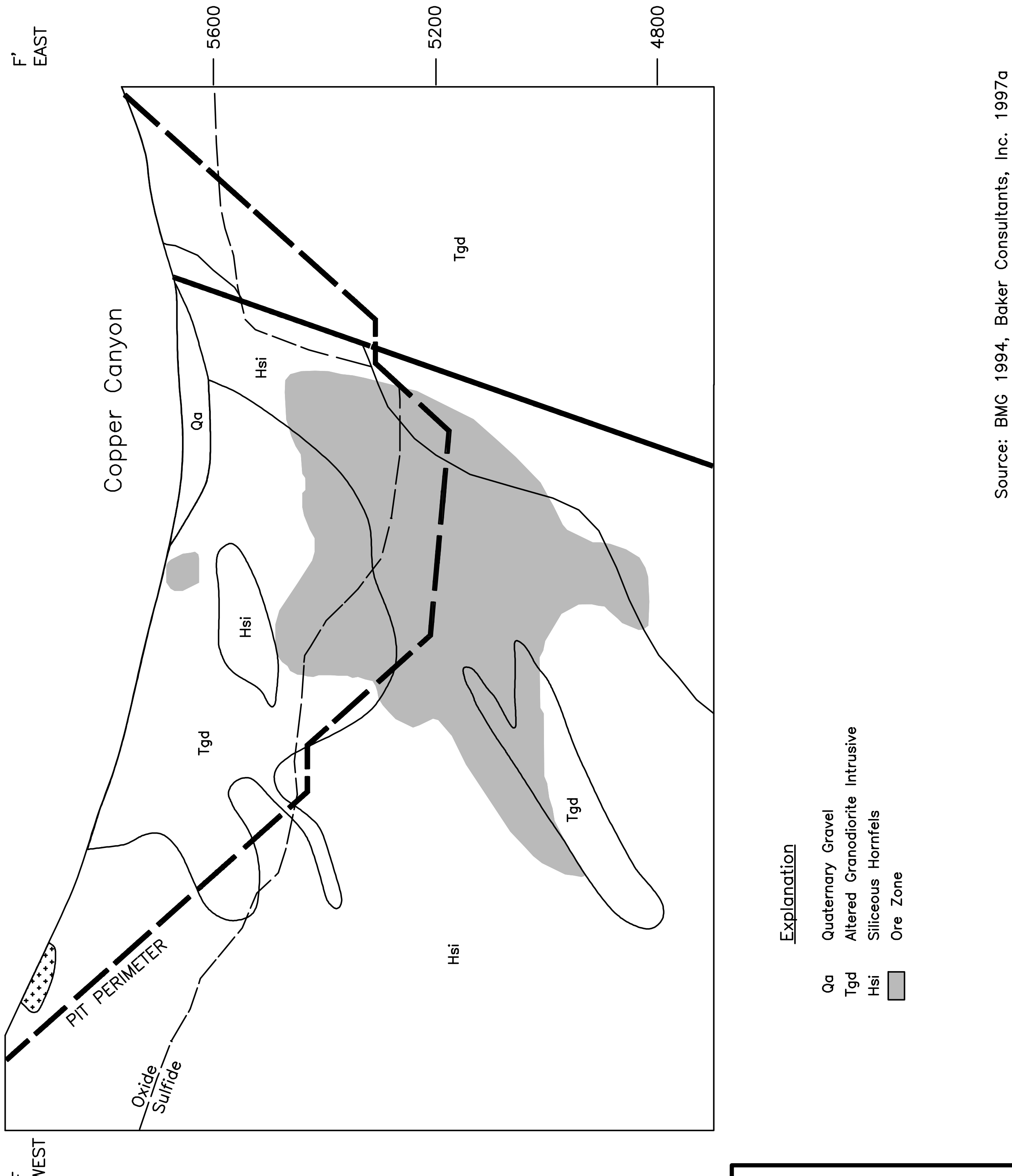
Phoenix Project

Figure 3.1-7

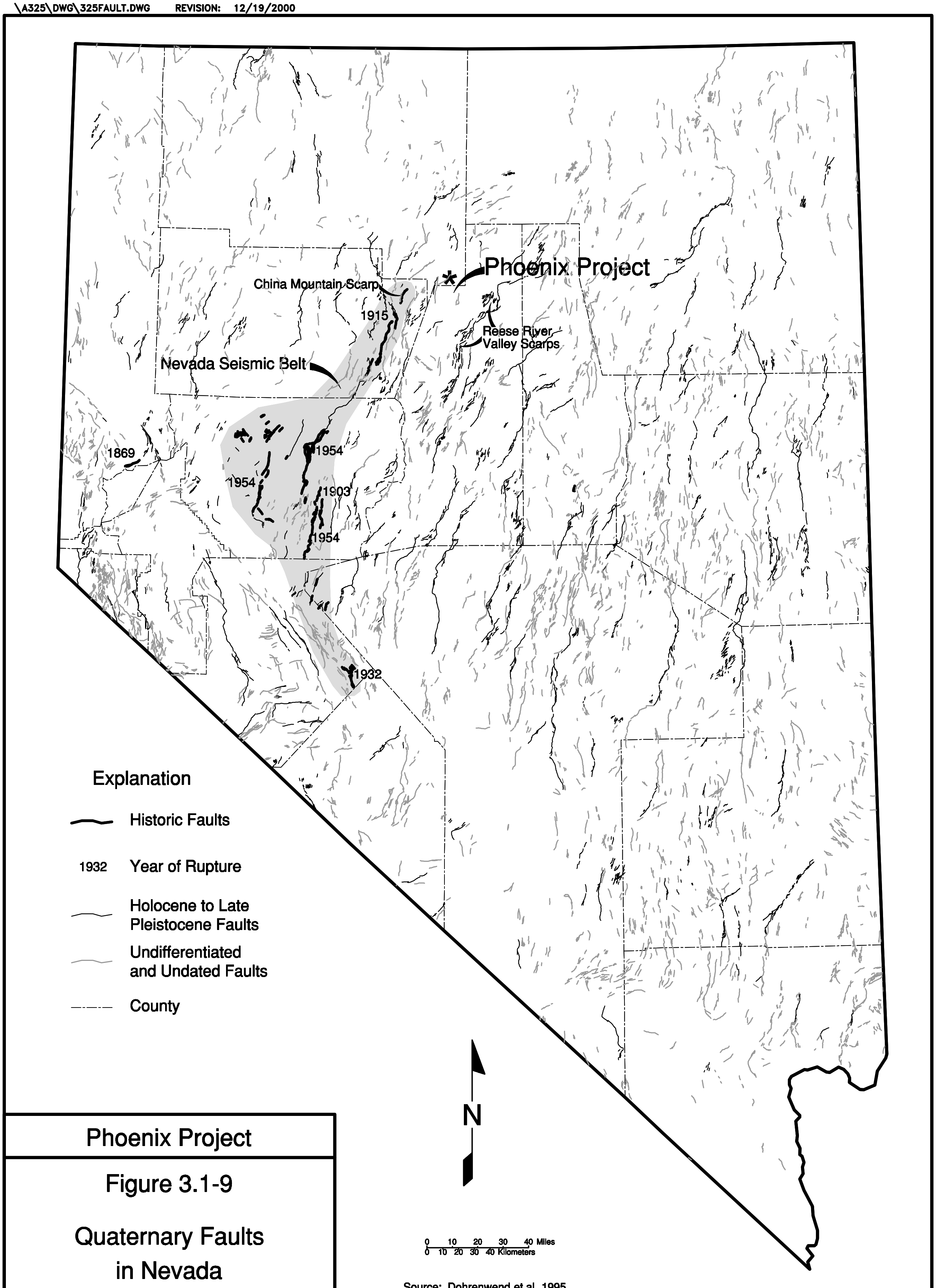
Geologic Cross-Section Through