Geology and mineralization of the South Pipeline Gold Deposit, Lander County, Nevada

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ABSTRACT

The South Pipeline deposit is an alluvium covered disseminated ("Carlin-type") gold occurrence situated along the Cortez trend approximately 2,440 meters west of the Gold Acres deposit along the west side of Crescent Valley. Host rocks are silty carbonates of the lower plate (eastern assemblage) Silurian Roberts Mountains Formation. The deposit is situated along the eastern margin of a quartz monzonite pluton identified beneath the Gold Acres deposit; however, no intrusive rocks have been identified within the deposit. North-northwest and northeast- striking high-angle faults served as the primary conduits for gold-bearing fluids, with gold hosted in a shallow, low-angle tabular zone and in a deeper zone displaying high-angle structural control. In plan view, the deposit occupies an area approximately 760 meters in a northerly direction by 915 meters east-west. Mineralized zones are up to 105 meters thick. As of December 31, 1994, the deposit contains a total measured and indicated resource of 88.7 million tonnes containing 4.4 million troy ounces of gold.

Two mineralized zones are evident. The first is a shallow, low-angle tabular zone that ranges from 10 to 155 meters deep and dips easterly approximately 20 degrees. Intense oxidation and variable degrees of decalcification, argillization and silicification are evident. Small pods and lenses of carbonaceous siltstone are rare within this zone. Shearing and decalcification appear to have enhanced host rock permeability allowing access of mineralizing fluids. No direct visual correlations exist between alteration intensity and gold grade.

The second mineralized zone is deeper and begins at approximately 335 meters. It is typified by high-angle structural control along north-northwest-striking high-angle faults. This zone includes high gold grades hosted in both oxidized and carbonaceous siltstones of the Roberts Mountains Formation. Calcite veining is peripheral to the mineralized zones. Quartz veining is rare, generally occurring as microveinlets within the deposit.

As, Sb, and Hg are geochemically anomalous, displaying weak to moderate, positive correlations with gold. Base metals do not occur in significant quantities. Pyrite is the only sulfide identified to date, typically as finely disseminated crystals or isolated framboids. Preliminary analysis and interpretations suggest the shallow mineralized zone has higher levels of the indicator elements and more intense alteration than the deeper zone.

INTRODUCTION

The South Pipeline deposit is a significant "Carlin-type" gold occurrence situated approximately 2.4 kilometers east-southeast of the Gold Acres deposit in Lander County, Nevada. Mineral rights to the deposit are the property of the Cortez Joint Venture (CJV). Placer Dome U.S. Inc. (PDUS) owns 60 percent of the CJV and is the operator of the property, with Kennecott controlling the remaining 40 percent. The deposit is one of the largest gold occurrences identified in the Cortez area. Measured and indicated resource estimates for the South Pipeline deposit include two mineralized zones which total 88.7 million tonnes containing approximately 4.4 million troy ounces of gold.

LOCATION AND ACCESS

South Pipeline is located approximately 130 kilometers southwest of Elko, Nevada, 10.5 kilometers northwest the Cortez Gold Mines (CGM) mill site and 2.4 kilometers east-southeast of the Gold Acres open pit operation in Lander County, Nevada, Township 27 North, Range 47 East, in the NE 1/4 of Section 6. The project site is accessed via Nevada State Highway 306, which extends southward from Interstate 80. Other gold deposits along the Cortez trend include Gold Acres, Pipeline, Cortez, Hilltop, Horse Canyon, Mule Canyon, Tenabo, Fire Creek, Buckhorn, Gold Bar, Tonkin Springs and Ruby Hill (Fig. 1).

HISTORY OF MINING AND EXPLORATION

Mining in the area dates to 1862, when silver was discovered in the Cortez and Mill Canyon areas. PDUS, formerly American Exploration and Mining Co. (AMEX), began

