GOLD DEPOSITS AT COPPER CANYON, LANDER COUNTY, NEVADA

David W. Blake, and Edward L. Kretschmer
Duval Corporation, Battle Mountain, Nevada 89820

ABSTRACT

Application of geologic concepts and a concentrated drilling program resulted in the discovery of the Tomboy and Minnie gold orebodies adjacent to Duval's Cu-Ag-Au open pit mine at Copper Canyon. These gold deposits were put into production during the Winter of 1978-79. The two gold deposits are located about 2 km south of the Copper Canyon open pit and represent a unique gold occurrence that has relations similar to the Cu-Ag-Au ore deposits in the district.

Gold occurs in a 30 meter thick, sulfide-bearing basal portion of the lower member of the Middle Pennsylvanian Battle Formation. In both the Minnie and Tomboy gold deposits, the Battle Formation consists of conglomerate and calcareous sandstone and shale that have been thermally metamorphosed to a calc-silicate bearing conglomerate and quartz-tremolite hornfels. Within the basal conglomerate, the matrix has been replaced primarily by pyrite and pyrrhotite, and lesser quantities of sphalerite, galena, marcasite, and chalcopyrite. This high sulfide-bearing, metaconglomerate contains the gold now being mined. The gold ore occurs mainly in closely spaced fractures and as replacement sulfides in the metaconglomerate. A north-south striking silicified granodiorite dike exposed in the Minnie deposit is believed to be genetically related to the deposition of gold-bearing sulfides and the hydrothermal alteration observed in both of these deposits. Recognizable hydrothermal alteration products include silicification, epidote replacing tremolite, chlorite, and clay minerals. Quartz veining rarely is observed in the deposits.

Geochemical study of surface media was undertaken to determine if anomalous gold concentrations in rocks and soils would outline the individual deposits in the Tomboy-Minnie area. Anomalous gold concentrations greater than 1.7 ppm in the first interval of drilling outlines both deposits. Anomalous gold in soil (greater than 1 ppm) corresponds with the known occurrence of gold in outcrops.

INTRODUCTION

The gold deposits at Copper Canyon are located in the south-eastern part of the Battle Mountain mining district about 19 km northeast of Reno. These gold deposits were put into production in late 1978, because of dwindling Cu reserves and a price increase in gold. Duval Corporation, a wholly owned subsidary of Pennzoil Company, also operates a open pit leach copper property at Copper Basin, 10 km north-northeast of Copper Canyon.

Since 1866, when the first claims in the district were located, various mining companies and lessees were active. Most of this activity prior to Duval's operations, was between 1916 and 1955 when the Copper Canyon Mining Company controlled the property at Copper Canyon. Most of the production during this period was from the undergound Copper Canyon Mine. Natomas Company operated a dredge at the mouth of Copper Canyon between 1947-1955 and according to Johnson (1973, p. 37-38) recovered 100,000 ounces of gold.

In the early 1960's, Duval Corporation acquired claims at Copper Basin and Copper Canyon from American Smelting and Refining Company. Exploration work conducted by Duval Corporation from 1962 to 1965 outlined a low grade deposit of Cu-Au-Ag at Copper Canyon and a Cu deposit at Copper Basin. The first concentrate was produced at Duval's mill located at Copper Canyon in 1967.

Total production for the district up to 1961 includes 150,000 ounces of Au, 2.1 million ounces Ag, 15,000 tons Cu, 5,000 tons Pb, and 1,500 tons Zn. Minor amounts of Sb have also been produced. Turquoise has been produced from mines located at Copper Basin. Morrissey (1968, p. 13) indicated that approximately $1 million in rough turquoise was produced from this area up to 1962.

In late 1978, Duval Corporation converted its Cu-Au-Ag mill at Copper Canyon to a cyanide Au operation. This gold operation, now in full production, culminated from a comprehensive geologic study which was combined with a three year drilling program. The application of geologic concepts based on the genetic models of ore deposits in the district was fully utilized in bringing these Au deposits into production.

A detailed evaluation of the gold potential in the Battle Mountain mining district was initiated in 1973. This study coordinated past and present geologic data that had been collected by many individuals. These geologic studies included publications by Theodore and Blake, 1975 and 1978; Blake, Theodore, and Kretschmer, 1978; Roberts, 1964; and Roberts and Arnold, 1965. Various unpublished company reports served as an aid in our evaluation of Au occurrences in inaccessible underground workings. The geologic information available and studies conducted by the authors led to the discovery of gold-bearing units in the Tomboy, Minnie, and Independence mines. Presently ore is being produced from open pits at the Minnie and Tomboy mines.

