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GEOLOGY OF NEWMONT GOLD COMPANY'S GOLD QUARRY DEPOSIT, EUREKA COUNTY, NEVADA

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ABSTRACT

The Gold Quarry deposit is the latest bulk-tonnage epithermal gold deposit in northeastern Nevada to be developed by Newmont Gold Company. Gold Quarry is the largest gold deposit of the "Carlin Trend".

The magnitude of Gold Quarry was discovered in 1979 when percussion drilling eventually delineated a deposit containing 130 Mt of ore that averaged 1.68 grams of gold per ton. Mill operations commenced in 1985 and 6.5t of gold are scheduled for production in 1986.

The spacial distribution of jasperoids, the wallrock alteration suite, and associated geochemistry all suggest a fossil hot-springs genetic model for Gold Quarry.

HISTORY

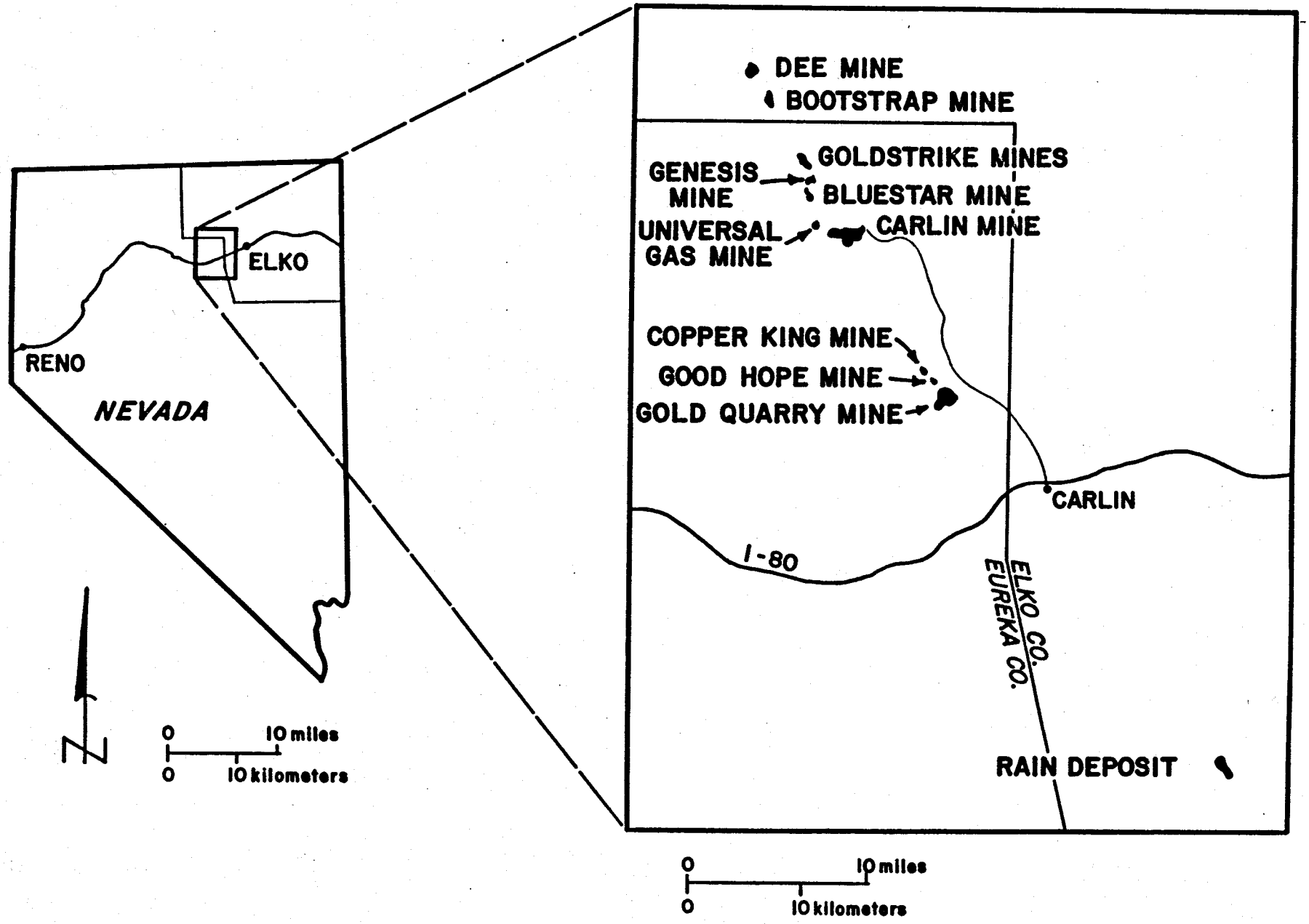
District.

The Gold Quarry deposit occupies the southern half of Section 35 (Township 34 North, Range 51 East) in the Tuscarora Mountains of northeastern Nevada. It is the largest gold deposit in the Maggie Creek (Shroeder Mountain) mining district, located 11 km northwest of the town of Carlin (Fig. 1).

The first prospecting in the district occurred soon after the transcontinental railroad was completed through Carlin in 1869. The first organized mining occurred at the Good Hope mine, located one kilometer northwest of Gold Quarry. A 75m deep inclined shaft was driven across the Good Hope fault to develop a one meter wide vein of galena, silver, copper carbonates and barite. No significant gold production was reported from this mine.

The Copper King base metal property is located two kilometers northwest of Gold Quarry, along strike of the Good Hope fault. Lode claims were first staked in 1908, with mining occurring a few years later. Ore minerals produced from the small surface and underground workings consisted of chrysocolla, azurite, malachite, and turquoise. Minor amounts of gold and silver were also mined. This mine was listed in 1974 as the only North American occurrence of the mineral Faustite, a hydrous zinc-copper aluminum phosphate (Roberts et al., 1974).

FIGURE 1. General Location Map of the Gold Quarry Mine and Other Gold Mines of the Carlin Trend, Nevada.


ELKO
RENO
NEVADA
N
0
10 miles
0
10 kilometers
DEE MINE
BOOTSTRAP MINE
GENESIS MINE
GOLDSTRIKE MINES
BLUESTAR MINE
UNIVERSAL GAS MINE
CARLIN MINE
COPPER KING MINE
GOOD HOPE MINE
GOLD QUARRY MINE
CARLIN
I-80
ELKO CO.
EUREKA CO.
RAIN DEPOSIT
0
10 miles
0
10 kilometers

The first recorded production at Gold Quarry was from quartz veins located in a highly silicified area of the deposit. In 1936, 54t of material that averaged 13 grams of gold and 27 grams of silver per ton were shipped to the railhead at Carlin. The ore was reported to be composed of iron-stained quartzite and chert (Roberts et al., 1967).

Total production for the Maggie Creek mining district from 1932 to 1958 was 26 kg gold, 136 kg silver, 297,581 kg copper and 12,520 kg lead.

Recent Development.

In 1960, the search for a large, near-surface gold orebody in Nevada was sparked by a paper written by Ralph Roberts entitled "Alinement of mining districts in north-central Nevada" (Ramsey, 1973). Geologist J. Alan Coope was brought in by Robert Fulton (Newmont Mining Corporation) to assist John Livermore in the evaluation of the Gold Acres, Gold Quarry and Lynn Window (Carlin Mine) areas. Exploration drilling centered around the Gold Quarry jasperoid had, by 1970, delineated a deposit of 306 Kt that averaged 4.1 g/t gold.

In 1962, Newmont discovered the Carlin deposit 10km to the northwest. Interest in Gold Quarry declined until 1972 when Donald M. Hausen (Newmont Exploration Ltd.) recommended renewed exploration due to significant alteration features in drill cuttings. In 1977, Carlin Gold Mining Company (now known as Newmont Gold Company) geologists Larry Noble and Charles Ekburg mapped and sampled a group of claims staked by Mike Barstow. These claims were located less than one kilometer southwest of Gold Quarry, and were to become a part of the Maggie Creek disseminated gold deposit.

The discovery of Maggie Creek prompted additional drilling and investigation of the Gold Quarry area. Activities were accelerated in 1979 when gold assays of over four grams per ton were reported in samples from a drill hole located 600m south of the Gold Quarry fault jasperoid. This drilling had encountered a blind ore zone beneath 75m of Pliocene lacustrine sediments. To define the ore, over 550 fifteen-centimeter conventional circulation holes were drilled from the surface to an average depth of 185 meters. All percussion drilling was vertical and was conducted on a 30m square grid. Both downhole hammers and tri-cone bits were used throughout the program.

