Geologic Overview of the Getchell Gold Mine Geology, Exploration and Ore Deposits, Humboldt County, Nevada

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INTRODUCTION

This summary focuses on the past history of the Getchell property, its general geology, and current published information relative to gold mineralization. It should provide background and a geologic context for the field tour of Getchell. The Getchell property dates back to 1934 gold discoveries and some of the earliest open pit oxide and sulfide gold production in Nevada. In retrospect, the early gold discoveries were some of the first discoveries of what is now known as Carlin-type, sediment hosted, micron gold deposits. Several other open pit mines were developed on similar deposits in what is now Nevada's Getchell Gold Trend.

Current Getchell Gold Corporation land holdings in the Getchell Trend cover 50 square miles at the northern end of the Osgood Mountains and the Dry Hills. With the 1991 discovery of the high grade underground orebodies from the Getchell Main (sulfide) open pit and the 1994 discovery and initial shaft development of the underground Turquoise Ridge Deposit, the Getchell Trend is entering a new era of bulk tonnage underground gold mining (Table 1).

Under a spring 1999 merger with Placer Dome U.S., Inc., the Getchell Gold Corporation will operate the mine. Placer Dome Exploration, Inc. is conducting the exploration at the property and continuing the reserve and resource expansion and the search for new discoveries. Getchell Gold Corporation is currently optimizing the Turquoise Ridge and Getchell mines through predevelopment work for bulk tonnage underground production.

The tour of the property will examine the surface geology of the existing open pits where the styles of gold mineralization are exposed, along with some key structural, alteration and stratigraphic features that relate to understanding the underground gold orebodies.

On behalf of Placer Dome Exploration, Inc. and Getchell Gold Corporation, welcome to Getchell.

RECENT HISTORY AND STATUS

The Getchell property has in the past been explored mostly for open pit oxide gold deposits. The recently recognized potential of the property for high grade underground deposits has been drill tested only in the 2.5 square mile area centered on the discoveries of Getchell Underground and Turquoise Ridge deposits. The underground potential on the rest of the property remains largely untested and is the focus of current exploration.

When Getchell Gold Corporation was formed in 1996 they were faced with depleted open pit sulfide reserves along the Getchell fault and responded by accelerating the exploration campaign for underground deposits. Drilling down dip of the Getchell Main open pit orebodies led to the discovery of several orebodies in the Getchell fault and in its hanging wall and footwall. The first portal of the Getchell Underground Mine was excavated from the lowest benches at the northern end of the Getchell open pit in 1994. Exploration continued from underground and surface drilling, and underground production expanded as new resources and reserves were added in the Northwest and 186 orebodies. In late 1996 and early 1997 the high grade 194 orebody was discovered by surface drilling northwest of the northern-most Getchell Underground Mine workings. Initial bulk tonnage trackless mining of the 194 soon followed.

In 1986 open pit resources were discovered above what is now the Turquoise Ridge underground mine. The pits were developed by 1993 and mining was completed by 1995. As open pit mining proceeded, several drill holes intersected some gold-bearing veins and stockwork zones in a "traditionally" barren pillow basalt unit in which the shallow holes were generally terminated. The concept that the open pit deposits might be leakage above a blind higher grade deposit was derived and deep holes were designed by Eric Berentsen, Exploration Geologist under the direction of Dick Nanna, then Vice Present of Exploration.

In 1993, hole 93-160-RC penetrated footwall rocks of the pillow basalt and cut 90.0 ft grading 0.522 opt Au in hornfels mudstones. Subsequent offset and exploration drilling led to the Turquoise Ridge discovery. The Turquoise Ridge Mine name was coined on the basis of narrow turquoise veins that outcropped on the hill mined by the open pits. By 1994 the A Zone was delineated and a feasibility study was commissioned as exploration drilling continued on the deposit. On positive feasibility, the sinking of Shaft 1 started in early 1996. A pilot hole had previously cut narrow gold intercepts (hole 95-094-CO, 15 feet grading 0.296 opt Au). As Shaft 1 was sunk, it cut a wide zone of ore grade gold and the Shaft Zone was discovered for later definition. Getchell Gold Corporation continued accelerated exploration of the deposit, and expanded resources and reserves in several orebodies, including the A Zone and the Shaft Zone. As drill results expanded reserves, the production shaft was started by late 1996.

Underground production and concurrent surface and underground exploration continued to expand the resources and reserves. New discoveries were made by surface drill holes south of the deposit (Powder Hill discovery) and north of the deposit (N Zone discovery). Excavation of the production shaft was completed in 1998 and it was put into service by December 1998.

December 1998 announced reserves at the Getchell Property by area are as follows:

TABLE 1. Proven and probable mineable reserves as of December 31, 1998 (Getchell Gold Corporation news release).