This report includes background information on the geology, mineralization and alteration of the Copper Canyon Cu-Au-Ag deposits. Geochemical distribution of gold in rocks and soils over and adjacent to the Au deposits is included to demonstrate our exploration usage of this metal to outline these relatively small gold deposits.

GEOLOGY AND MINERALIZATION AT COPPER CANYON

Sedimentary rocks of Paleozoic age are host for the various ore deposits at Copper Canyon. Intruded into these Paleozoic sedimentary rocks

and spatially associated with Cu-Au-Ag deposits is a small pluton of mid-Tertiary altered granodiorite porphyry and dikes of similar composition.

The two deposits that were mined from 1967 to 1978 at Copper Canyon include the east and west orebodies (Figure 1). These two deposits were mined primarily for their Cu content, but they also contain significant Au and Ag as by products.

Economic hypogene sulfide mineralization is confined to favorable former calcareous-bearing sedimentary units of the Middle Pennsylvanian Battle and Pennsylvanian(?)-Permian Pumpernickel formations. Supergene concentrations of Cu also occur in these units but such secondary copper constitutes ore only in the Upper Cambrian Harmony Formation and altered granodiorite where major faults have localized chalcocite.

Mineralization in the east orebody is mostly confined to the lower member of the Battle - a metamorphosed calcareous conglomerate. In the west orebody, mineralization occurs in the lowermost part of the Pumpernickel Formation. This thrust block of Pumpernickel has moved eastward along the Golconda thrust which at Copper Canyon separates tectonically the Pumpernickel from the underlying Battle Formation.

Thermal metamorphism, mineralization, and hydrothermal alteration are genetically and spatially related to the altered granodiorite porphyry (Figure 1). This granodiorite porphyry forms a 250 meter thick laccolith. The sulfides in the two orebodies exhibit zonal relations with the granodiorite porphyry (Figure 1). These sulfide and alteration zones have been described by Blake, Theodore, and Kretschmer (1978). Detailed description of the geology, mineralization and geochemistry of the west and east orebodies can be found in Theodore and Blake (1975, 1978). Pyrite, pyrrhotite, chalcopyrite and lesser quantities of galena, sphalerite, marcasite, molybdenite, arsenopyrite, and covellite are the recognizable sulfide minerals associated with the ore deposits at Copper Canyon. These minerals occur as disseminations, replacements, fracture fillings and in quartz veins and veinlets. The majority of economic sulfide mineralization occurs within a halo of potassic alteration and within an area of greater than 2 volume percent iron sulfide (Figure 1).

Siliceous and calcareous conglomerate in the basal part of the lower member of the Battle in the east orebody hosted a fairly uniform body of Cu-Au-Ag mineralization (Figure 1). This 20-30 meter thick ore zone was the first orebody mined by Duval. Alteration minerals within the ore zone consist of varying quantities of quartz, K-feldspar, biotite, and tremolite, depending on the overall original composition. Depth of oxidation ranges from 0 to 20 meters over an irregular 20 meter-thick chalcocite bearing zone. Malachite, azurite and chrysocolla in the oxidized zone indicate the former presence of copper sulfides. In and near faults in all rock units, oxidation and chalcocite development are extensive.

The west orebody occurs in a garnetiferous and calc-silicate assemblage of rocks directly north of the granodiorite porphyry (Figure 1). The garnet skarn is enveloped by diopside, tremolite-actinolite and biotite. Pyrite and pyrrhotite with lesser concentrations of chalcopyrite are the