HQ wire-line core drilling was used to collect rock from the central, oxidized portions of the orebody for geological and metallurgical testing. Three inclined and one vertical hole were drilled to average depths of 235 and 105 meters, respectively. Seven vertical PQ-size holes that averaged 177 m in depth were used to collect additional metallurgical test material.

Drilling eventually defined a deposit that contained geologic reserves of over 248t of gold. Proven and probable reserves, mineable by open pit, are estimated at 130 Mt of ore that averages 1.68 grams of gold per ton. This includes high-

grade ore zones of 45 Mt, averaging 2.64 grams of gold per ton, which currently feed the Carlin #2 mill at an average rate of 7000 tpd. About 10% of the mill grade ore is carbonaceous in nature. The remaining 85 Mt reserves, averaging 1.2 grams of gold per ton, are to be treated by dump leach methods. Total 1986 production from the #2 mill is estimated at 6.5t of gold.

In 1982, a central area of the near surface portion of the orebody was opened and more than 900 Kt of material removed for heap leach and milling tests. The Carlin #2 mill was built two kilometers east of Gold Quarry by the Bechtel Corporation in 1984 at a cost of U.S.$130 million.

REGIONAL AND DISTRICT STRUCTURE

Regional.

The complex structural history of Nevada is described in great detail by Stewart (1980). Briefly, the Roberts Mountains Thrust is a product of the Antler orogenic event of the Late Devonian (to possibly earliest Triassic - Ketner, 1982). A subduction-related highland formed immediately west of the North American craton and a thick sequence of deep-water siliceous and volcanic rocks was transported at least 145 km eastward along the Roberts Mountains Thrust Fault over coeval shallow-water miogeoclinal rocks. The upper plate of the Roberts Mountains Thrust is composed of interleaved, broad, thin, thrust plates commonly subparallel to bedding. Differential movement of these plates has caused a juxtapositioning of western siliceous and transitional (mixed carbonate and siliceous) assemblages. The transitional siltstone and silty limestone of the Roberts Mountains allochthon are separated from the western siliceous rocks both stratigraphically and by small thrust and high-angle normal faults. Most of the upper plate lithologies are folded along a northwest axis.

As tectonic regimes changed through the Paleozoic and Mesozoic, major fault trends shifted from west to north, then to northwest. Doming of both allochthonous and autochthonous rocks along a northwest trend began during or shortly after thrusting. Cretaceous and Tertiary intrusive events combined with subsequent erosion to produce a N45W trend of fensters, or windows.

Cenozoic extensional faulting in the area commenced about 17 million years ago. Displacement along these north to northeast striking high-angle faults has formed the mountains and valleys that dominate the present topography of the Basin and Range province.

District.

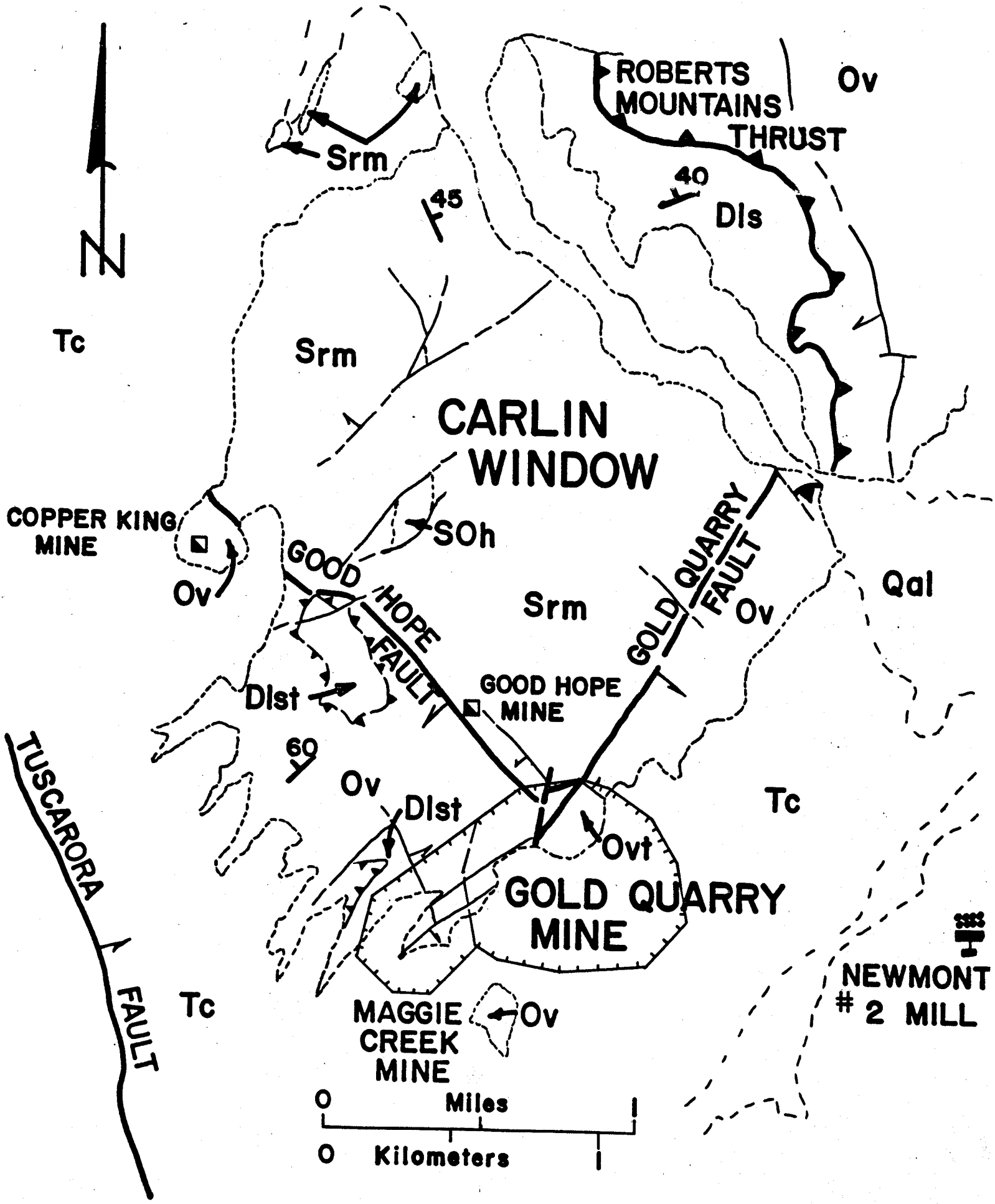
The Carlin Window is the principal geologic feature of the Gold Quarry area. It is roughly circular in outline and is about three kilometers in diameter (Fig. 2). The window exposes thin-bedded silty limestone of the Roberts Mountains Formation and an overlying, relatively massive unnamed Devonian limestone.

FIGURE 2. Maggie Creek Mining District General Geology.

EXPLANATION:

Qal = Quaternary alluvium
Tc = Tertiary Carlin Formation

Dls = Devonian unnamed limestone
Dlst= Devonian Transitional limestone
Srm = Silurian Roberts Mountains Formation
SOh = Silurian/Ordovician Hansen Creek Formation
Ov = Ordovician Vinini Formation
Ovt = Ordovician Vinini/Transitional siliceous sediments


N
ROBERTS MOUNTAINS THRUST
Ov
Srm
45
40
Dls
Tc
Srm
CARLIN WINDOW
COPPER KING MINE
SOh
GOOD HOPE FAULT
GOLD QUARRY FAULT
Ov
Srm
Ov
Qal
Dlst
GOOD HOPE MINE
60
Ov
Dlst
Tc
Ovt
GOLD QUARRY MINE
TUSCARORA FAULT
Tc
MAGGIE CREEK MINE
Ov
NEWMONT # 2 MILL
0 Miles
0 Kilometers

These carbonates are exposed through siltstone, shale, sandstone, chert and impure limestone of the Roberts Mountains allochthon.

The Carlin Window is defined on the northeast by the Roberts Mountains Thrust and on the southwest and southeast by the high-angle Good Hope and Gold Quarry faults, respectively. The northwest boundary is buried by Quaternary alluvium and Tertiary lacustrine sediments.

STRATIGRAPHY

The stratigraphy of the Carlin Window has been described by Evans and Cress, 1972, Roberts, 1967, Stewart, 1980, and West, 1976. A brief summary of their work, and the work of others, is given below.

Western Assemblage - Siliceous.