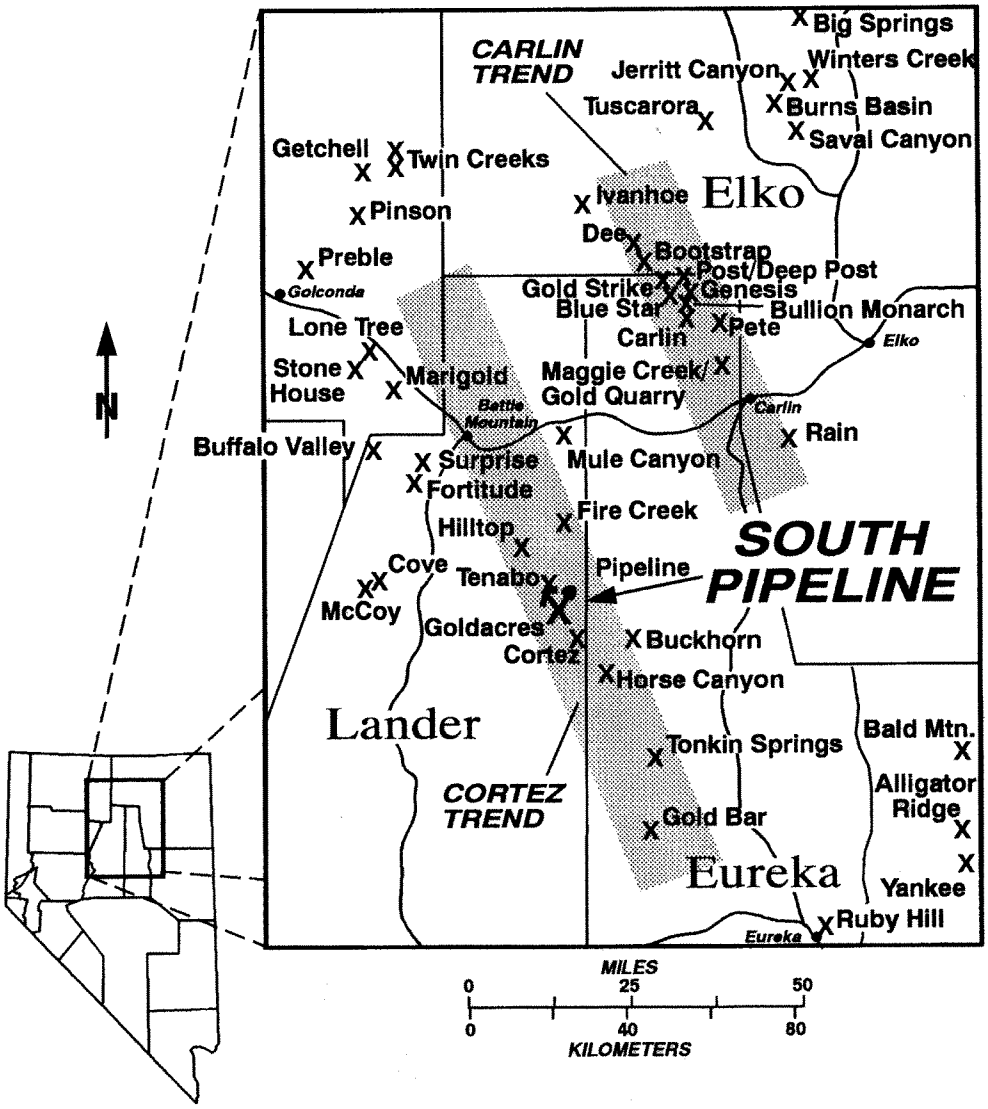

Figure 1—Location of the South Pipeline deposit and other gold deposits in the region. The general locations of the Carlin and Cortez Trends are also shown.

exploring the district in 1959. The Cortez Joint Venture was formed in 1964 to reduce the capital risk of continued exploration (McFarland and Kirshenbaum, 1990). At this time the United States Geological Survey (USGS) had initiated geological mapping and geochemical sampling programs throughout the area. In 1966, anomalous gold values were identified from an obscure subcrop of oxidized and weathered silty carbonate exposed through gravels along the range front (Wells and others, 1969). Subsequent drilling by AMEX led to the discovery of the Cortez Gold deposit, from which 5.8 million tonnes containing approximately 872,870 troy ounces of gold have been mined, to date. Initial production by the CJV began in 1969 and lasted until 1973. Mining in the Cortez deposit area was reactivated in 1988 and continued until 1993. Remaining mineralized material at the Cortez deposit contains about 250,000 troy ounces of gold.

Gold Acres is approximately 13 kilometers northwest of the CGM millsite. Mining at Gold Acres was initiated in 1935, and continued until 1960. In 1969, the CJV began exploration drilling around the deposit, with acquisition occurring shortly thereafter. Mining by the CJV occurred from 1973 to 1976. Operations at Gold Acres resumed in

1987 and continue today, exploiting both carbonaceous refractory ore and lower grade oxidized material. Total production from this deposit (historic and recent) is estimated to exceed 500,000 troy ounces of gold.

The Pipeline deposit was discovered on CJV controlled claims by CGM mine geologists in March 1991. This discovery was the result of deep condemnation drilling undertaken in an area designated as an expansion site for Gold Acres heap leach pads. As of December 31, 1994, proven and probable ore reserves for the Pipeline deposit include 30 million tonnes containing approximately 4.2 million troy ounces of gold.

The South Pipeline deposit was discovered by CGM mine geologists in November 1991. Drillhole PR91-12, which was sited based on photo linear projections interpreted as high-angle faults, indicated an oxidized mineralized zone from 130 to 195 meters which averaged 5.1 grams per tonne. Subsequent reverse circulation (RC) and core drilling completed during the remainder of 1991 and the first half of 1992 resulted in identifying an indicated resource containing approximately 400,000 troy ounces of gold. However, cursory economic evaluations were completed which indicated this resource was not economic.

In August 1992, a drilling program was conducted to the west of the then known South Pipeline deposit to acquire hydrological data for dewatering studies related to the Pipeline deposit to the north. No previous drilling had been completed in this area 365 meters west of the known South Pipeline deposit. Arrangements were made to collect and assay samples from these holes, including drill hole TH-1, which was a pilot hole to determine the optimum site on which to drill a water well for pumping tests. Results indicated an extensive oxidized zone of gold from 60 to 170 meters which averaged two grams per tonne, including 18 meters averaging 6.7 grams per tonne. Follow-up drilling confirmed this relatively shallow gold occurrence and also identified a deeper zone of higher gold grades. Step-out drilling continued through 1992 and into early 1993. By the end of 1992, an indicated resource containing 1.2 million troy ounces had been identified. Additional core and RC drilling, which brought the average distance between holes to approximately 43 meters, was initiated in early 1993 and continued through 1994. As of December 31, 1994, 249 core and RC drill holes have been completed in the project area totaling 6.8 kilometers. In December 1994, an updated resource estimate was completed which indicates a total of 88.7 million tonnes which contain 4.4 million troy ounces of gold. This measured and indicated resource includes both the shallow and deep zones broken down as follows:

Zone	Tonnes	Grams gold/tonne	Contained ounces (troy)
Shallow	83,672,300	1.340	3,609,400
Deep	5,076,600	4.320	750,000
Total	88,748,900	1.540	4,359,400

Mining of the Crescent pit, which includes the nearest surface portion of the deposit above the water table, began in mid 1994.