the Phoenix Pit



Phoenix Project

Figure 3.1-8

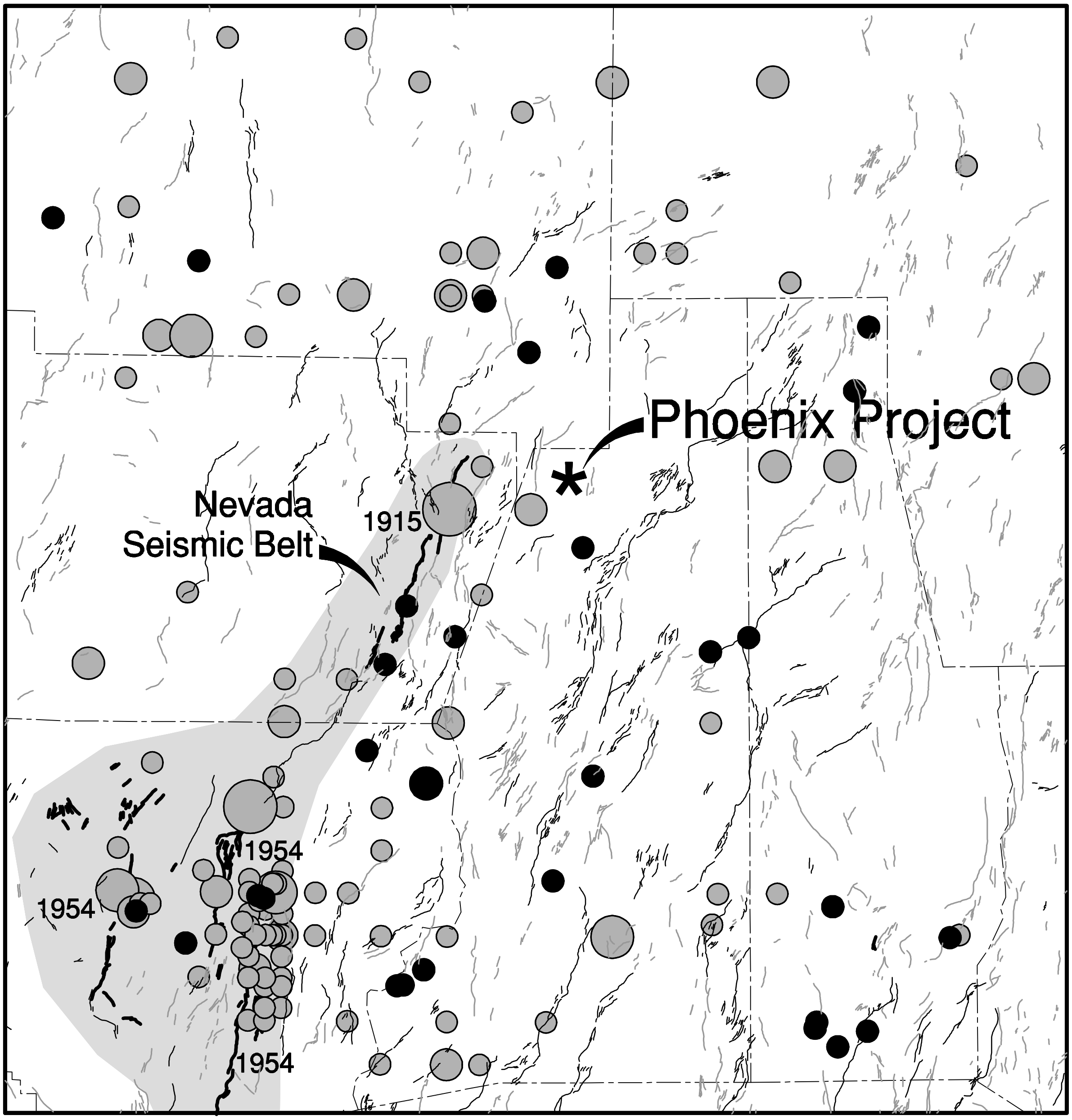
Geologic Cross-Section Through the Reona Pit