A thick sequence of Ordovician strata assigned to the Vinini Formation is exposed in the Tuscarora Mountains. The sequence is primarily composed of medium-bedded black and green chert, thin bedded shale, minor sandstone, quartzite and rare greenstone. Ten to 20 kilometers north of the Gold Quarry area, this formation is greater than 4300 meters thick. In the vicinity of the Carlin Window, a 765 meter section of the Vinini Formation is composed of carbonaceous shale, siliceous shale, chert, siltstone, quartzite and minor limey siltstone.

Transitional Assemblage - Siliceous and Carbonates.

Roberts and others, 1958, described rocks of mixed siliceous and carbonate facies in northern Nevada as "transitional assemblage". These rocks are primarily siltstone, silty limestone, shale, sandstone and chert. This sequence has been recognized by the author as composing the dominant host lithologies of the Gold Quarry deposit. The transitional section at Gold Quarry is estimated to be over 450 meters thick. These Ordovician siltstones are typically thin-bedded and noncompetent. Bedding generally strikes about N45W and dips between 30 and 80 degrees either southwest or northeast. Isoclinal folding of bedding is common, with chaotic, discordant bedding near large faults. Low-amplitude folding on a northwest trend is also present.

Eastern Assemblage - Carbonates.

The youngest member of the eastern assemblage is an unnamed Devonian limestone exposed in the northern part of the Carlin Window, the upper portions of which have been cut by the Roberts Mountains Thrust. This formation is a thick to massively bedded sequence of dark grey to black (often fossiliferous) dolomitic limestone. The silt content of this Devonian limestone increases vertically and grades upward into a sandy limestone. Devonian corals and crinoids are common. Estimated thickness of this formation varies from 75 meters in the Carlin Window to 175 meters for the equivalent Popovich limestone at the Carlin mine, 10 kilometers to the northwest.

The Silurian Roberts Mountains Formation makes up the bulk of the exposed rock within the Carlin Window. This formation is a dark grey, platey, fine-grained, silty dolomitic limestone. The basal unit of the Roberts Mountains Formation is a three meter thick section of black chert overlain by a pyritic, carbonaceous silty dolomite that contains some thin chert lenses. A grey, dolomitic, locally sandy limestone with intercallated thin, dark grey, bioclastic limestone beds and lenses of chert overlies the dolomite. These carbonates typically weather to a light grey slope of angular plates and are estimated to be 350 meters thick.

Several fault-bounded exposures of the Silurian-Ordovician Hansen Creek Formation are found on the southern portion of the Carlin Window. This formation consists primarily of grey to black dolomite and chert lenses. Due to limited outcrop, the thickness of this formation within the window is estimated at only 50 meters.

Tertiary Sediments.

To the south of Gold Quarry, Tertiary volcanic flows dammed major drainages of the area. This created basins where extensive lacustrine deposits accumulated during the Tertiary. These deposits are divided by Regnier, 1960, into several formations. One of these, the Carlin Formation, rests either unconformably on, or in fault contact with, the Paleozoic bedrock of the district. This formation consists of over 200m of lacustrine tuffaceous siltstone, conglomerate, diatomite, shale, limestone and rhyolite tuffs. The Carlin Formation is considered to be of Pliocene age (Regnier, 1960). The depositional basin deepens to the east to include over 700m of other Tertiary sediments (all a part of the 2200m section of Cenozoic rocks in northeastern Nevada). Within the Gold Quarry mine, the Carlin Formation includes well-defined scour and fill channels, gravel bars that contain siliceous angular to sub-rounded clasts, and bedded vitric tuffs. Adjacent to the orebody, clay and siliceous gravel of the Carlin Formation were derived from the erosion of hydrothermally altered Paleozoic rocks, giving the appearance of mineralized Tertiary sediments (as suggested by Ekburg, 1986). The author believes that the Pliocene age of the Carlin formation postdates the mineralization at Gold Quarry.

Small faults and gentle folds are common; the dip of the Tertiary beds ranges from 10 to 20 degrees to the east. The occurrence of a basal montmorillonitic - hematitic clay layer usually marks the Paleozoic bedrock contact. This layer appears lateritic in nature and is considered by the author to represent a paleosol horizon.

Igneous Rocks.

The only igneous rock exposed in the immediate area is found in the west pit of the Maggie Creek mine, about 925m southwest of the center of Gold Quarry. The dike is classified as a latite-

porphyry, being composed of minute quartz phenocrysts in an argillically altered feldspar groundmass. The dike contains both anomalous gold and arsenic values and is stained by iron oxides. It is exposed along a northwest strike for about 10m and averages about one meter in width. No age dates are available for the dike.

ALTERATION

Hypogene.

Silicification and argillization are the principal alteration processes observed at Gold Quarry. Descriptions of wallrock subjected to either style range from slightly noticeable effects to total erasure of original bedding features. Silicification appears to be more directly associated with gold deposition.

Silicification at Gold Quarry is the most pervasive style of alteration observed and has been superimposed on siliceous siltstone and silty limestone. Silica flooding has produced unique rock characteristics, the most noticeable being a cherty, flint-like rock containing over 97% silica. Roughly one-half of the drilled area is composed of slightly to highly silicified rock (Fig. 3); about 60% of the total contained gold in the deposit is associated with these rocks. The effects of silicification are noted to be concentrated along high-angle faults, particularly in their hanging walls. In general, the intensity and amount of silicified rock decreases with an increase in depth. This decrease results in the deposit appearing to have a "silica cap" that overlies moderately argillized and silicified lithologies.

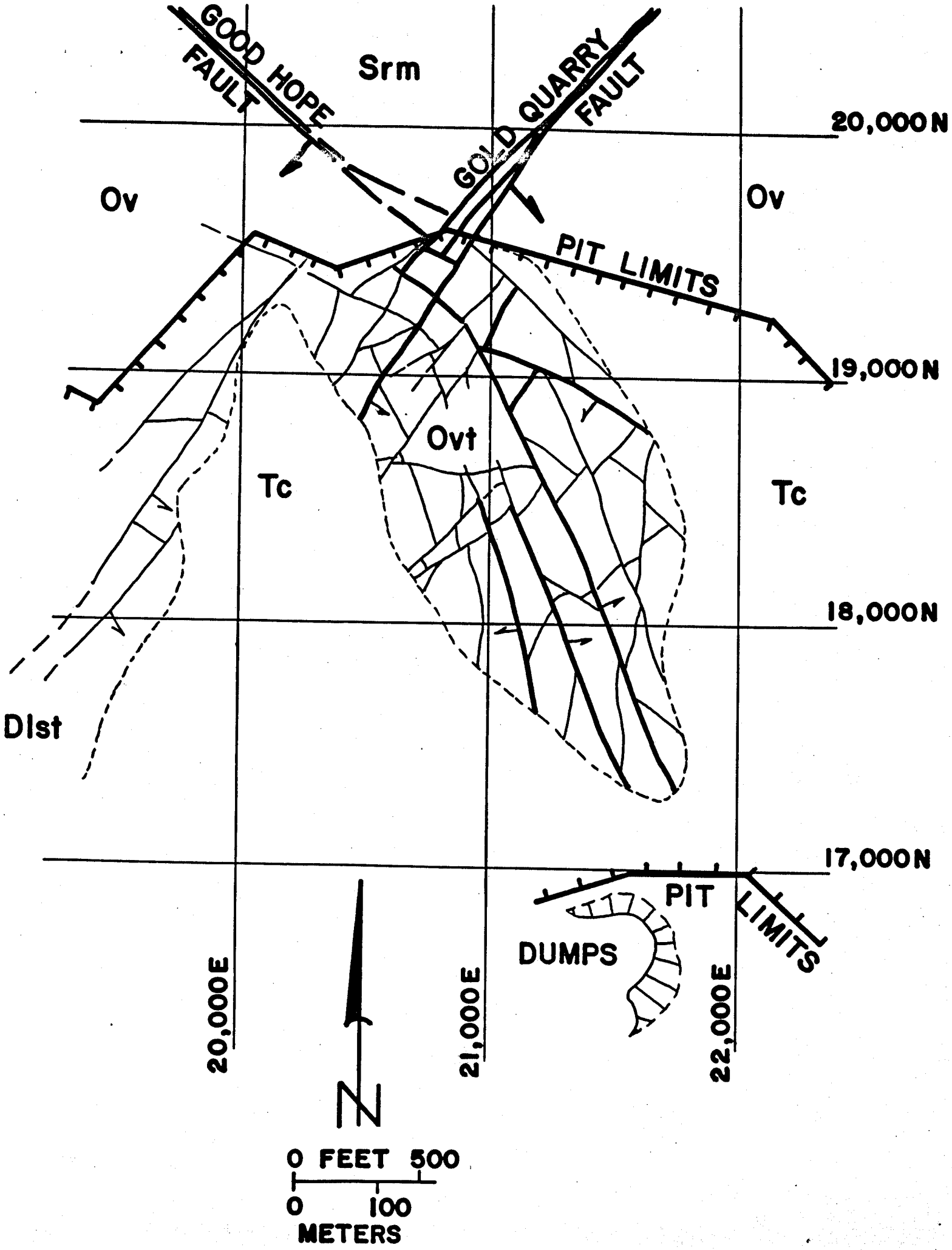
The first hydrothermal silica to be introduced at Gold Quarry is probably represented by quartz veinlets that contain abundant organic carbon ("black quartz"). Black quartz from the 5540 bench was examined by J. Coe in 1983. She states that, "The black speckled inclusions in the quartz were very minute (about 2 to <0.5 microns) and medium to dark grey in reflected light, similar to organic carbon... Microscopic textural evidence suggests that the organic carbon was derived from a form of asphalt bitumen that was mobilized by [hydrothermal] solutions, and became embedded in vein quartz penecontemporaneous with barite and gold..." It has been suggested that the carbonaceous material in these veins was derived from carbonate source rocks by fluids that pre-date the formation of the auriferous hydrothermal system (Kuehn, 1986). The pre-existing pyrobitumen reservoir was intersected by the first pulse of hypogene fluids and micron-sized particles of carbonaceous material became included in the quartz.