REGIONAL GEOLOGY

Comprehensive regional geologic studies of the Cortez area include Gilluly and Masursky (1965), Gilluly and Gates (1965), and Madrid (1987). Other publications discuss more detailed geologic features of the Cortez (Wells et al., 1969), Gold Acres (Hays and Foo, 1990) and Horse Canyon (Foo and Hebert, 1987) gold deposits.

The South Pipeline deposit is situated along the Cortez trend in north-central Nevada. The deposit occurs within an alluvium covered erosional window in the Roberts Mountains thrust near the eastern flank of the northern Shoshone Range (Fig. 2), and is hosted within the Silurian Roberts Mountains Formation (Srm). This erosional window occurs on the west side of the Crescent Valley. Gravel thicknesses increase from west to east, and are estimated to exceed 3,050 meters along the eastern portion of the valley. The South Pipeline deposit area is covered by alluvium ranging in thickness from approximately 10 to more than 75 meters.

The deposit occurs near the eastern margin of the Gold Acres stock, a buried quartz monzonite pluton centered approximately 1.6 kilometers south of the Gold Acres deposit. No igneous rocks have been identified within the South Pipeline deposit.

A complex structural setting created by thrusting and high-angle faulting allowed mineralized hydrothermal solutions to access zones favorable for gold deposition. These receptive zones were highly permeable due to original silty lithology and/or structural preparation. Favorable rock chemistry promoted reaction with the acidic hydrothermal solutions which enhanced permeability within the silty carbonate host rocks prior to gold deposition.

Deposit Geology

The South Pipeline deposit is a disseminated, "Carlin-type," gold occurrence located near the eastern flank of the northern Shoshone Range in Lander County, Nevada. Carlin-type deposits are typified by structurally controlled, submicroscopic gold particles evenly distributed throughout sedimentary host rocks, with anomalous levels of arsenic, antimony and mercury usually associated with gold. The South Pipeline deposit lies along the Cortez Rift. The Cortez Rift is within the northern Nevada Rift defined by Stewart and others in 1975, and is a distinct geological feature within the Battle Mountain-Eureka mineral belt defined by Roberts in 1960. The deposit is within the projected extent of the lower plate Gold Acres window. It is hosted in variably altered, silty carbonate units of the lower-plate Srm. Two mineralized zones have been delineated: A shallow zone with a depth to the top of the zone ranging from 10 to 155 meters and a deep zone which begins at approximately 335 metes. The shallow mineralized zone exhibits both low-angle and high-angle structural controls to gold deposition and occupies an area approximately 760 meters in a northerly direction by 915 meters in an easterly direction. Thickness of the shallow zone ranges up to 105 meters. The deep zone is up to 75 meters thick and has more closely spaced high-angle structural control; it occupies an area approximately