Phoenix Project

Figure 3.1-9

Quaternary Faults in Nevada



Explanation

Seismic Event Pre-1970

Seismic Event Post-1969

Historic Faults

Holocene to Late Pleistocene Faults

Undifferentiated and Undated Faults

County

Magnitude

> 7.0

6.0 - 6.9

5.0 - 5.9

4.0 - 4.9

N

0 10 20 30 40 Miles

0 10 20 30 40 Kilometers

Note: Due to improvements in the seismic recording network, earthquake epicenter are more accurately located for events that occurred after 1969.

Source for Fault Traces: Dohrenwend et al. 1995
Source for Seismic Events: USGS 1997

Phoenix Project

Figure 3.1-10

Seismic Events

Table 3.1-1
Recorded Earthquakes with Richter Magnitude of 5.0 or Greater Located Within 60 Radial Miles of the Mine[1]

Year	Month/Day	Location (latitude, longitude)	Approximate Distance from the Site (miles)	Estimated Magnitude	Estimated Peak Bedrock Acceleration[2]
1872	3/23	40.0,-117.5	41	5.5	0.02
1873	11/5	40.0,-118.0	58	5.5	0.01
1915	10/3	40.5,-117.5	19	6.1	0.09
1915	10/3	40.5,-117.5	19	7.8	0.22
1916	2/3	41.0,-117.8	48	5.9	0.03
1916	8/15	41.0,-117.5	38	5.0	0.01
1917	4/11	40.0,-118.0	58	5.1	0.01
1945	9/18	40.6,-116.5	33	5.1	0.02
1946	1/15	40.5,-117.3	6	5.1	0.17
1954	12/20	40.0,-118.0	58	5.0	0.01
1966	10/22	40.6,-116.3	44	5.1	0.01
1968	7/6	41.1,-117.4	42	5.5	0.02
1984	2/16	39.9,-117.6	52	5.2	0.02

[1]Seismic data from U.S. Geological Survey Earthquake Database (U.S. Geological Survey 1997).
[2]Peak bedrock acceleration was estimated based on the plot by Idriss 1985.

Table 3.1-2
Design Earthquake Evaluation Summary

Potential Seismogenic Source	Fault Type	Distance (miles)	MCE[1] Range	Selected MCE	PGA[2] (*g*)[3]
Maximum Background Earthquake	Normal	6	6.5	6.5	0.36
Battle Mountain Fault	Normal	7.5	6.3-7.1	6.6	0.36
Shoshone Range Fault	Normal	11	7.0-7.4	7.2	0.34
Buffalo Mountain Fault	Normal	15	6.5-7.1	6.8	0.20
Buffalo Valley Fault	Normal	15.5	6.9-7.1	7.1	0.23
Whirlwind Valley Fault	Normal	21	6.7-7.1	7.1	0.17
Pumpernickel Valley Fault	Normal	22	7.0-7.1	7.1	0.16
Southern Sheep Creek Range Fault	Normal	22	6.9-7.1	7.1	0.16
Pleasant Valley Fault	Normal	24	7.0-7.6	7.6	0.19

Sources: Golder Associates 1999a,d.
[1]MCE = maximum credible earthquake.
[2]PGA = peak ground acceleration.
[3]*g* = force of gravity.

facilities. A design parameter known as peak ground acceleration was evaluated for two design seismic events:

- Maximum Credible Earthquake: peak ground accelerations at the site resulting from a maximum credible earthquake were used to model the long-term stability of the facilities.

- Operating Basis Earthquake: peak ground accelerations at the site resulting from the operational basis earthquake were used to model the stability of the facilities during the operation and closure period.

Maximum Credible Earthquake (Long-term Seismic Hazard). The process for developing peak ground accelerations for facility designs involves seismic hazard evaluations. Golder Associates (1999d) followed a deterministic approach to assess the long-term seismic hazard. This approach considers the Maximum Credible Earthquake on potential seismogenic sources such as known active faults in the region around the project site. The basic steps in the deterministic seismic hazard assessment were:

1) Identification and characterization of potential seismogenic sources within 25 miles of the site.

2) Development of seismic source parameters for use in calculating peak ground accelerations originating from each source.

3) Calculation of the peak ground accelerations generated from the potential seismogenic sources, and selection of the peak ground accelerations for use in design slope stability analyses.

Nine potential seismogenic sources were identified within 25 miles of the site. These included eight mapped active faults or potentially active faults, and one assumed random or maximum background earthquake. These seismogenic sources and their distance from the site are summarized in ***Table 3.1-2***.

The seismic source parameters (including fault type, distance to site, and estimated Maximum Credible Earthquake) were used to estimate the peak ground accelerations that could potentially be generated from each source. A range of potential Maximum Credible Earthquake magnitudes was calculated for each source based on the geologic and geometric characteristics of the fault, and empirical fault rupture-earthquake magnitude relationships. An estimated Maximum Credible Earthquake for each causative fault was then selected from the calculated range of maximum credible earthquakes based on historic seismicity and the tectonic setting. The range of possible Maximum Credible Earthquakes and the selected Maximum Credible Earthquake for each source are shown in ***Table 3.1-2***.