The exact number of silica introduction events is difficult to estimate. Besides the black quartz, at least one clear quartz and one quartz-barite veining event are observed in the deposit. Three episodes of silica flooding are also recognized, thus three degrees of general wallrock silicification are noted in the mine.

FIGURE 3. General Geology of the Gold Quarry Mine.

EXPLANATION: Tc = Tertiary Carlin Formation

Dlst= Devonian Transitional limestone
Srm = Silurian Roberts Mountains Formation
Ovt = Ordovician Vinini/Transitional siliceous sediments


GOOD HOPE FAULT
GOLD QUARRY FAULT
Srm
Ov
Ov
PIT LIMITS
Ovt
Tc
Tc
Dlst
20,000N
19,000N
18,000N
17,000N
PIT LIMITS
DUMPS
20,000E
21,000E
22,000E
N
0 FEET 500
0 100
METERS

The final silica event appears to consist of supergene milky quartz that filled open fractures, cross-cutting all previous veins (Fig. 4).

Alunitization followed the main stages of silicification, with alunite occurring as replacements along fractures and as vertical stockwork veins that transect earlier quartz-barite veins. Hausen et al. (1983) noted that these replacements are more common at Gold Quarry than at other Carlin-type gold deposits. Most of the alunite occurs in siliceous sediments and appears to be both lithologically and structurally controlled. Numerous veins, from 1mm to 10cm wide, are noted to have assimilated small fragments of country rock, suggesting that most alunite formed under hypogene conditions. Alunite occurring along open fractures may be of supergene origin. The center of the deposit contains most of the alunite. Late argillic alteration has obscured the alunite veins so that field identification is difficult.

Argillic alteration followed silicification and alunitization. Clay alteration fronts are observed in the mine to encroach upon slightly to highly silicified rock. Argillic alteration has been observed to penetrate two to three centimeters into highly silicified rock from post-silicification fractures, leaving a core of siliceous rock surrounded by a clay rind (that is still composed of about 75 to 80% silica). Argillic alteration of sedimentary lithologies produces a slightly soft rock to a fluffy or greasy clay. Alteration minerals near the top of the deposit consist predominately of illitic clay and kaolinite (Table 1) with traces of montmorillonite. The roots of the deposit are predominately kaolinitic. Deere et al. (1966) note that illitic clays may have a hydrothermal origin and are often found in alteration zones around hot springs and metalliferous veins. The vertical zonation of illite at Gold Quarry suggests that it is hypogene in nature, accentuated by near-surface acid leaching. Because even the most argillic rocks are a product of wallrock-fluid interaction, even the most altered sediments still contain 50 to 60% quartz (as detrital grains).

Decalcification, the removal of carbonate minerals from limestone through hydrothermal processes, has occurred along many faults and local areas in silty limestone within the deposit. A general decrease in bulk density and increase in porosity of the affected rock is usually associated with this process (Hausen and Kerr, 1968). This left most of the silty limestone very receptive to silica-bearing fluids; the former carbonate units are now highly silicified and contain little to no calcite. No hydrothermal calcite veins have been noted within the siliceous sediments in Gold Quarry, however, the nearby Maggie Creek mine contains abundant calcite veins.

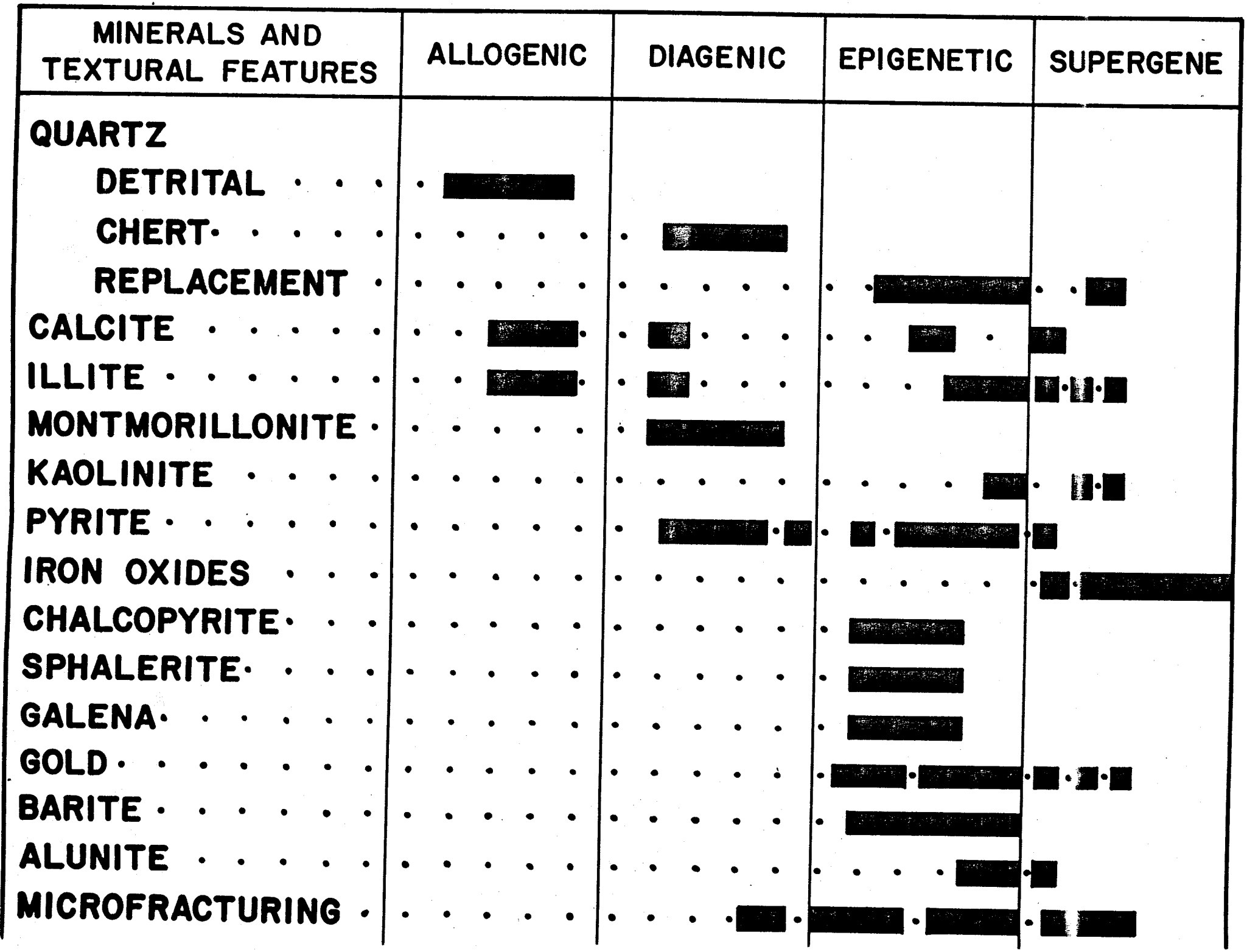
Baritization has occurred throughout Gold Quarry, especially in the vicinity of large faults. Bladed barite crystals up to 5cm have been taken from the highly iron-stained, open-spaced breccias of a few northwest-trending faults. Barite is also

TABLE #1

WALLROCK ALTERATION FEATURES
(Distribution in wt. %)

	WHOLE DEPOSIT (Disseminated values)	LOCALIZED CONCENTRATIONS (Structural Values)
Quartz	40.0 - 60.0 %	>90.0 %
Alunite	5.0 - 20.0	30.0 - 40.0
Iron Oxides	2.0 - 6.0	10.0 - 18.0
Brite	-	1.0 - 3.0
Illite	4.0 - 5.0	10.0 - 15.0
Kaolinite	-	4.0 - 20.0

FIGURE 4. Gold Quarry Paragenetic Sequence (after D.M. Hausen).