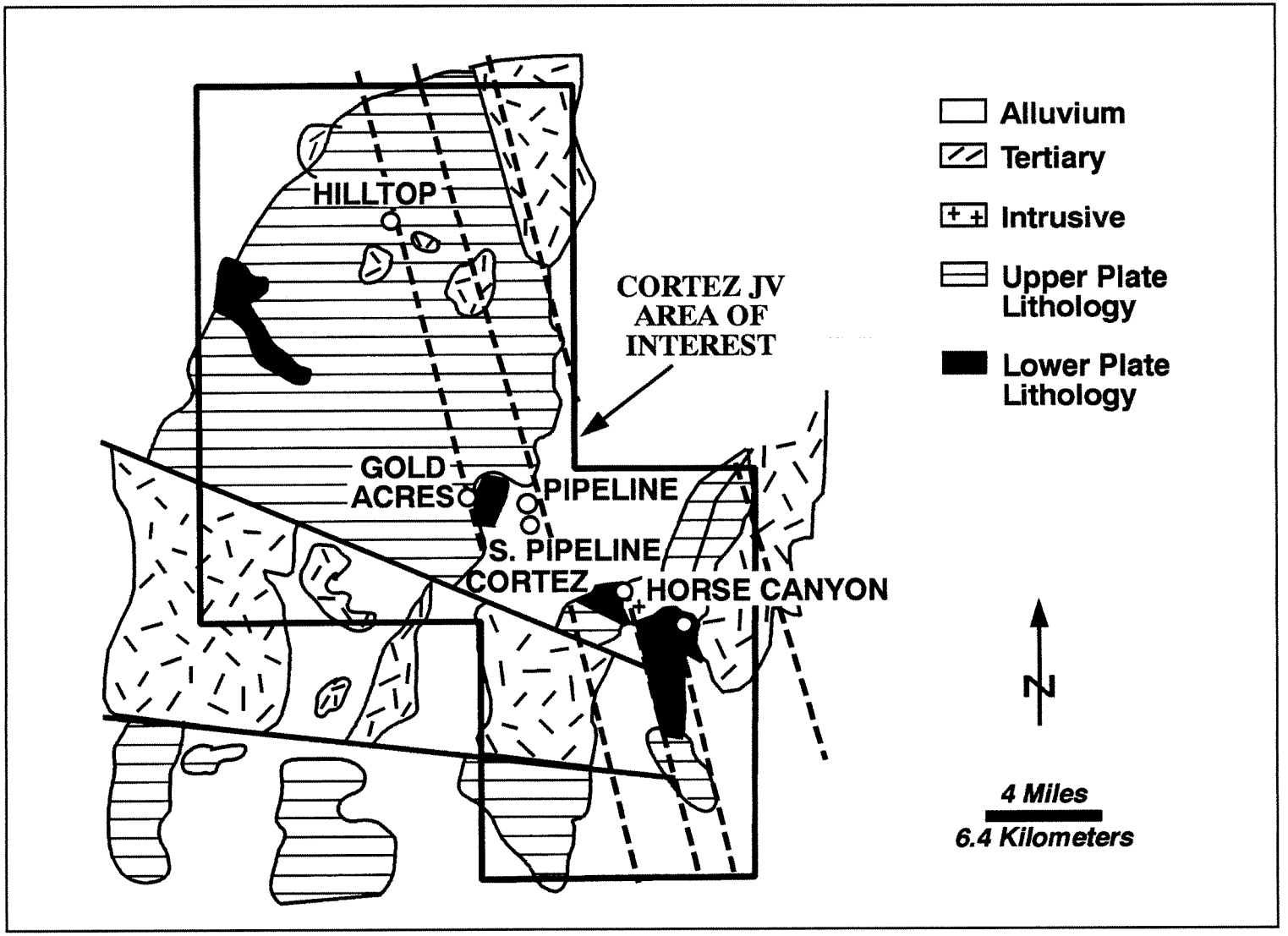

Figure 2—Simplified geology of the Cortez JV area of interest. The Pipeline and South Pipeline deposits are located along the eastern flank of the northern Shoshone Range within a buried erosional window.

400 meters in a northerly direction and is more than 150 meters E-W (Fig. 3).

Stratigraphy

Two principal lithologic units are identified within the immediate deposit area. Quaternary alluvium covers the area and contains a wide range of grain sizes from coarser cobbles and boulders of chert, argillite, siltstone, limestone and quartzite to fine sands and silts. Assay results from alluvial samples suggest potential for a low grade (less than 1.7 grams per tonne) gold occurrence near the bedrock contact. This occurrence is hosted in fragments of the paleo-outcrop from the nearest surface portions of the South Pipeline deposit which were eroded and deposited in paleo-channels and later covered with alluvium. The alluvium-bedrock contact dips gently to the east (less than 10°) at an angle shallower than, and sub-parallel to, the bedding of the strata below. Old mill tailings from pre-1960 milling activity at Gold Acres cover a portion of the alluvium.

The most important rock formation within the deposit area is a silty carbonate unit defined principally by lithologic description as the Srm. The Srm is grouped in the laminated limestone province of north-central Nevada, resulting from deposition in a deep water, low energy environment on the outer continental shelf. Unaltered Srm is typically black to dark grey, thin- to medium-bedded, thinly laminated, calcareous to dolomitic siltstone, containing abundant poorly sorted detrital silt-sized grains of quartz and feldspar (Stewart, 1980). Carbonaceous material and pyrite are common. Fossiliferous horizons are noted in the deposit area, but detailed identification and dating have not been completed.

Unaltered Srm, which is comprised of silt-sized grains of approximately 80 percent calcite, 15 percent angular fragments of quartz, five percent potassium feldspar, and less than one percent muscovite flakes (Gilluly and Masursky, 1965), is rare in the deposit area. It is usually moderately to intensely oxidized and variably silicified, decalcified and/or argillized in the deposit area, typically comprised of 10 to 80 percent subangular quartz silt, with up to 10 percent very fine subround quartz sand; 0 percent (probably decalcified) to 90 percent very fine to fine carbonate; and accessory levels of detrital argillaceous mud, illite and limonite pseudomorphs after authigenic pyrite.

The type section of the thickest Srm in the Roberts Mountains is 580 meters thick. In the Cortez Mountains, the thickest measured section is 305 meters (Gilluly and Masursky, 1965). Drill data suggests the thickness of the Srm exceeds 760 meters in the deposit area. Thickening is thought to be the result of repeated orogenic activity from the Antler through the Sevier Orogenies. Doming, related to the Jurassic intrusives, may account for additional thickening along the margins of the igneous body.

The lower plate Devonian Wenban limestone (Dw) is exposed to the west of the deposit and is also evident to the south at depth. The Dw is similar to the Srm, but is typically thicker bedded with less detrital silt grains. It is generally a more crystalline limestone that was deposited in the moderately deep outer shelf environment (Stewart, 1980). Although Dw is not evident within the deposit, it may comprise portions of the ultimate western pit wall. The Ordovician Hanson Creek Formation (Ohc) is also evident from RC drill cuttings to the south at depth. The stratigraphy of the deposit area is summarized in Table 1.

Structure

The Gold Acres area is interpreted to lie in an eastwardly dipping fault block related to Basin and Range tectonism. Bedding in the South Pipeline deposit area appears to follow a similar pattern. Locally, bedding can be highly contorted.