Once a Maximum Credible Earthquake is established for a particular seismogenic source, the peak ground acceleration is calculated using an equation known as an attenuation relationship that takes into account the fault type, ground conditions, and distance. This site was characterized as "rock," and an attenuation relationship developed by Sadigh (1993) for strike-slip faults was used to estimate the peak ground acceleration. The peak ground acceleration values calculated by the Sadigh (1993) procedure were increased by 20 percent to account for the normal-slip faults that are more typical of the regional setting. The estimated peak ground acceleration for each source is shown in ***Table 3.1-2***. These analyses identified a peak bedrock acceleration of 0.36 the force of gravity (*g*) associated with the Maximum Credible Earthquake.

Operational Basis Earthquake (Short-term Seismic Hazard). Golder Associates (1999d) relied on a previous study by AGRA (1977) to define the Operational Basis Earthquake. The Operational Basis Earthquake was determined using a probabilistic approach, in contrast to the deterministic method used for estimating the Maximum Credible Earthquake. The probabilistic method was developed by the U.S. Geological Survey (Frankel et al. 1996).

The Operational Basis Earthquake was determined to be an earthquake having a magnitude 6.5 located approximately 11 miles from the site. An event of this magnitude is expected to occur on the average of once every 2,600 years or more. The peak ground acceleration associated with this Operational Basis Earthquake is 0.15g.

3.1.2 Environmental Consequences

Issues related to geology and minerals include 1) geologic hazards created or exacerbated by project development; 2) failure of or damage to critical facilities caused by seismically induced ground shaking; and 3) exclusion of future mineral resource availability caused by the placement of facilities (tailings, heap leach, waste rock, or ore stockpile). Potential impacts associated with acid generation from sulfide-bearing rock are addressed separately in Section 3.2, Water Resources and Geochemistry.

Environmental impacts to geology and minerals would be significant if the Proposed Action or No Action alternative result in any of the following:

- Impacts to the facility site or design caused by geologic hazards, including landslides, debris flows, ground subsidence, and active fault rupture
- Structural damage or failure of a facility caused by seismic loading from design earthquakes
- Limited future extraction of other known mineral resources because of facility location
- Alteration of the geologic terrain resulting in a geologic hazard.

3.1.2.1 Proposed Action

Direct impacts of the Proposed Action on geologic and mineral resources would include 1) the generation and permanent disposal of approximately 135 million tons of tailings material, 910 million tons of waste rock, and 50 million tons of spent heap leach material; 2) the permanent alteration of geologic terrain associated with new disturbance of 4,295 acres on both private and public lands; and 3) the recovery of approximately 5.2 million ounces of gold, 27 million ounces of silver, and 360 million pounds of copper.

Geologic Hazards and Geotechnical Considerations

The most important potential geologic hazard in the area is related to the regionally high seismic (earthquake) potential. There are no known active or potentially active faults or landslides in the immediate vicinity of the mine facilities. Therefore, the risk of facility damage from fault rupture or landsliding is not anticipated. Potential earthquake ground motion effects on critical facilities are addressed in the following paragraphs. The risk associated with possible erosion or damage to project facilities during flooding events is addressed in Section 3.2, Water Resources and Geochemistry.

The primary geotechnical issues considered in this evaluation are related to ground movements and the associated damage to primary process and storage facilities during both operation and post-closure periods. Potential ground movements considered include slope instability under static and earthquake loads and settlement of earth fills or foundations. Impacts associated with ground movements are discussed relative to 1) the probability (or likelihood) that movement would occur, and 2) the consequences if movement does occur. Depending on the timing, ground movements caused by mining activities or earthquakes could release chemicals into the environment, injure or cause loss of life to workers, or inhibit the success of reclamation efforts.

Terminology. The stability of an earth slope under static loading (no earthquake), whether it is manmade fill or a natural slope, is expressed as a factor of safety against slumping or sliding. Factors of safety are calculated as part of the engineering design of waste rock fill, tailings dams, pit walls, etc. The calculations are based on the geometry (steepness) of the slope relative to the shear strength and weight of the soil or rock materials in the slope, the level of ground water, and possibly other factors. A computed factor of safety greater than or equal to 1 implies that the slope will be stable and is strong enough to support the assumed static design loads. Engineers design fill or cut slopes to have factors of safety greater than 1 to account for uncertainties about the strength of materials, future ground water levels, or unforseen loading conditions. Typical minimum static factors of safety used to design stable manmade slopes, or to assess the adequacy of stability of an existing slope, range from about 1.2 to 1.5.

Earthquake slope stability evaluations are handled somewhat differently. During an earthquake, most earth slopes respond by progressively deforming in response to each cycle of shaking. The seismic stability is evaluated on the basis of how much cumulative ground deformation might occur as a result of the earthquake. The total amount of slope deformation that may develop depends on the strength and mass of the material, the slope geometry, and the duration and magnitude of the earthquake shaking. Seismic deformation analyses (Makdisi and Seed 1978) were performed as part of the engineering design of the tailings and waste rock facilities under the Proposed Action.

Earth slopes in, or founded on, materials that are subject to liquefaction may experience catastrophic slope failure or flow slides during or shortly following an earthquake, instead of the progressive deformation previously described. Liquefaction is the near complete loss of shear strength within certain soil materials. It is caused by fluid pressure within the soil increasing very quickly in relation to the ability of the soil mass to drain and relieve the pressure. Liquefaction can occur when saturated, loose granular soils are shaken by an earthquake, or when fill is placed too rapidly on liquefiable soils. Loose, saturated silts and sands, like the gold tailings in Tailings Area #3, are the types of soils most prone to liquefaction. Well compacted, dense sandy soils, rocky or gravelly soils, clayey soils, and soils that are not fully saturated generally are not subject to this phenomenon. Soils not subject to liquefaction in the project area include the waste rock facility materials, the heap leach materials, and most of the tailings in Tailings Areas #1 and #2, which are unsaturated.