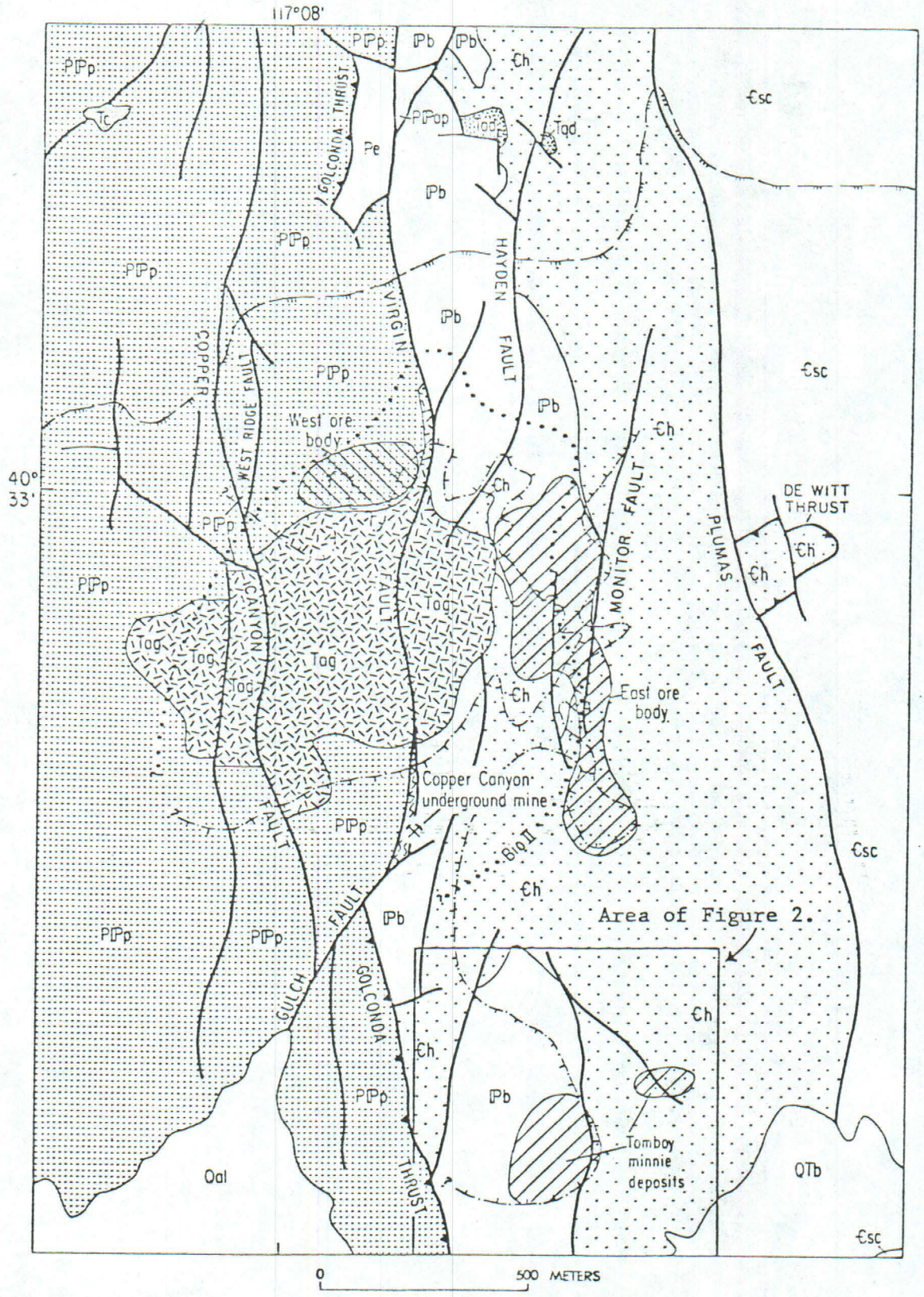
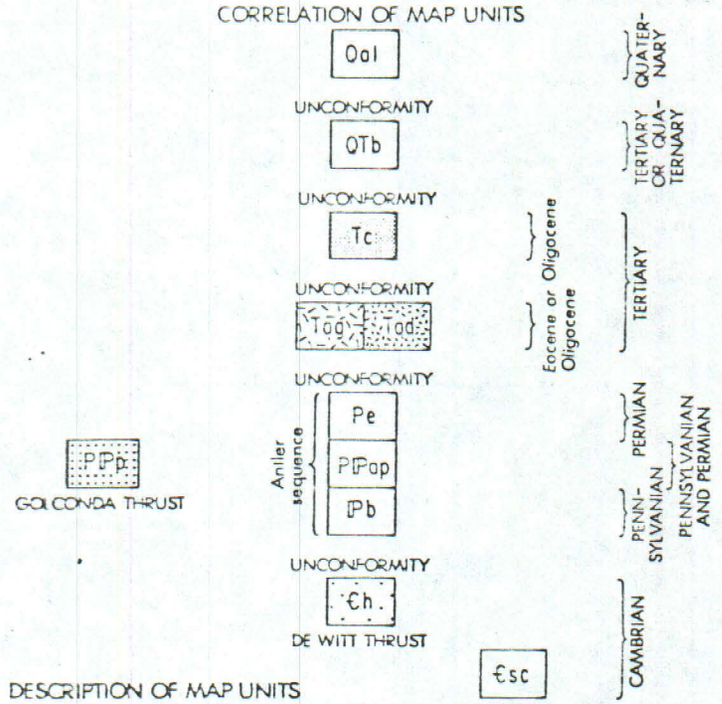


FIGURE 1. Geology of the Copper Canyon area.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Qal — ALLUVIAL DEPOSITS