A primary ore controlling feature of the shallow mineralized zone is a low-angle sheared zone ranging from less than three meters thick to greater than 105 meters thick in the deposit area. The sheared zone has an overall easterly dip of less than 20°. It is generally steeper to the west (30°) and flatter to the east. The zone is intensely sheared, shattered and/or brecciated, with offsets along the high-angle faults anticipated. Bedding within the zone varies from low-angle to the zone to highly contorted. Some deformed bedding appears, in places, to be soft-sediment deformation.

Current interpretations suggest this shearing may represent a zone of imbricate thrusting subparallel to and beneath the Roberts Mountains Thrust. A similar southwesterly dipping feature is identified as a primary ore controlling feature at the Gold Acres deposit. It is hypothesized that the South Pipeline deposit, with an easterly dip, occurs on the opposite limb of an anticline, or a domed feature, related to the intrusion of the Gold Acres stock (Fig. 4). The direction of movement along the hanging wall of the South Pipeline sheared zone, which is parallel to subparallel with bedding, is probably west to east.

A weakly developed structural zone is present beneath and subparallel to the sheared zone, which is referred to as the microbreccia zone. The rocks within this zone appear weakly altered in hand sample, but in thin section display patchy silicification and quartz veinlets within a brecciated texture. In the microbreccia zone, gold is associated with silica in veinlets or replacements of the matrix, and occurs in and on limonite pseudomorphs after pyrite. Decalcification is not pervasive in this zone, and when present is confined to fractures. The microbreccia zone is thought to be a weakly developed structural horizon similar to the sheared zone described above that contains most of the gold.

High-angle faults include a NNW-striking fault set (N15W to N20W), of which the Pipeline fault is the most readily identifiable. This fault has a steep (75° to 85°) easterly dip. The Pipeline fault parallels the overall Cortez trend and is inferred to be an offset extension of the Cortez fault (McCormack and Hays, 1995). Cross-section interpretations suggest a subparallel fault (N15W to N20W) on the west side of the ore body that truncates the deep mineralized zone, but is cut by the shallow zone, which is truncated by a N35W, subvertical fault (Fig. 5). Intersecting the NNW fault system is a

NE-striking set of high-angle faults (N30E to N50E). Conjugate shear planes of similar age develop at about 30° to Sigma I or at approximately 60° to each other. These faults are about 60° from each other, and assuming that the NNW and NE faults are of similar age the NNW faults would have normal oblique right slip and the NE faults some component of normal movement with significant left slip. It is anticipated that multiple fracture and joint sets will be encountered which are parallel to the NNW and NE fault systems. Both systems appear to be important ore controls for both the shallow and deep mineralized zones as shown by the grade x thickness plot (Fig. 6).

Table 1—Stratigraphy of the Pipeline/South Pipeline area.

CENOZOIC	QUATERNARY		COLLUVIUM, ALLUVIUM, PLAYA	
			GRAVELS	
	TERTIARY		BASALTIC ANDESITE FLOWS QUARTZ LATITE AND RHYOLITE TUFF QUARTZ PORPHYRY DIKES	
MESOZOIC	CRETACEOUS		GRANITIC STOCK	
	JURASSIC			
	TRIASSIC		CHINA MOUNTAIN FM.	
PALEOZOIC	PERMIAN		HAVALLAH FM.	
	CARBONIFEROUS	PENN.	ANTLER PEAK FM. BATTLE CONGLOMERATE	
		MISS.	UPPER PLATE (western facies)	LOWER PLATE (eastern facies)
	DEVONIAN		SLAVEN CHERT	PILOT SHALE WENBAN LIMESTONE
	SILURIAN		ELDER SANDSTONE	ROBERTS MOUNTAINS FM.
	ORDOVICIAN		VALMY FM.	HANSON CREEK FM. EUREKA QUARTZITE
				PROSPECT MOUNTAIN FM. PIOCHE SHALE ELDORADO DOLOMITE SHWIN FM.
	CAMBRIAN		HARMONY FM.	

Alteration

The South Pipeline deposit is contained within an extensive altered and mineralized system currently estimated to be over 3,050 meters long (N-S) and approximately 915 meters wide (E-W). Although economic gold grades do not occur over the full expanse of this system, varying degrees of hydrothermal alteration are evident throughout. Alteration types include oxidation, decalcification, weak contact metamorphism, argillization, silicification and carbonization. Alteration types commonly overlap one another, in no clear pattern. Thus, no distinct sequence of alteration is clearly evident. Multiple phases of hydrothermal processes are postulated. Gold can accompany any individual alteration type or any combination of alteration types. Although the alteration sequence is not clear, the types of alteration are discussed in the order that they may have developed.

Decalcification affects most of the deposit area and is typified by the partial or complete removal of carbonate matrix material. Replacement of calcite is not always present, which either results in the reduction of rock density and an increase in porosity and permeability, or in compaction and volume reduction and an increase of the rock density. Although there is an abundance of pore spaces and voids, no solution textures are present. Dissolved calcite was redeposited in veins and microveinlets throughout the periphery of the deposit. Late-stage calcite microveins crosscut all types of altered rock, and are monomineralic, except where they occur with late iron oxides or follow earlier quartz veining.