Tailings and Tailings Embankment Stability. The proposed tailings facilities include Tailings Areas #1 and #2 and, potentially Tailings Area #3 and the South Optional Use Area. These areas are shown in ***Figure 2-4***. Tailings Areas #1 and #2 would form one contiguous impoundment. A geomembrane liner would be incorporated as a hydraulic barrier to cap the existing copper tailings and to provide containment for the underdrain solution that would be generated during the new gold tailings deposition. Tailings Area #3 would be constructed on the existing gold tailings area. The gold tailings consist of fine grained, saturated materials that are likely to settle substantially with placement of additional tailings. Construction over the existing gold tailings (#3) materials would be difficult and relatively expensive to stabilize the underlying tailings mass and ensure long-term performance of the geomembrane liner (Golder Associates 1999d). The South Optional Use Area could be used initially as a borrow source for construction materials for Tailings Areas #1 and #2, and possibly for #3. After borrow is removed, the area could be regraded and compacted and used for construction of a heap leach pad or a lined, above-grade tailings impoundment (Golder Associates 2000a).

Tailings Areas #1 and #2. Golder Associates (1999d) evaluated slope stability for a typical maximum height cross section of the dam for Tailings Areas #1 and #2. The maximum embankment height would be approximately 120 feet. The dam would be constructed of compacted tailings, mine waste and alluvial borrow materials over existing copper tailings and alluvium. Slope stability analyses were completed for both the downstream and upstream slopes of the Tailings Area #1 and #2 dam, under both static and earthquake loading conditions. The minimum static factors of safety that were calculated for the downstream and upstream slopes were 1.84 and 1.90, respectively.

Seismic deformation analyses were completed for short-term (operational basis) and long-term design earthquake events. The Operational Basis Earthquake has a smaller magnitude and shorter return period than the long-term design event, which is a Maximum Credible Earthquake. The Operational Basis Earthquake was based on analyses by AGRA (1997), which predicted a peak ground acceleration of 0.15g (= 15 percent of gravitational acceleration). The Maximum Credible Earthquake was evaluated by Golder Associates (1999d) using a deterministic seismic hazard assessment that considered seismogenic sources within a radius of 25 miles around the site. Seismogenic sources are active, or potentially active, faults and statistically based random (or background) earthquakes not associated with known faults. The maximum peak ground acceleration was estimated as 0.36g. This estimate was based on an Maximum Credible Earthquake of magnitude 6.6 occurring on the Battle Mountain Fault, approximately 12 miles from the site, or a random event of magnitude 6.5 occurring at an epicentral distance of 10 miles. The dynamic displacement analyses indicate that neither the Operational Basis Earthquake nor the Maximum Credible Earthquake design earthquake events would induce deformations during or after construction of the Area #1 and #2 dam (Golder Associates 1999d).

Liquefaction is not anticipated to be an issue for long-term stability of Tailings Areas #1 and #2, because the existing copper tailings materials are fairly well drained and are expected to remain unsaturated. The starter dike and subsequent containment embankments would be constructed of soil materials that are not vulnerable to liquefaction. The copper tailings are expected to remain unsaturated after construction of Tailings Areas #1 and #2 because the geomembrane liner should prevent infiltration into the underlying tailings.

During construction, the existing tailings would consolidate under the weight of the new embankments. This consolidation would cause the copper tailings to become temporarily saturated and thus vulnerable to liquefaction and loss of shear strength. Short-term (construction) liquefaction potential would be monitored using piezometers, and stability would be maintained by controlling the rate of construction of the Tailings Area #1 starter dam and subsequent fill placement. Golder Associates (1996b, 1999d) recommended installation of piezometers within the existing copper tailings prior to commencement of fill placement to monitor construction-induced pore pressures. The recommendation is to install two piezometers at 1,000-foot intervals along the alignment of the starter dam. The purpose of these instruments would be to monitor pore pressures in the tailings under the dam to ensure that excessive construction-induced pore pressures do not develop. Golder Associates (1999d) recommended that construction lift thickness be limited based on results determined by construction of a test fill. The recommended lift thickness and rate of fill placement would be established such that excess pore water pressure would dissipate before placement of the next lift. The use of geogrid reinforcement may be required in isolated locations to maintain stability during construction (Golder Associates 1996c).

Settlement of the foundation under Tailings Areas #1 and #2 was evaluated by Golder Associates (1999d). The purpose of the settlement analysis was to evaluate the potential impacts of maximum and differential settlements on the geosynthetic lining system. The predicted maximum strain (stretching) of the liner under the differential settlements that were predicted was very small (about 1 percent, or 6 inches over a slope length of 60 feet). These calculations were performed in 1996 for an earlier anticipated tailings embankment that was about 100 feet high, or about 20 feet lower than the currently proposed embankment. The analyses were not redone for the revised embankment height because the additional 20 feet of loading is not expected to change the conclusion. Linear, low-density polyethelene liners can accommodate strains up to 90 percent. The low magnitude of anticipated settlement is not expected to impact the integrity of the liner system (Golder Associates 1999d).

Tailings Area #3. Golder Associates (2000a) prepared a conceptual-level design and prepared preliminary recommendations for possible construction of a tailings impoundment on the gold tailings in Tailings Area #3. The conceptual design and recommendations consider the geotechnical challenges of constructing an embankment raise on the fine grained, soft, saturated gold tailings including constructability, settlement, bearing capacity, slope stability, and liquefaction potential of the raised embankment.