QTb — BASALT FLOWS

Tc — CAETANO TUFF

Tag — ALTERED GRANODIORITE OF COPPER CANYON

Tqd — QUARTZ DIORITE

Pe — EDNA MOUNTAIN FORMATION

PPap — ANTLER PEAK LIMESTONE

PPp — PUMPERNICKEL FORMATION

PPb — BATTLE FORMATION

Ch — HARMONY FORMATION

Csc — SCOTT CANYON FORMATION

——— Contact

——— Fault

———— Thrust fault. Sawteeth on upper plate

———— Area of more than 1 percent dispersed iron sulfides

• • Bio II • • Area of strongly developed potassic alteration. Chiefly secondary biotite

———— Area of more than 2 percent dispersed iron sulfides

dominant sulfides in this approximately 35 meter thick ore zone. Total sulfide content ranges from 10 to over 75% and decreases northward away from the granodiorite porphyry. Chalcopyrite is best developed near the intrusive contact. In addition, Au and Ag concentrations decrease northward. Oxidation and supergene enrichment are limited to the near surface and along structures respectively.

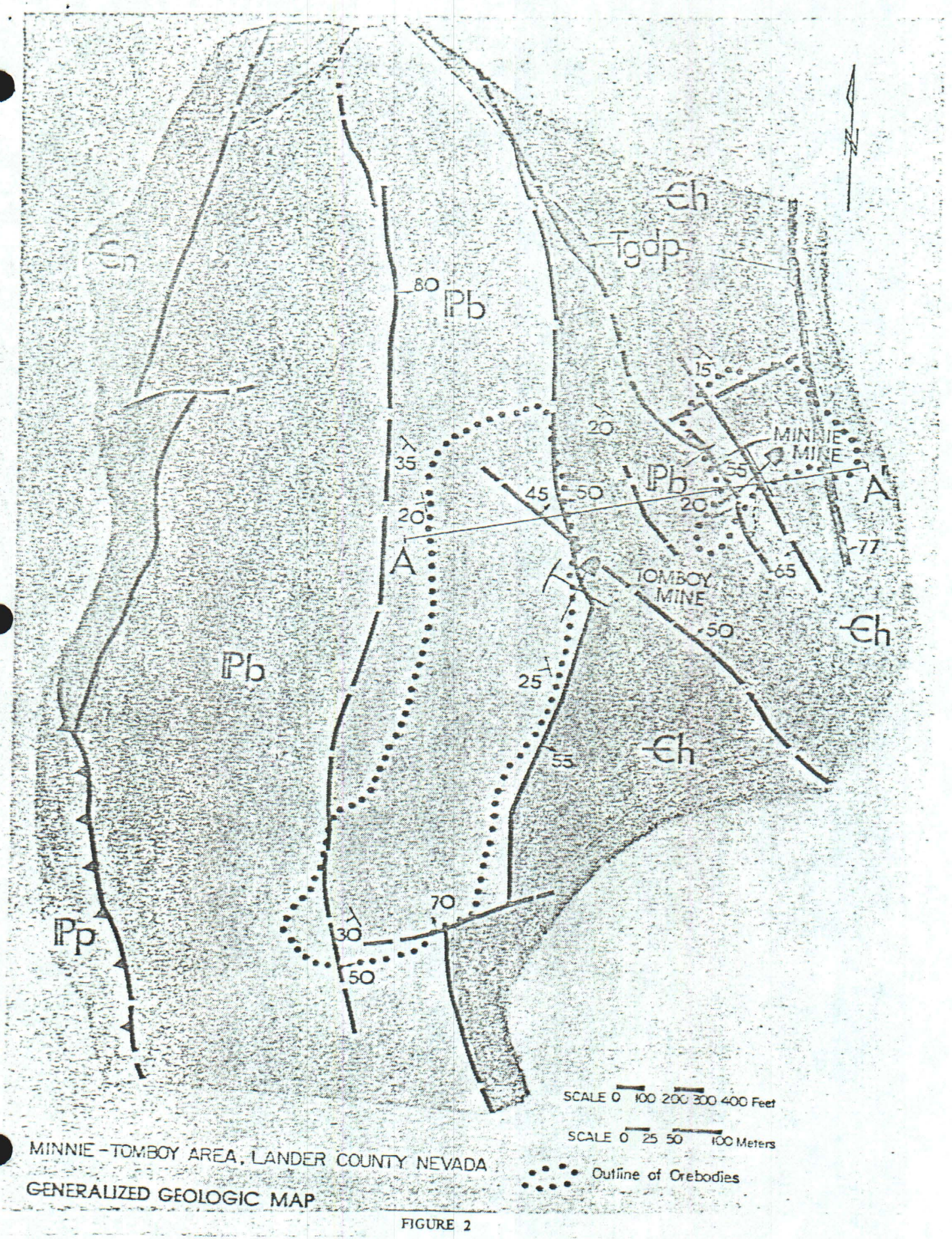
GOLD DEPOSITS

Duval Corporation started producing gold ore from the Tomboy and Minnie open pits in late 1978. Since that time the geologic setting for these two deposits has been studied using standard pit-mapping techniques. Detailed studies pertaining to the genesis of these gold deposits have only recently been undertaken. Therefore, much of the description of these orebodies in this report has been taken from the pit mapping and examination of drill cuttings.