Carbonization is typified by a pronounced, black, sooty appearance to the host rock resulting from thermal maturation of organic carbon (Edison and Hallager, 1987). Carbonaceous-altered Srm is composed of the same mineralogy as oxidized material, and has similar alteration and structural characteristics. Carbon occurs as disseminations and wisps, which are commonly localized in bedding planes or fractures, in local concentrations as great as 2 to 3 percent. Carbon-rich zones often contain pyrite (up to 2% by visual estimates) and commonly contain significant concentrations of disseminated or fracture controlled hematite or other iron oxides.

The presence of iron oxides along fractures, and as disseminations and pseudomorphs associated with pyrite and carbon, suggests that reduction/oxidation (redox) relationships in carbonaceous material are complex.

Contact metamorphism from the intrusion of the Gold Acres stock in the deposit area has produced local low-grade/low-temperature metasomatic changes in the Paleozoic

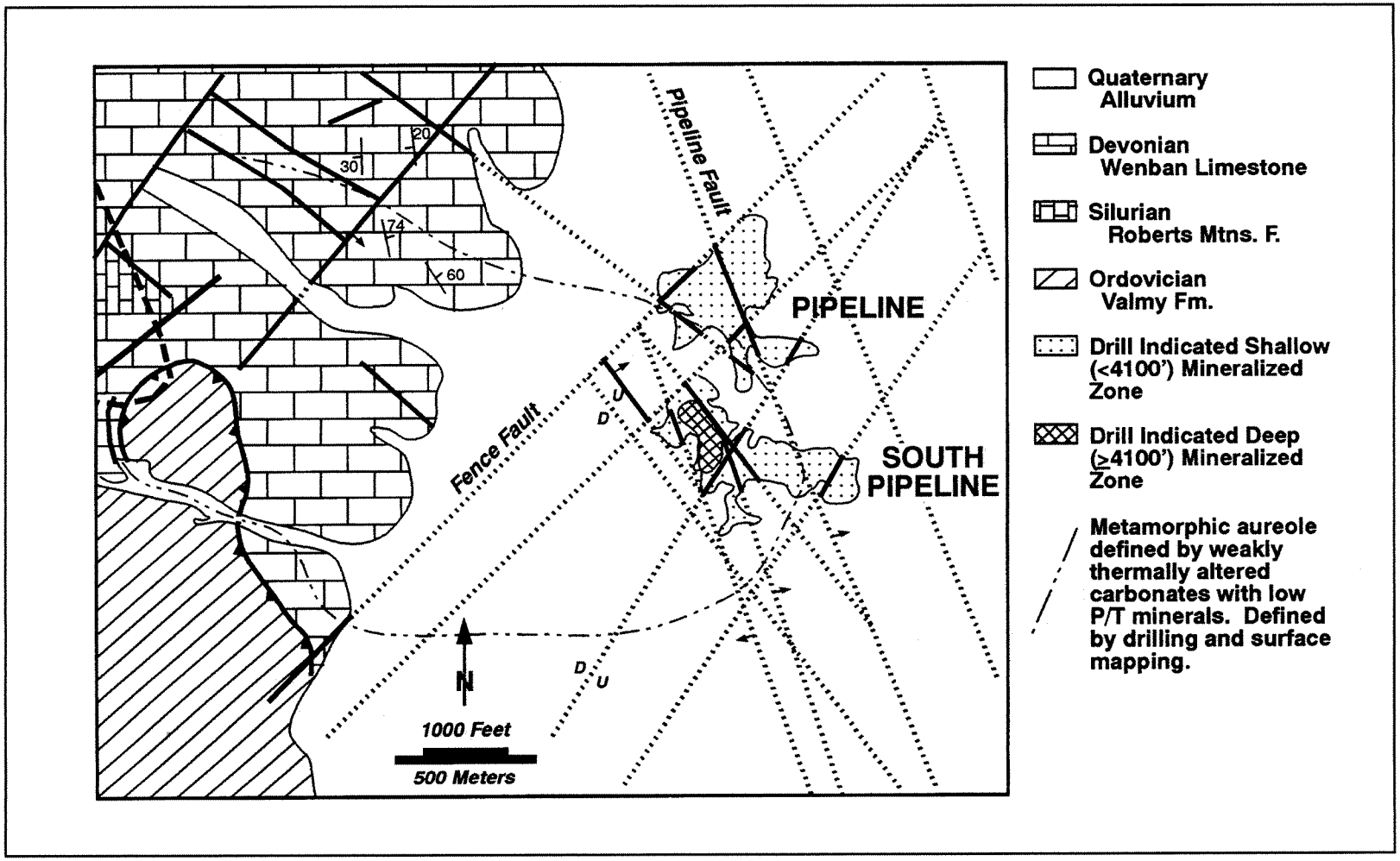

Figure 3—Simplified geologic map of the Pipeline/South Pipeline deposit areas. Drill-indicated Au-mineralized zone outlined for each deposit.