Any new embankment fill would be placed on a geomembrane liner over the top of the existing gold tailings in Tailings Area #3. Placement of the liner would require preparation of the gold tailings to limit postconstruction settlement that could tear the membrane. Given the saturated, soft condition of the existing tailings, the importance of controlling and limiting settlement under the liner, and the need to prevent liquefaction, enhancing the drainage capacity of the tailings using an engineered system would be necessary. A conceptual scheme for enhancing drainage of the saturated tailings was proposed by Golder Associates (2000a) that uses vertical band drains installed within the tailings and horizontal drains placed on top of the tailings under the liner. To minimize settlement, Golder also proposed installing horizontal drains through the face of the existing dam and preloading particularly soft slime areas within Area #3 during construction of Area #1. The preloaded areas would be consolidating and gaining strength over time before any additional tailings would be placed in Area #3.

Construction and operation of Tailings Area #3 relies on the gold tailings being drained and maintained in an unsaturated condition using a system such as the one proposed by Golder Associates (2000a) in order to maintain stability and prevent liquefaction of the tailings under earthquake loading. Assuming such a system is implemented, and the gold tailings can be drained and maintained in an unsaturated condition as verified by monitoring of pore pressures within the tailings, the impoundment is expected to be stable under both static and earthquake loading conditions. Golder Associates (2000a) recommended the containment dams be designed to achieve a minimum static factor of safety of 1.4

South Optional Use Area. Stability and liquefaction are not expected to be of concern for a tailings impoundment constructed in the South Optional Use Area (Golder Associates 2000a). The foundation conditions in this area are expected to be similar to the alluvial fan deposits under the existing copper tailings and gold tailings facilities. These materials should provide a stable base for a new tailings impoundment on this site.

Golder Associates (2000a) developed a conceptual design and idealized plan and cross sections for a tailings impoundment or heap leach facility on this site. The area is anticipated to be used initially as a borrow pit. After borrow material is removed for use in Tailings Areas #1 and #2 and/or Area #3, the surface would be regraded and compacted to prepare the foundation for construction of a new facility. Design criteria, including a minimum factor of safety of 1.4 for static stability and small to zero seismic deformation, would apply to the detailed design at this location of either facility type (tailings or heap leach pad).

Waste Rock Facilities. The proposed waste rock facilities are described in Section 2.4.2 and shown in ***Figure 2-4***. The required capacity and proposed final slope for each surface-deposited waste rock facility and pit backfill slope are listed in ***Table 3.1-3***. The critical mode of failure (lowest calculated factor of safety) for all waste rock facility slopes is surficial raveling of the slope face and/or shallow slope failures in the new waste rock material (Golder Associates 1999a). This minimum factor of safety is indicated in ***Table 3.1-3*** for each reclaimed slope, along with the computed factor of safety for deeper mass slope failures (Golder Associates 1999b). The predicted seismic displacements along critical failure surfaces also are summarized. The design criteria adopted for the stability analysis used a minimum factor of safety of 1.4 for both shallow and deep rotational failures, and a maximum displacement of 1 foot during seismic loading. As shown in ***Table 3.1-3***, all factors of safety and calculated maximum seismic displacements meet the design criteria. Therefore, waste rock facility and pit backfill slopes are expected to remain stable with regard to mass slope stability. The likelihood of disruptions to reclamation covers or caps caused by mass slope instability is expected to be low.

Reona Heap Leach Facility. Under the Proposed Action, the Reona Heap Leach Facility would be expanded. Construction would consist of four leach pad cells adjacent to the east side of the existing leach pad. WESTEC (1997) conducted geotechnical site investigations and analyses, and developed the proposed expansion design. The expanded pad would use the same type of composite liner system as the existing facility, comprising an 80 mil high-density polyethylene geomembrane liner over an engineered bedding. The liner bedding would consist of an upper friction layer of coarse material on a compacted silt bed. Friction layers have a high coefficient of friction in contact with the geomembrane. It would be included in the design to maximize the stability of the pad since the most critical failure modes involve slipping on the liner. The grading plan for the extension shows a slightly flatter graded toe than the first three phases of the existing facility, providing a higher factor of safety against instability. Static factors of safety for the facility were calculated to be greater than 1.5.

Slope stability and deformation analyses for the proposed expanded heap leach pad were performed by WESTEC (1997) and Golder Associates (2001a,b). Static factors of safety for the facility were calculated to be greater than 1.4 (Golder Associates 2001a). Pseudo-static analyses performed by WESTEC (1997) for the Operational Basis Earthquake design indicated factors of safety greater than 1.15. This indicates the heap leach facility would likely be stable under an Operational Basis Earthquake design. Pseudo-static analyses were performed to evaluate slope stability under seismic loading during long-term, postclosure conditions (Golder Associates 2001b). The results of the pseudo-static analyses indicate that during a Maximum Credible Earthquake (defined as the largest earthquake that could conceivably impact the site), the slopes could be unstable (factor of safety <1). A deformation analysis was performed to evaluate the amount of displacement that could be anticipated during the Maximum Credible Earthquake. The results of the deformation analysis indicated that sliding displacements of up to 6 inches could occur during the Maximum Credible Earthquake. No significant impacts are anticipated considering the anticipated infrequency of such an event and the minimal predicted displacement. Displacements of up to 6 inches would cause cracking and minor surface disruption, but they are not expected to result in catastrophic slope failure of the reclaimed facility. The heap leach materials are not susceptible to liquefaction because of their gradational characteristics.

Pit Slopes. The existing Minnie and Iron Canyon pits and the proposed Phoenix, Reona, and Midas pits are described in Sections 2.2 and 2.4.1.1 and shown in ***Figures 2-2 and 2-4***. Under the Proposed Action, the pits would be partially or completely backfilled. Stabilization of the pit walls is not an issue for the Reona, Minnie, and Iron Canyon pits, which would be completely backfilled.