MINERALS AND TEXTURAL FEATURES
ALLOGENIC
DIAGENIC
EPIGENETIC
SUPERGENE
QUARTZ
DETRITAL
CHERT
REPLACEMENT
CALCITE
ILLITE
MONTMORILLONITE
KAOLINITE
PYRITE
IRON OXIDES
CHALCOPYRITE
SPHALERITE
GALENA
GOLD
BARITE
ALUNITE
MICROFRACTURING

a common feature of the jasperoidal faults and quartz-gold veins within the deposit. Deposition of barite ranges from early through late epigenesis of the orebody (Fig. 4).

Supergene.

Late-Tertiary supergene oxidation followed formation of the Gold Quarry orebody. Drill data indicates that primary, unoxidized, pyritic, carbonaceous ore begins between 120 and 200m below the Paleozoic bedrock surface. The oxidation boundary, in general, reflects the erosional bedrock surface above it. Deep weathering is indicated by the occurrence of pyrite molds in siliceous rock, lateritic soil development and the abundance of hematitic and limonitic clays found on nearly all open fractures of the near-surface portions of the deposit. These iron-rich clays give the Gold Quarry pit a distinctive red hue. Supergene redistribution of some gold is indicated by Hausen (1983), "...small amounts of pyrite have been detected in Gold Quarry ores, most of which is assumed to be auriferous, analogous to Carlin, Getchell, Cortez, and other similar deposits. Small amounts of gold are therefore assumed to be liberated during this late period of oxidation of sulfides." Unexpectedly high ore grades encountered in mining immediately beneath the bedrock surface also tend to support some supergene movement of gold.

GOLD MINERALIZATION

Gold Quarry is the largest deposit of the Carlin Trend, a 60 km long northwest alignment of epithermal, sediment-hosted, disseminated gold deposits. Collectively, these deposits contained more than 620t of gold, with Gold Quarry alone accounting for nearly forty percent of the total.

Primary Controls.

Detailed pit mapping at Gold Quarry has shown that steeply dipping normal faults, and associated fracturing, are the major controlling features of gold deposition. Mechanically induced permeability was important to the formation of this deposit. Highly pervasive fracture systems produced by faulting provided the ore bearing fluids access to the host rocks. This produced the stockwork distribution pattern of greater gold values along major faults, connected by overlapping, disseminated, lower grade zones. The attitudes of the northwest-trending Good Hope fault and the intersecting, northeast-trending Gold Quarry fault are mirrored by many smaller faults and fractures within the deposit (Figs. 5 and 6). Antithetic and sympathetic fracturing down to a spacing of a few centimeters can be traced through the deposit along these trends.

Nearly all faults within Gold Quarry appear to pre-date gold deposition and most of the large faults show signs of post-ore movement. North-northwest trending faults dominate the current pit geology and ore distribution, with northeasterly-trending faults and fractures in a subordinate role. Silica-filled

FIGURE 5.. General Cross-Section of Gold Quarry Deposit.

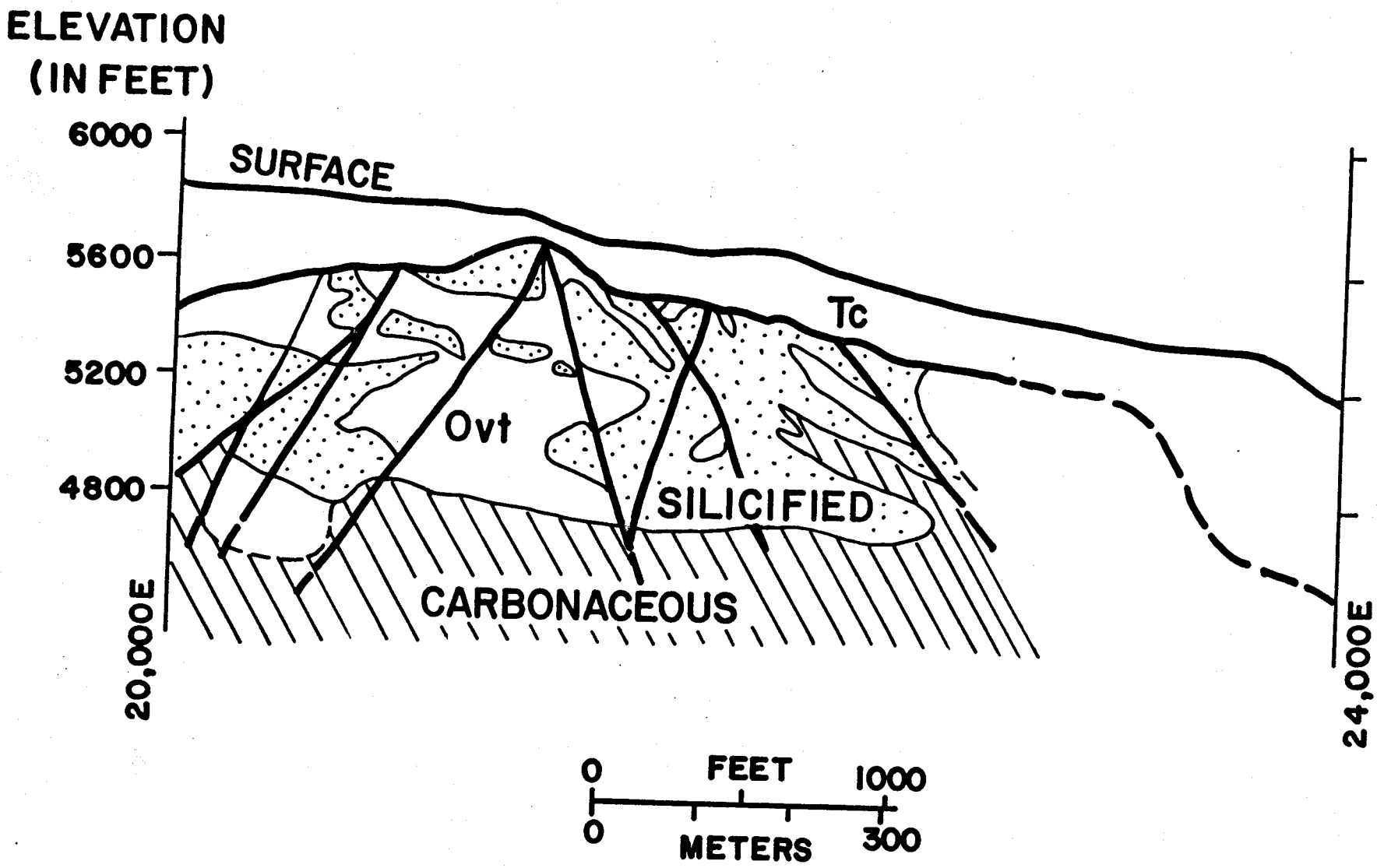
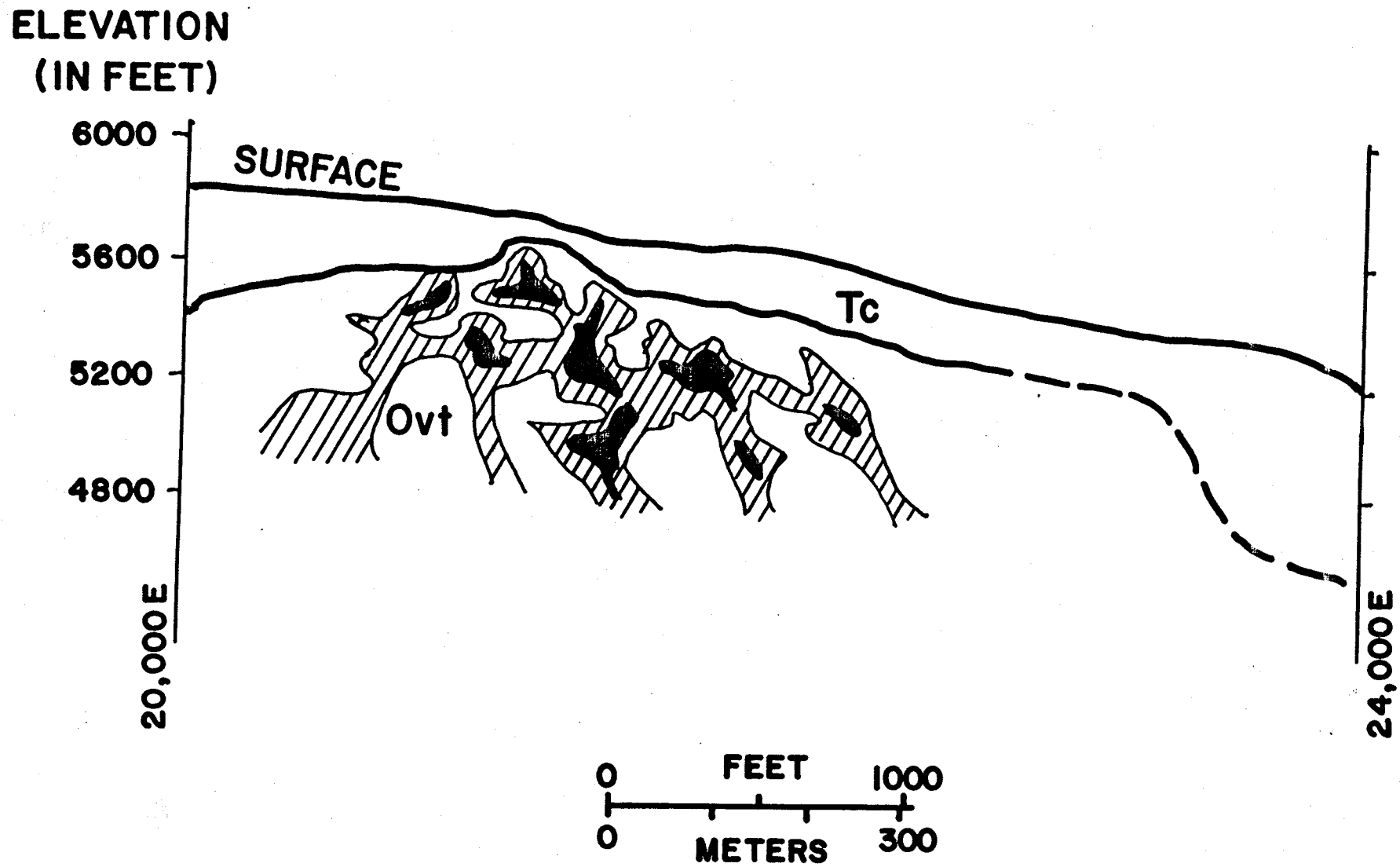