The Minnie and Tomboy gold deposits are located about 1200 meters south of the Copper Canyon Cu-Au-Ag deposits (Figure 1). Mineralization in the gold deposits occurs in a 30 meter thick basal part of the lower member of the Battle that overlies weakly metamorphosed sandstone and shale of the Harmony (Figure 2). Along the southwestern part of the area (Figure 2), chert and siltstone of the Pumpernickel overlies the Battle above the Golconda thrust. Along the eastern limits of the Minnie ore body, a north-trending granodiorite porphyry dike crops out. A similar igneous dike that is extensively argillized crops out north of the Tomboy pit.

Structural relations between the deposits is shown in Figure 3. The Minnie deposit has been down-dropped along a northwest striking normal fault with an approximate dip slip offset of 200 meters. A northwest striking reverse fault has offset these older normal faults and displaced gold-bearing conglomerate, much of which now has been eroded. The eroded portion of the auriferous metaconglomerate was probably the source of most placer gold discovered in Box Canyon. A series of northwest mineralized fractures dipping moderately to the northeast have served as channel-ways for the fluids associated with gold deposition in the conglomerate of the Tomboy deposit.

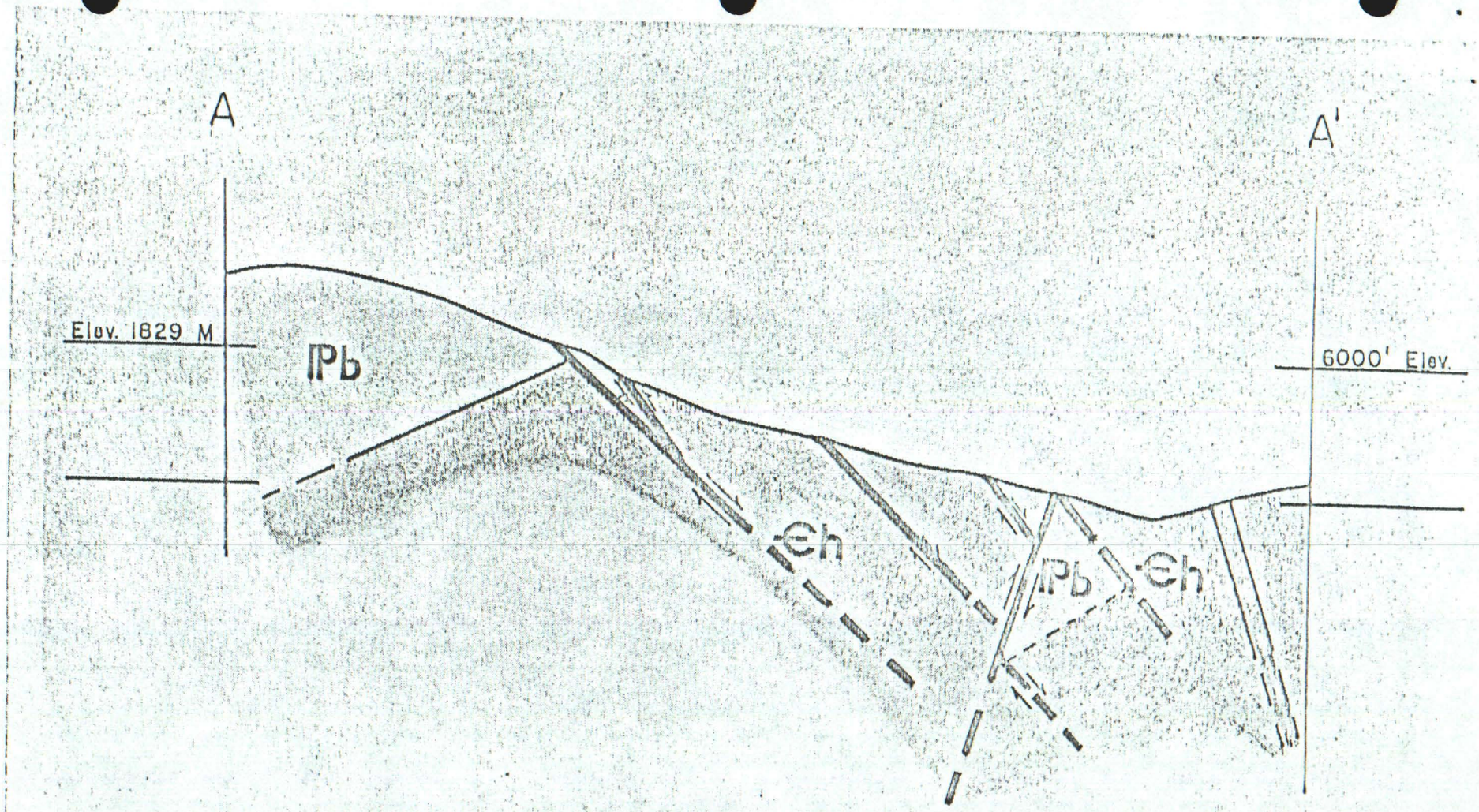
Gold is uniformly restricted to the basal part of the Battle in both deposits. Economic concentrations of gold are not found in the Harmony below the unconformity. In the Tomboy mine, the conglomerate attains a total thickness of 100 meters and dips westward approximately 30 degrees. Within the two gold deposits, the conglomerate consists of subangular to subrounded clasts up to one-half meter across. Clasts are chert, quartzite and rare limestone. Matrix for these clasts consists of metamorphosed medium-grained tremolite-bearing sandstone. Locally graded bedding is apparent and throughout the Battle lenses of former calcareous shale and limy units have been converted to tremolite. A few limestone clasts have been metamorphosed to garnet, quartz, diopside and tremolite.