Table 3.1-3
Waste Rock Facility Geotechnical Summary

Waste Dump	Critical Slope Angle	Surface Failure Static F.S.	Deep-Seated Failure Static F.S.	Seismic Displacement (ft)
	Design Criteria	> 1.4	> 1.4	< 1
Box Canyon	2H:1V	1.8	1.9	< 0.1
Butte Canyon	2.1H:1V	1.5	1.7	< 0.2
Iron Canyon East	2.5H:1V	1.8	1.9	< 0.1
Iron Canyon North	2.1H:1V	1.5	1.7	< 0.2
Iron Canyon South	2.5H:1V	1.8	1.9	< 0.1
Natomas	2.5H:1V	1.8	1.9	< 0.1
North Fortitude	2.5H:1V	1.8	1.9	< 0.1
Philadelphia Canyon	2.1H:1V	1.5	1.7	< 0.2
Iron Canyon Pit Backfill	2.1H:1V	1.5	1.7	< 0.2
Midas Pit Backfill	2.5H:1V	1.8	1.9	< 0.1
Phoenix Pit Backfill	2.5H:1V	1.8	1.9	< 0.1
Reona Pit Backfill	2.5H:1V	1.8	1.9	< 0.1

Source: Golder Associates 1999a,b.
FS = Factor of Safety.
H = horizontal.
V = vertical.

Operational stability of the Phoenix and Midas highwall pit slopes was evaluated by Seegmiller (1999). Seegmiller concluded from analysis of existing information that discontinuity-controlled failure planes are not expected in the pit walls. The pit slopes should be stable as long as the ground water levels are maintained below the elevation of the pit floor. Where ground water exists in the pit slopes, the stability would be marginal and slope failures would likely occur locally (Seegmiller 1999).

The Phoenix and Midas pits would be partially backfilled to elevations above the projected postmining ground water levels. The remaining exposed pit walls may experience periodic slope instability because of weak geologic materials; adversely oriented geologic structures, such as bedding, faults, and jointing; and the presence of ground water. Stabilization of the pit walls is not proposed as part of closure or reclamation. After some period of weathering, it is likely that portions of the pit walls would eventually experience some degree of slope failure. Typical slope failures that occur in steep rock cuts include rock falls, toppling, and localized block slides.

The North Fortitude Waste Rock Facility is situated fairly near the crown of the Phoenix Pit. The potential impact of this situation was evaluated for both the operational time period and the long term. During operations, the potential influence of the weight of the waste rock fill on the pit slope stability was addressed by Golder Associates (1999b). The waste rock fill is closest to the crown of the pit where the fill was placed as a haul road. This haul road/waste rock fill could experience instability where the west end of the haul road/waste rock fill connects with the haul road into the pit if ravelling of the pit walls occurs near the haul road connection. The maximum height of the haul road/waste rock fill is about 50 feet at this location. Golder Associates (1999b) recommended removing the haul road/waste rock fill at the dump-to-pit transition during reclamation grading so that the toe of the dump at all locations is set back at least 100 feet from the crest of the pit high wall. After regrading to the 100-foot setback at the design 2.5 horizontal:1 vertical side slope, the resulting surcharge loads imposed by the waste rock would have minimal, if any, effect on the stability of the pit slope.

Progressive slope failure through time would tend to expand the perimeter of the pits and reduce the overall angle of pit slopes. After reclamation, the toe of the North Fortitude Waste Rock Facility would be set back at least 100 feet from the crown of the Phoenix Pit, and more than 800 feet in most locations. The Iron Canyon North and Iron Canyon South waste rock facilities would be set back even farther from the pit highwall. The additional surcharge effect caused by the weight of the waste rock fills is not expected to be a significant factor affecting the mass stability of the pit walls. However, long-term progressive raveling of the pit wall has a potential for ultimately undermining the toes of these facilities in some locations.

Mineral Resources

Existing geologic information and condemnation drilling results indicate the placement of the proposed facilities would not conceal known or inferred mineable ore. The mineralization below the facilities is low grade and presently constitutes non-minable ***(including proposed backfilled pits)*** ore (Lane 1999, 2000). The existing information indicates that with respect to public lands, the Proposed Action would not inhibit future attempts to recover minerals.

3.1.2.2 No Action Alternative

Direct impacts of the No Action alternative on geologic and mineral resources would include 1) the generation and permanent disposal of up to approximately 4 million tons of waste rock and 2 million tons of spent heap leach material; 2) the permanent alteration of geologic terrain associated with new disturbance of approximately 45 acres on both private and public lands; and 3) the mining recovery of approximately 40,000 ounces of gold and 270,000 ounces of silver.

Geologic Hazards and Geotechnical Considerations

Tailings and Tailings Embankment Stability. No new tailings facilities would be constructed under the No Action alternative. The existing tailings facilities are shown in ***Figure 2-2***, and include the Gold Tailings Facility, the Canyon Placer Tailings, and the Copper Tailings Facility. The Copper Tailings Facility was originally constructed in 1966; the Gold Tailings Facility was constructed in 1974 and modified in 1985 with an approved embankment raise. At the time of their construction, these facilities were built to the applicable standards and do not include impermeable liners for containment purposes (BLM 1993).

Waste Rock Facilities. The waste rock facilities for the No Action alternative are listed in Section 2.3 and shown in ***Figure 2-2***. The South Canyon, Bonanza, and Sunshine waste rock facilities have an overall slope angle of 2.5 horizontal:1 vertical (BLM 1993). Based on the slope stability analyses that were performed for the proposed waste rock facilities (***Table 3.1-3***), dump slopes at these angles should be stable in terms of mass stability.

Reona Heap Leach Pad/Beneficiation Facility. The existing Reona Heap Leach Pad is shown in ***Figure 2-2***. The environmental consequences for the Reona Heap Leach Pad were addressed in a Bureau of Land Management 1993 Environmental Assessment (BLM 1993).