ELEVATION
(IN FEET)
6000
5600
5200
4800
SURFACE
Tc
Ovt
SILICIFIED
CARBONACEOUS
20,000E
24,000E
0
FEET
1000
0
METERS
300

FIGURE 6. General Cross-Section Distribution of Gold in the Gold Quarry Deposit.



GOLD VALUES ≥1.3 g/t Au ≥3.2 g/t Au

faults within the Gold Quarry ore zones appear to have been enhanced by hydrothermal dissolution and brecciation, as these faults are less noticeable when away from centers of ore deposition. Seismic, or mechanical, brecciation appears to have provided hypogene fluids an open access through these strucures, allowing additional hydrothermal brecciation and microbrecciation to occur.

Secondary Controls.

Secondary ore controls are provided by the host rock lithologies. Relatively porous siltstone and silty limestone are noted to localize ore zones away from the main controlling faults. The dense primary chert that occurs within the deposit contains gold on fracture surfaces only and, therefore, tends to be of a lower ore grade than the more permeable lithologies.

Brecciation.

Hydrothermal breccias occur as silica-cemented vein and pod-like bodies from 1cm to 20cm in width throughout the deposit. These breccias are distinquished by their single lithology, angular to rounded clasts locked within a quartz or quartz-barite matrix, and their ability to be "re-assembled" if the supporting matrix material could be removed. Hydrothermal breccias may occur within a fault, but are often found away from recognized structures. Mechanical breccias will often occur within a recognized fault zone, be composed of several lithologies, contain "rock flour" between clasts and generally be clast-supported.

The combination of large, open space, siliceous to moderately argillic hydrothermal breccias, barite crystals, gypsum crystals and abundant manganese and iron oxides appear to define possible "vent" areas near the top of the deposit. According to Berger (1985), areas such as this may have been formed by predominately gaseous discharges. Aqueous fluids were prevented from flooding these areas because of boiling during late-stage steam dominance in the hydrothermal system. These "vent" features are often isolated at northeast-northwest fault intersections and do not usually display anomalous gold values.

Timing and Fracturing.

According to Hausen (1983), gold deposition began immediately following initial silicification, and continued until the last silicification events. Through petrographic examinations conducted while studying a large mass of highly silicified rock, Hausen states, "Gold mineralization appears to have occurred over an extended period of time, beginning with the early introduction of quartz-barite veins and continuing during the waning stages of late cherty silicification. The most intense period of gold mineralization appears to be associated with this late stage of silicification, related to low temperature hot springs activity." Gold particles occur mostly as fine, native granules of less than one to ten microns in size, associated with microfractures or a microcrystalline cherty matrix.

In 1983, D.M. Hausen found evidence for several periods of microfracturing relevant to gold deposition. At least three periods were recognized, the first being described as "pattern fracturing". This microfracturing is pervasive, is usually recemented by quartz and often contains gold. Spacing of these fractures ranges down to about 50 microns. A later period of fracturing transgressed the pattern fractures. This second period is commonly filled by vuggy quartz, and also contains some gold. A final period of fracturing is post-mineralization in nature and is related to post-mineral faulting. These latest fractures are generally open in nature, but often contain varying amounts of iron oxide, clay, and alunite. Density of these latest fractures ranges from 3cm to 10cm in argillized rock and from 10cm to one meter in silicified rock, as mapped in the Gold Quarry pit.

Silver is present in highly anomalous amounts at Gold Quarry. Sub-economic silver grades of 0.3 to 3.5 g/t are common within the gold ore zones. Silver deposition may have predated gold; the general background of silver values appear to be overprinted by gold, as indicated by drill sample studies. Limited tests have shown silver to occur at about a 2:1 Au/Ag ratio in mill grade (>1.71 g/t) gold ore, ranging up to 1:3 in leach grade (0.68 to 1.70 g/t) ores. Both gold and silver seem to have been controlled by the same pre-existing faults and fractures.

GEOCHEMISTRY

Surface geochemistry was of limited use as an exploration guide at Gold Quarry due to the thick blanket of post-mineral lacustrine sediments of the Tertiary Carlin Formation. Gold values in the surface jasperoid were found to be highly variable, ranging from nil to over 2 ppm within a few meters. Gold was found to be the best geochemical pathfinder (Fig. 6 and Table 2). In general, sampling of soil, outcrop, and stream sediments all provided surface indications of the gold deposit.

The second best indicator of gold was arsenic (Fig. 7 and Table 2). Anomalous arsenic values were found to be directly associated with gold deposition. This arsenical association is common at other disseminated gold deposits, including the Maggie Creek and Carlin mines. The arsenic distribution appears to be controlled by the same faults, fractures and lithologies that control gold deposition.

Geochemically anomalous antimony, copper, lead, nickel and mercury occur in the Gold Quarry deposit (Table 2). Most of the trace elements are restricted to fault-controlled gold ore zones, so that their distribution mirrors the gold. Anomalous zinc values usually define the carbonate lithologies and are not closely related to gold deposition.