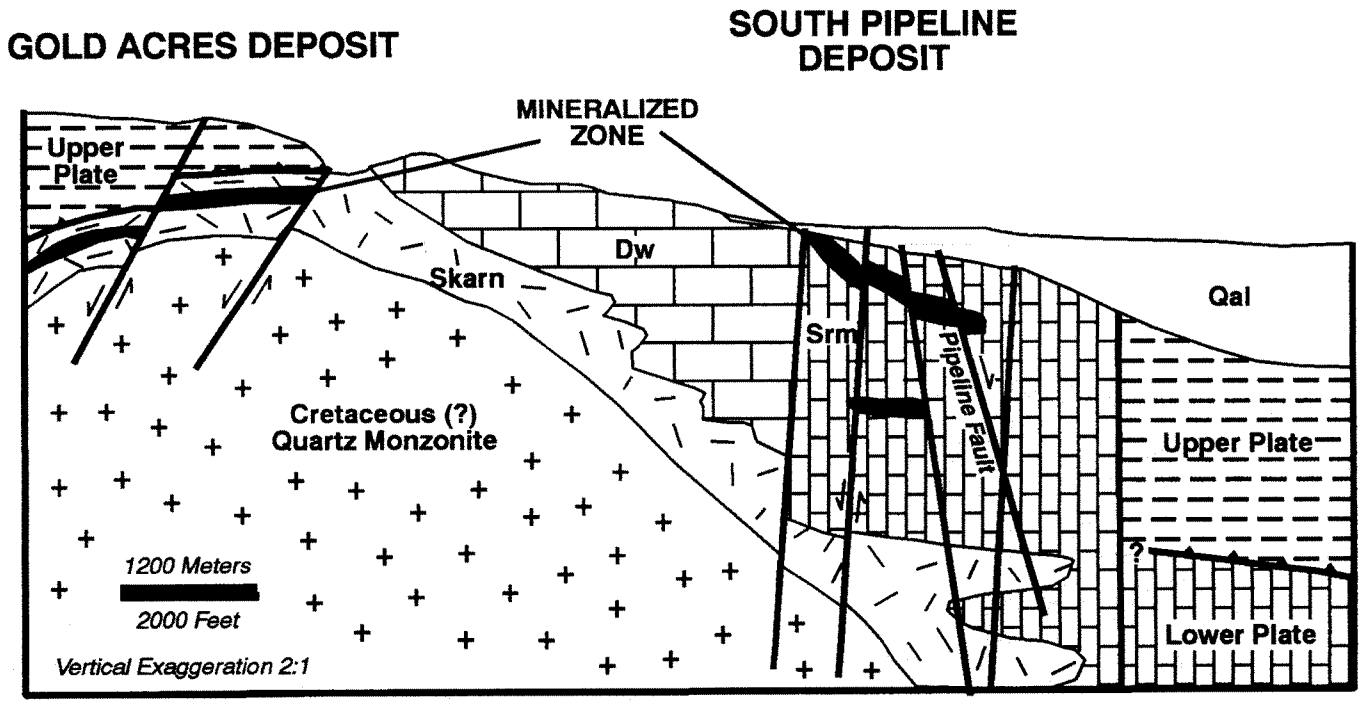

Figure 4—Idealized geologic section of the South Pipeline deposit area. South Pipeline is inferred to be on the eastern limb of a domed feature, and Gold Acres to be on the western limb.