MINNIE-TOMBOY AREA, LANDER COUNTY NEVADA

GENERALIZED GEOLOGIC MAP

FIGURE 2



CROSS-SECTION THROUGH MINNIE-TOMBOY MINES LANDER COUNTY, NEVADA

0 100 200 300 400 Feet

0 25 50 100 Meters

URE 3

Sulfide minerals recognized in the gold deposits are pyrite, pyrrhotite, and lesser quantities of sphalerite, galena, marcasite, and chalcopyrite. The majority of these sulfides occur as disseminations and replacements of the tremolite-bearing matrix. Zoning of sulfide minerals is present in the deposits. Above the Au zone, pyrite and rare pyrrhotite are the only sulfides having a total combined sulfide content of 10 to >50 volume percent. Pyrrhotite is more abundant than pyrite.

The deposition of Au in these deposits is related to the introduction of pyrite and pyrrhotite and possibly to subsequent alteration of pyrrhotite to marcasite. Gold occurs as free minute grains, commonly less than .05 mm. Disseminated and replacement sulfides carry the gold as well as fracture-filling sulfides in the conglomerate. Silver mineralization is low throughout the two deposits, but high Ag assays correspond with high Pb concentrations.

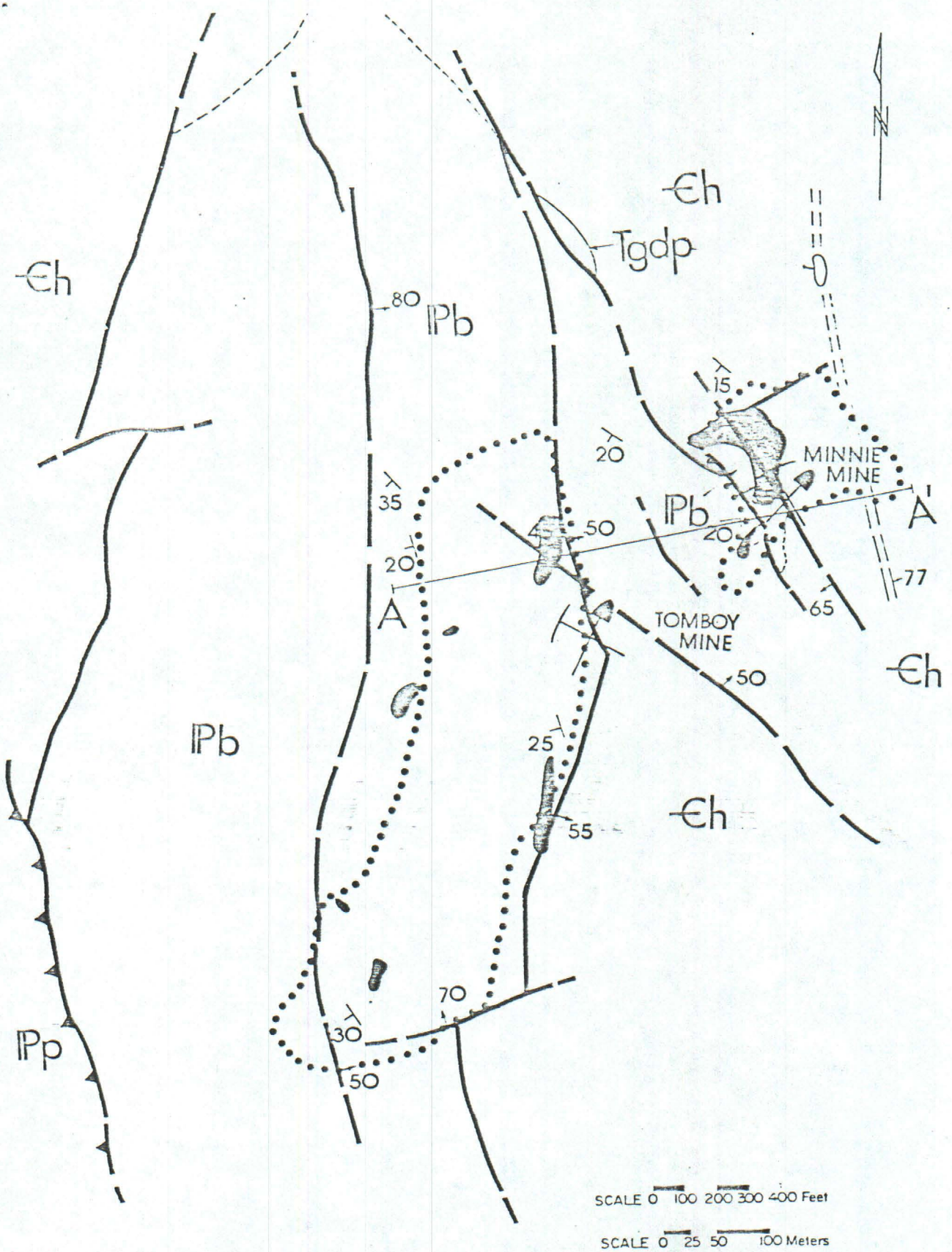
Thermal metamorphism of the conglomerate has produced tremolite-bearing siliceous conglomerate. Hydrothermal alteration associated with gold deposition is reflected in the replacement of tremolite and other metamorphic products by epidote, chlorite and clay minerals. Epidote also occurs in fractures. Most of the clay is restricted to faults and as thin selvages along mineralized fractures. Aside from the silicification of the conglomerate and underlying clastic units of the Harmony Formation, quartz as a gangue mineral is rarely observed in veins or veinlets containing sulfides. The north-trending granodiorite dike is weakly silicified and contains minor alteration products typical of the propylitic assemblages.

GEOCHEMICAL STUDIES

Geochemical sampling was carried out after most of the drilling had terminated and during the initial pre-stripping stage. Therefore, we attempted to utilize what data was available and supplement it with randomly selected soil samples to correlate with the results of assays of rocks from the drilling. Figure 4 illustrates the Au assays from the first interval of bedrock drilled by rotary drill (RDH). Figure 5 shows the results of our soil sampling. We selected the B horizon here because geochemical results for gold were most reliable. All soil material analyzed was the minus 80 mesh fraction. On both of these figures, the dotted line outlines the surface projection of the two gold deposits.