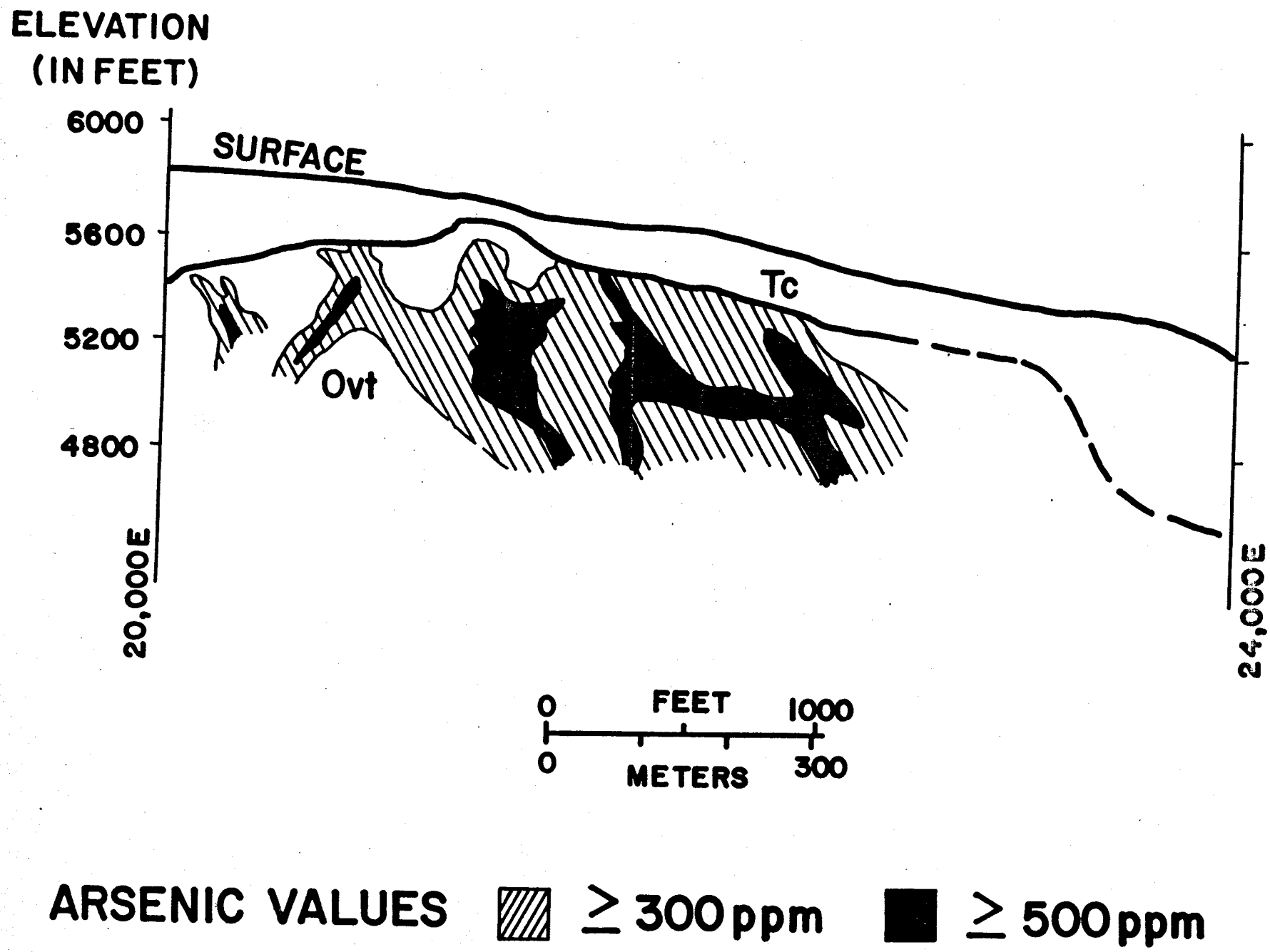
TABLE #2

GOLD QUARRY GEOCHEMICAL VALUES
(Distribution in parts per million)

WHOLE DEPOSIT (Disseminated Values)		LOCALIZED CONCENTRATIONS (Structural Values)
Gold	0.3 - 3.0 ppm	>6.9 ppm
Silver*	0.1 - 2.0	>6.9
Arsenic	<200.0	>500.0
Antimony	<50.0	200.0 - 2000.0
Mercury	<1.0	>50.0
Lead	<100.0	500.0 - 3000.0
Copper	<50.0	200.0 - 1500.0
Manganese	<200.0	500.0 - 1000.0
Nickel	<100.0	300.0 - 1000.0

*Limited Data

FIGURE 7. General Cross Section Distribution of Arsenic in the Gold Quarry Deposit.


ELEVATION
(IN FEET)
6000
5600
5200
4800
SURFACE
Tc
Ovt
20,000E
24,000E
0
FEET
1000
0
METERS
300
ARSENIC VALUES
≥ 300 ppm
≥ 500 ppm

GENETIC MODEL

Several factors point directly to an eroded fossil epithermal/hot springs genetic model for the Gold Quarry deposit. The spacial relationship between gold deposition, jasperoids, silicified wallrock, argillized wallrock and seismic and hydrothermal brecciation are summarized in this section.

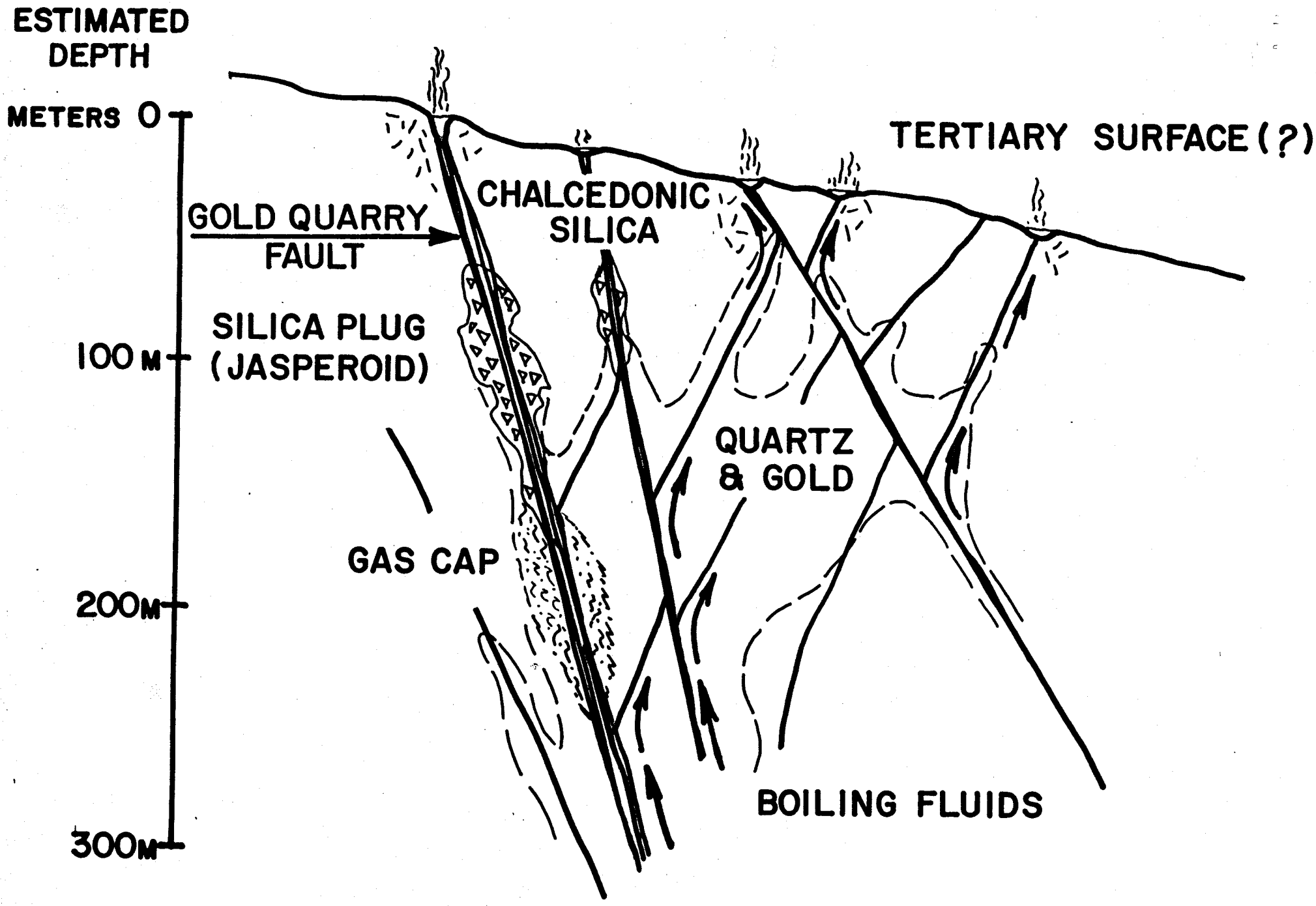
Jasperoids and Silica.

The concept of a silica cap and the occurrence of large silica-filled faults at Gold Quarry can be compared to the active geothermal system at Waiotapu, New Zealand, as described by Hedenquist and Henley (1985). Briefly, in the present-day system, ascending hydrothermal fluids begin to cool as they near the surface due to a decrease in hydrostatic pressure and resulting boiling and vapor loss. Below a depth of 100m, silica is usually deposited as quartz; above 100m silica is more often deposited as chalcedony. Almost no hydrothermal chalcedonic silica has been found in the Paleozoic rocks at Gold Quarry, indicating that any surface sinter, and the upper 100m of the deposit, have been removed by erosion. Ore and gangue mineral deposition, as a result of boiling, serves to decrease the permeability in the upper portion of the system. Fault conduits to the surface become sealed at different rates depending on the ratio of flow rate to fracture width, temperature-pressure drop, and the periodic occurrence of tectonic activity.