The No Action alternative would include placement and processing of up to an additional 2 million tons of oxide ore on the existing Reona Heap Leach Pad. Impacts associated with the No Action alternative would be similar to those previously described under Proposed Action.

Pit Slopes. The pits associated with the No Action alternative are listed in Section 2.3 (No Action Alternative) and shown in ***Figure 2-2***. Two of the pits (Fortitude and Midas) may develop lakes. The Minnie Pit and Tomboy Pit could be backfilled or partially backfilled (see Section 2.3.2). Open pits commonly experience periodic slope instability problems because of weak geologic materials; adversely oriented geologic structures, such as bedding, faults, and jointing; and the presence of ground water.

Under the No Action alternative, seven pits would not be backfilled. Stabilization of the pit walls is not proposed as part of closure or reclamation. After some period of weathering, it is likely that portions of the pit walls would eventually experience some degree of slope failure. Typical slope failures that occur in steep rock cuts of this nature include rock falls, toppling, and localized block slides. Progressive slope failure through time would tend to expand the perimeter of the pit and reduce the overall angle of pit slopes. There is the potential for damage to portions of waste rock facilities situated within close proximity to the final pit rim (such as North Fortitude, East Fortitude, South Fortitude, Northeast Extension, Copper Leach and Waste, and Tomboy Minnie Waste Rock Facility). Long-term retrogressive failure of the pit walls during the postclosure period could potentially undermine adjacent waste rock facilities resulting in 1) disturbance to reclaimed waste rock materials, and 2) exposure of acid generating waste rock material (if present). Therefore, the potential for damage to these facilities from long-term retrogressive failure of the pit walls is considered a significant impact.

Stability analyses were conducted on the pits to determine bench and slope angles (Seegmiller 1997a,b,c). These analyses indicated no major stability problems for the Northeast Extension Pit (Seegmiller 1997b); a few bedding instabilities on the east slopes could occur in isolated locations.

No major stability problems are expected for the Iron Canyon Pit; however, a few local bench-scale instabilities on the northwest slopes could occur (Seegmiller 1997c).

Mineral Resources

Existing geologic information and condemnation drilling results indicate the placement of the No Action alternative facilities would not conceal known or inferred mineable ore. The mineralization below the facilities is low grade and presently constitutes non-minable ore (Lane 1999, 2000). The existing information indicates that with respect to public lands, the No Action alternative would not inhibit future attempts to recover minerals.

3.1.3 Cumulative Impacts

Surface mining activity affects geology and mineral resources through excavating, modifying, or covering natural topographic and geomorphic features and by removing mineral deposits. The cumulative effects area for geology and mineral resources includes the area surrounding the Battle Mountain range and extends north to Interstate 80, east to State Highway 305, west to Buffalo Valley Road, and south to Buffalo Valley Road and the area around the clay burrow area. The mines within the cumulative effects area include the Battle Mountain Complex, Marigold Mine, and Trenton Canyon Project. Section 2.6 (Past, Present, and Reasonably Foreseeable Future Actions) identifies the locations (***Figure 2-7***), and permitted acreages for projects described in this section.

Past and present mining disturbance in the area has included exploration (drilling, sampling, and road construction), open-pit and underground mining, waste rock facilities, heap leach facilities, ore stockpiles, ore milling and processing, and tailings disposal. Production in these areas has included gold, silver, copper, gold placer, antimony, lead, and manganese (Stager 1977). There is an estimated 8,800 acres of existing mining-related disturbance in the cumulative effects area. The Proposed Action would add an additional 4,295 acres of mining-related disturbance. This represents an approximate 48 percent increase over the existing conditions. Geologic hazards and geotechnical considerations would be local in nature and specific to individual facilities; therefore, no cumulative impacts are anticipated. There would be an incremental increase in the extraction and recovery of mineral resources from the mines within the cumulative effects area. Because gold mining is a major activity in this area, it is reasonable to assume that large-scale mining would continue to expand the acreage of disturbance in the cumulative effects area.

3.1.4 Monitoring and Mitigation Measures

Potential impacts to geology and minerals would be minimized by the following recommended mitigation measures.

G-1: Facility Stability. Designs for Tailings Area #3 and for facilities that could be constructed in the South Optional Use Area (including a tailings impoundment and/or heap leach facility) were not available for review as part of the EIS. All of these facilities would be designed, constructed, and maintained in a stable manner during both the operations and postmining periods. ***Geotechnical investigations and s***tability analyses would be performed to demonstrate that all of these proposed facilities ***would be properly designed and*** remain functional after an Operational Basis Earthquake and would not fail catastrophically or release fluids or materials during a Maximum Credible Earthquake. The minimum factors of safety and seismic displacements for all facility slope designs would be determined as part of the permits and approvals granted by the Nevada Division of Environmental Protection and the Nevada Department of Water Resources, Dam Safety Division.

G-2: Pit Slope Setback. The potential for damage to existing and proposed waste rock facilities from pit slope failures would be minimized by conducting geotechnical investigations and slope stability analyses to determine an appropriate setback distance for each existing and proposed facility located within 1,000 feet of a final pit rim. In determining the design setback distance for these facilities, potential failures that could occur during both the operational and postclosure periods would be considered. Options to preclude impacts to existing or proposed facilities from future pit slope failures include modifying the final pit rim location or adjusting the facility location to provide an adequate setback distance. If potentially unforeseen adverse geologic conditions are exposed in the pit wall as mining progresses, the final setback distance of any potentially affected facility would be modified as necessary to reduce the potential for damage during the operation and postclosure periods.

3.1.5 Residual Adverse Effects

There would be no residual adverse effects to geology and minerals under either the Proposed Action or No Action alternative with implementation of recommended mitigation measures.