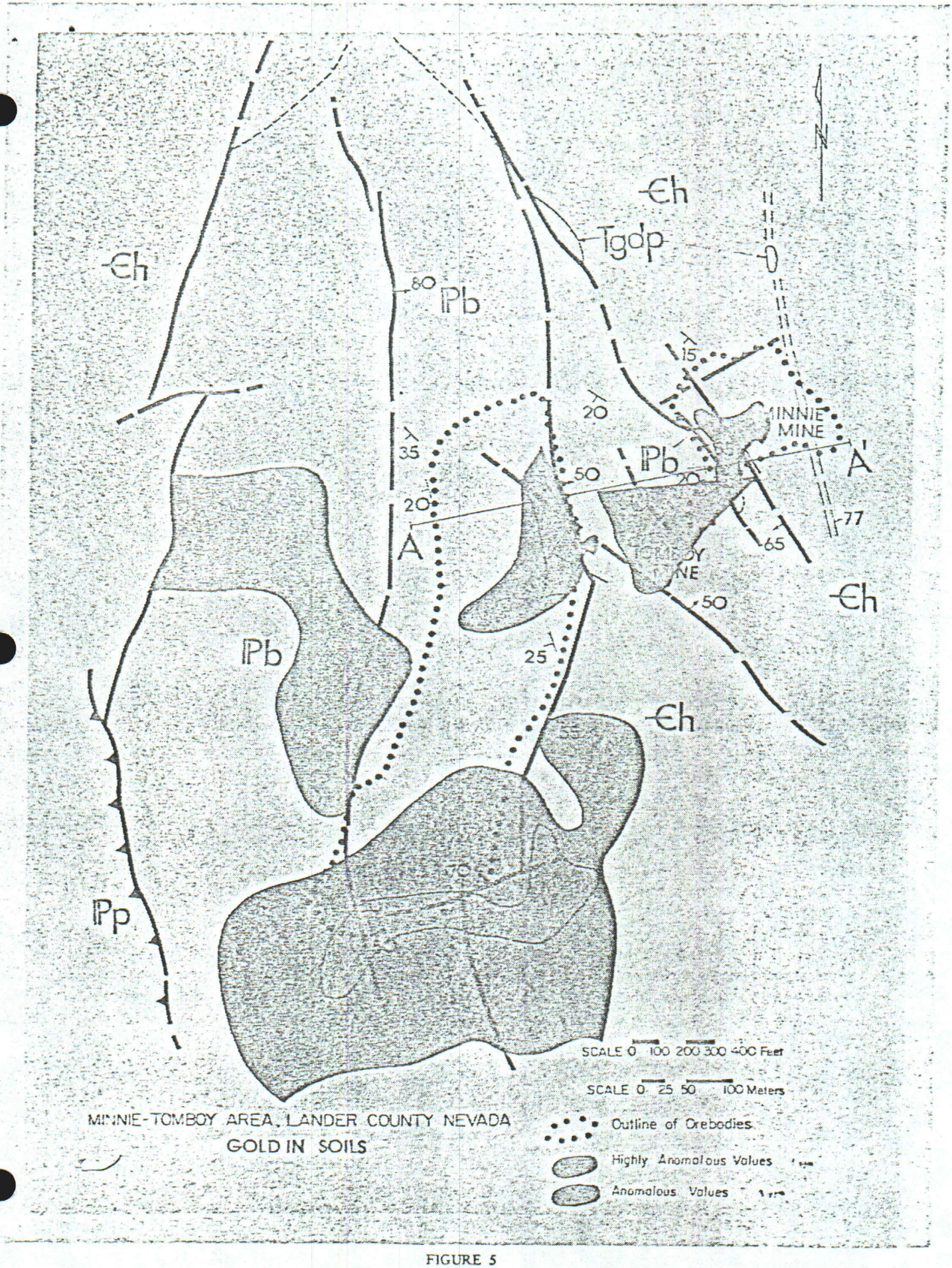
Gold concentrations greater than .050 oz/ton (1.7 ppm) clearly delineate the two deposits based on rock material assayed from the first interval of drilling (Figure 4). The broken north-south elongate pattern of the gold distribution in the Tomboy ore body reflects primarily the exposed basal Au-bearing member of the Battle that dips westward here about 30 degrees. In the Minnie deposit, anomalous gold was found in rock samples directly over the ore deposit.

Figure 5 shows the results of our soil geochemistry for gold, contoured using two sets of Au concentrations. Those samples considered highly anomalous, or greater than 1 ppm, overlie the original discovery for both the Minnie and Tomboy mines. The highly anomalous area along the



MINNIE-TOMBOY AREA, LANDER COUNTY NEVADA
GOLD ASSAYS REPRESENTING FIRST INTERVAL OF RDH'S

FIGURE 4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SCALE 0 100 200 300 400 Feet
SCALE 0 25 50 100 Meters
MINNIE-TOMBOY AREA, LANDER COUNTY NEVADA
GOLD IN SOILS
Outline of Orebodies
Highly Anomalous Values
Anomalous Values

FIGURE 5

southern edge of the Tomboy deposits reflects some structural control in the Au deposition of Au. The area of .3 ppm Au in soils is significantly more extensive than the zone of 1 ppm Au. The 0.3 ppm Au in soils encloses most of the high concentrations of Au. Further, the zone of 0.3 ppm Au in soils west of the Tomboy probably indicates downslope transport of gold by weathering from the main geologic occurrence at the Tomboy.

Based on our limited geochemical work at these two gold deposits, geochemical sampling using soils and bedrock material would have detected and outlined the ore zones. The most important geologic exploration guide is that the economic concentrations of Au are restricted to a favorable stratigraphic unit within a well-defined Au-Ag zone established on a district-wide scale. Thus, evaluation of a previously known Au occurrence in this district by sound geologic concepts of ore genesis in conjunction with limited geochemical sampling successfully outlined the deposits.

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