A local interpretation of this concept for the fossil Gold Quarry system is sketched in Figure 8. A highly fractured hanging wall provides channels accessible to ascending fluids when the main feeder conduit (in this case the Gold Quarry fault) becomes plugged with silica. Repeated tectonic movement and hydraulic fracturing brecciates and opens the silica plug, releasing the backpressure from below. Silicification and gold deposition in the hanging wall rock decreases when the main conduit vents to the surface. Resealing of the conduit begins, possibly lower in the system, due to a decrease in pressure (venting to the surface). The jasperoids presently exposed at the surface have developed at this point.

Jasperoid formation within the large, high-angle normal faults that border the Carlin Window can be directly linked to repeated silicification of the Gold Quarry host rocks. These faults were a part of the pre-existing plumbing system that directed the ascending hydrothermal fluids. Brecciation and silicification appear to have occurred periodically within these faults, indicating a repeated history of seismic and hydrothermal events. As these conduits became sealed near the surface, silica flooded out into the hanging-wall rocks, creating zones of varying intensities of silicification (depending on the spacial overlapping of flood events). Jasperoid bodies at Gold Quarry become narrower at depth, existing over a vertical range of only 75m. This may indicate a fluctuation in depth of formation of the silica seal. Areas of "spongy" (porous, vuggy) silicification ore often spacially associated with the large jasperoid bodies,

FIGURE 8. Sketch Section of Gold Quarry Deposit During Mainstage Gold Deposition.


ESTIMATED DEPTH
METERS 0
100 M
200M
300M
TERTIARY SURFACE (?)
CHALCEDONIC SILICA
GOLD QUARRY FAULT
SILICA PLUG (JASPEROID)
QUARTZ & GOLD
GAS CAP
BOILING FLUIDS

and may be further indications of a near-surface environment of formation (Berger, 1985).

Argillic Alteration Patterns.

The spacial distribution of argillic alteration at Gold Quarry is similarly consistent with a fossil hot springs genetic model. Deere et al. (1966) note that, in laboratory experiments, acidic conditions favor the formation of kaolinite. The clay mineral assemblage at Gold Quarry reflects these conditions.

The nature of hypogene argillic alteration at Gold Quarry was probably intensified by "acid leaching" processes. This is a supergene process, involving the formation of sulfuric acid through the oxidation of sulfur-bearing minerals or gases, and the effects of these descending acidic waters upon wallrock. Features diagnostic of a surficial alteration are relict rock structures of a siliceous residue and a kaolin-alunite zone immediately beneath (Schoen et al., 1974). The concentrations of kaolinite in the roots of Gold Quarry, beneath the central alunitic zone, are consistent with this model (Fig. 9).

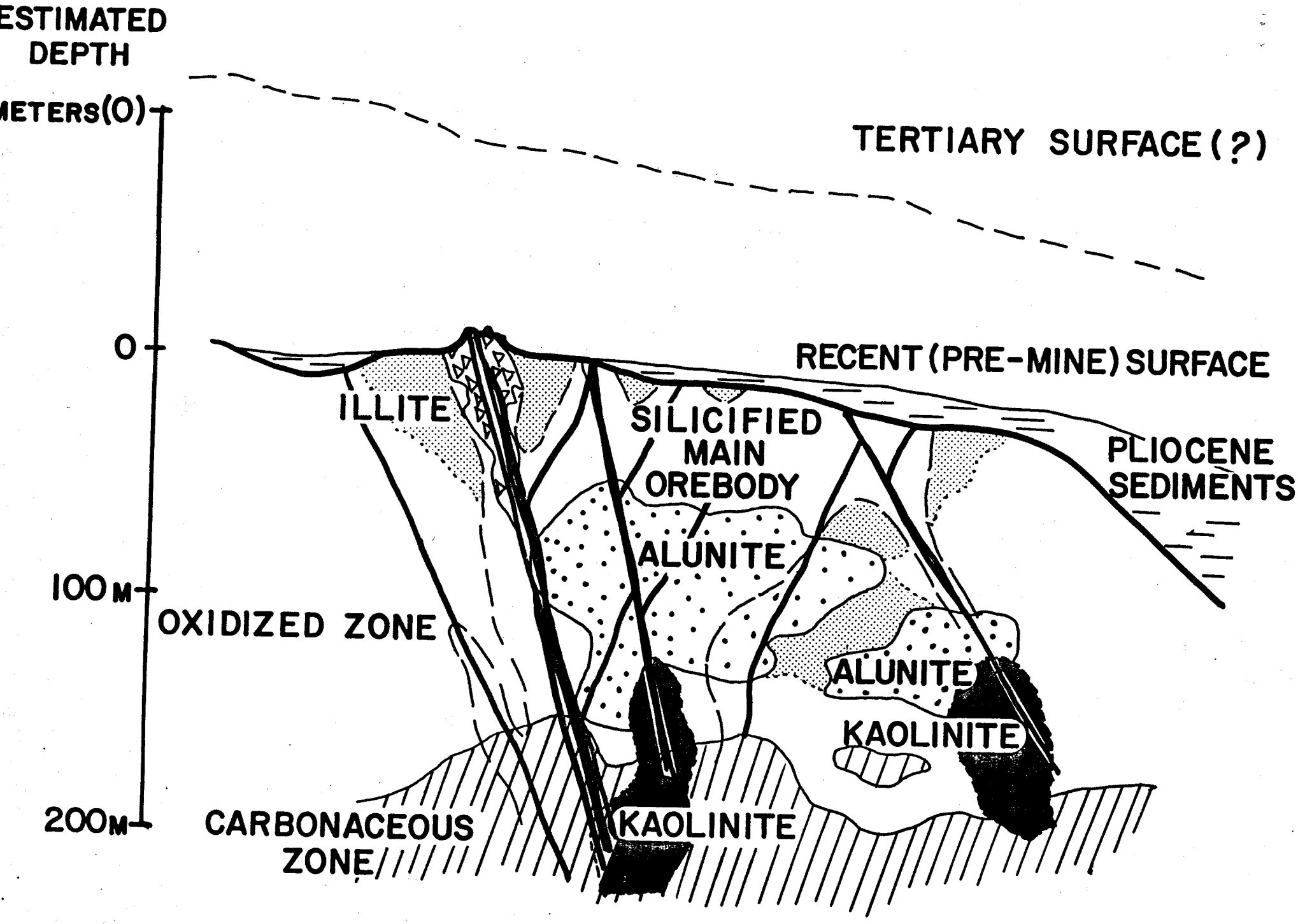
Evidence of a former hot springs environment can also be indirectly gathered from the pathfinder element assemblage at Gold Quarry. The elemental association of gold, silver, arsenic, antimony, mercury, lead, copper, manganese and nickel at Gold Quarry is similar to the group reported from the active geothermal system at Waiotapu (Hedenquist and Henley, 1985), although the concentrations vary somewhat.

Age.

While the age of mineralization at Gold Quarry is still in question; recognized chronologic relationships provide relative age constraints.

The precursor to the present Humboldt River drainage system was dammed by Tertiary volcanic flows between 6 and 17 Ma. This led to sedimentation in the Pliocene basins (1.6 to 5.3 Ma) and deposition of the Tertiary Carlin Formation. Siliceous mineralized material eroded from Gold Quarry is incorporated in this formation both as basal gravels lying immediately above the unconformable bedrock contact and as gravel bars throughout the Pliocene sediments. Since erosion of the deposit occurred after the main stages of mineralization, the incorporation of gravels in the Carlin Formation places the age of mineralization as older than 6 Ma. Stewart, 1980, shows that Cenozoic igneous activity in northeastern Nevada was at its peak between 43 and 34 Ma. Intrusive rocks of this age are mineralized elsewhere, thus, mineralization is probably related to the high heat flow in this area of that time. This dating (between 43 and 6 Ma) places a probable early Oligocene age on the mainstage Gold Quarry mineralization events.

FIGURE 9. Sketch Section of Gold Quarry Deposit Before Mining.


ESTIMATED DEPTH
METERS(0)
0
100 M
200M
TERTIARY SURFACE (?)
RECENT (PRE-MINE) SURFACE
ILLITE
SILICIFIED MAIN OREBODY
PLIOCENE SEDIMENTS
ALUNITE
OXIDIZED ZONE
ALUNITE
KAOLINITE
CARBONACEOUS ZONE
KAOLINITE

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