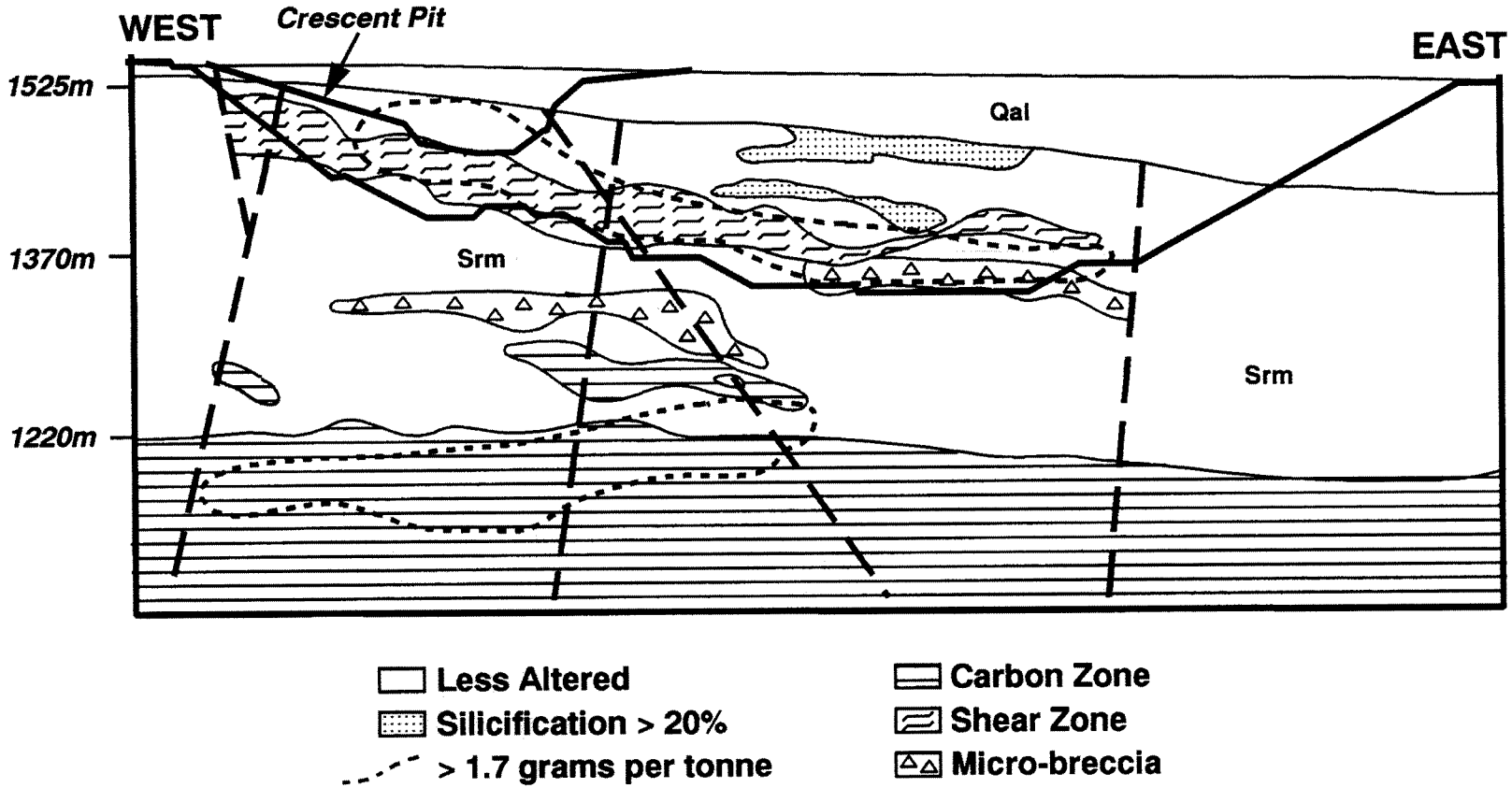

Figure 5—Simplified geologic cross-section through the South Pipeline deposit.

Figure 6—Grade x thickness plot of the South Pipeline deposit. Mineralization is strongly controlled by the structural fabric. Upper gold zone defined by solid line and lower gold zone by dashed line.

host rock. In core samples, the presence of up to five percent of disseminated calc-silicate minerals, or the re-crystallization of limy or siliceous beds, marks the thermal aureole of the stock.

Argillization is characterized by illite and/or sericite and occurs pervasively throughout the rock or as concentrations along fractures. An accessory amount of authigenic sericite grains typically occurs along bedding planes. Some high-grade samples are partially to intensely argillized; some so strongly that the sample is easily squeezed and crumbled in the hand.

Silicification occurs as bedding replacements after decalcification and as microveins. Locally, microveining is intensely developed, forming an interconnected mesh of linear and irregular fillings. Bedding replacement occurs along what were carbonate-rich interbeds, forming a coarse, interlocking, crystalline, granular, central core which grades into a fine-grained exterior. With increasing intensity of silicification these interbeds become massive silicified zones. In silicified rocks,

it is common for segregated and interlocking irregularly shaped, coarse quartz grains to be disseminated through a finer rock matrix. These may have formed by interstitial replacement of carbonate, or by partial redissolution or replacement of angular brecciated quartz fragments. The silicification of scapolite confirms the occurrence of at least one phase of post-metamorphic silicification. It is uncertain whether this silicification was related to the gold mineralizing event.

Oxidation is the most common type of alteration and has effected almost the entire deposit area, including some of the deep carbonaceous units. The oxidation is typically disseminated to pervasive. It is commonly bedding and fracture controlled, and is often present as abundant iron oxide pseudomorphs after iron sulfides. Hematite, identified in polished section, and limonite are common, while goethite and other identified forms of iron oxides occur as stainings. The only pyrite protected from oxidation is contained in carbonaceous material. In the carbonaceous samples, oxidation occurs as fracture coatings, disseminations, and pseudomorphs. Uninterrupted oxidation extends to depths in excess of 395 meters. In some areas, oxidation is isolated from the surface occurring beneath fresh to weakly carbonaceous sedimentary rock at depths in excess of 550 meters.

Mineralization

Gold typically occurs as submicroscopic disseminated grains in both sheared and unsheared Srm associated with all alteration types. Petrographic examinations showed microscopic gold particles most commonly occurred as sparse, very fine (1 or 2 microns), irregularly shaped blebs disseminated through the host matrix. Gold most typically occurs associated with silica, in replaced matrix and in quartz veinlets, and in and on larger limonite pseudomorphs after authigenic pyrite. Gold observed in carbonaceous samples also is associated with silicification, but displayed no obvious association with pyrite.

The original presence of pyrite is inferred from limonite and hematite pseudomorphs; however, pyrite does occur locally in low concentrations (typically <2%) in carbonaceous samples along bedding planes, fractures, open-space fillings, and occasionally as framboids. Extremely fine (1 to 3 micron) pyrite commonly occurs in all samples encapsulated in silica. These occurrences suggest that both authigenic and syngenetic pyrite are present.

Geochemistry

Pulverized samples from seven drill holes (594 composites) from the South Pipeline deposit were analyzed for 31 elements by ICP scanning methods. These data were then merged with fire assay gold data and statistically evaluated. The results of regression analyses indicate that gold is most closely associated with mercury and possibly thallium. Factoring indicates gold appears in two distinct statistical populations: Au, Sb, Hg, ±Tl and Au, As, Fe, -Ca.

CONCLUSIONS

The South Pipeline deposit is one of the largest gold deposits discovered in the Cortez area, and represents one of the most significant gold discoveries in the world in the 1990s. The discovery represents the results of persistent exploration efforts in an active mining district and is indicative of the potential for additional discoveries throughout the region.

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