Area	Average		Contained Ounces
	Ore Tons	Grade (oz/ton)	
Underground Reserves			
Turquoise Ridge	7,155,800	0.365	2,608,600
North Zone	5,279,800	0.425	2,242,360
Getchell Underground	4,700,900	0.358	1,682,330
Total Underground Reserves	17,136,500	0.381	6,533,290
Surface Reserves			
Hansen Creek (Sulfide)	85,500	0.138	11,800
Section 13	1,139,700	0.044	50,240
Stockpile	138,500	0.085	11,770
Total Surface Reserves	1,363,700	0.054	73,810
Total Proven & Probable			6,607,100

As of December 31, 1998, resources totalled an additional 9.4 million contained ounces of gold.

In 1998 Getchell Gold Corporation sought a partner in developing and exploring the property. On May 27, 1999 Getchell Gold Corporation and Placer Dome U.S. merged. Placer Dome Exploration, Inc. initiated exploration.

In 1999 Getchell Gold Corporation suspended initial underground production to pursue optimizing the mine and support underground exploration as surface and underground exploration continued to delineate and expand the resources in the A Zone, Powder Hill, and the N Zone. The deposits remain open away from the shafts. Step-out and exploration drilling continue. Exploration drilling now indicates that the southern strike extension of the N Zone orebody may extend beneath the A Zone and underground mine infrastructure. Underground exploration and development headings are being excavated southward to access Powder Hill and northward to access N Zone. Surface delineation and exploration drilling to expand the deposit continues.

Ongoing surface and underground exploration has focused on discovery and expansion of Getchell Underground Mine resources and underground deposit discoveries elsewhere on the property.

GEOLOGIC SETTING

The Getchell deposits are sediment hosted, micron-gold deposits of the Carlin type. Getchell deposits are generally controlled by the intersection of mineralized high and low angle faults and favorable stratigraphic units. Mineralized sedimentary units within the Getchell Trend include Cambrian Preble Formation, Ordovician Comus and Valmy Formations, and Pennsylvanian Etchart Formations.

The Osgood Mountains and the Dry Hills formed during Basin-and-Range age, extensional faulting. These fault blocks are capped by Miocene andesitic basalt and the volcanic rocks are tectonically tilted and surrounded by Quaternary alluvial gravel-filled, fault-bounded basins. Geologic mapping of the mountain ranges (Hotz and Willden, 1964; Jones, 1991) documents Cambrian through Pennsylvanian to Permian metamorphic and sedimentary rocks, which are cut by Cretaceous stocks. These units are unconformably overlain by the Miocene volcanics. The Cretaceous (92 Ma) Osgood Mountains granodiorite stock (Groff, 1996; Silberman et al., 1974) cores the Osgood Mountains and is exposed within a horst of metamorphic and sedimentary country rocks. The horst in the core of the Osgood Mountains plunges north to the north end of the range.

On the east flank of the Osgood Mountains, in the vicinity of the Getchell and Twin Creeks mines, the rocks, low angle structures and internal unconformities generally have shallow (15 degree) north dips and northeast strikes. Major offset of the composite stratigraphic section has occurred only along a few major north-south, northeast and northwest faults (e.g. NS Getchell fault). Mapped formations (Groff, 1996; Hotz and Willden, 1964; Jones, 1991; compiled and ongoing PDX mapping) include the Cambrian Preble, Ordovician Comus, Valmy, and Pennsylvanian to Permian Etchart Limestone (Antler Limestone equivalent), and the allochthonous Goughs Canyon and Farrel Canyon formations. Rocks of the Comus and Valmy are locally juxtaposed by the Roberts Mountain thrust (1999 Placer Dome Exploration, Inc. drill holes).

At a more detailed scale the property geology is more complex. The Osgood stock and other associated poorly exposed and projected blind intrusives (geophysical survey data) have locally strong and wide contact metamorphic aureoles which overprint metamorphic and sedimentary country rock formations. The contact metamorphic aureoles include garnetite and wollastonite gneiss and porphyroblastic schist, porphyroblastic phyllite, phyllite, spotted hornfels, biotite and chlorite hornfels. In the vicinity of major known gold deposits at Getchell, this contact metamorphic overprint is in turn cut by gold-related hydrothermal alteration assemblages and often well-developed varieties of tectonites. Most gold host rocks are fine-grained sedimentary rocks; with the metamorphic, alteration and tectonic overprints, microfossils have degraded, and exact lithologic correlation and mutual contact and stratigraphic and structural relationships are often interpretive and equivocal. This small scale geologic complexity and questions raised by key drill hole exposures have prompted a geologic remapping campaign over the entire property that is underway and will be reported in the future.

Many of you will be familiar with the published Lower Paleozoic and Mesozoic history of north-central Nevada. Shallow-water carbonate-dominated sedimentary rocks originated on a continental shelf to the east; more siliceous sedimentary rocks (chert, shale, quartzite) to the west are interbedded with mafic volcanics and thinner calcareous units (Groff, 1996; Jones, 1991; Hotz and Willden, 1964). A transitional facies was deposited on the continental slope between the western and eastern facies, perhaps where the Osgood Mountains are now (Hotz and Willden, 1964). This interpretation is consistent with both the depositional style of the sedimentary rocks, and the location of the (^{87}Sr / ^{86}Sr) = 0.706 isopleth marking the ancient continental margin in this region (Groff, 1996; Solomon and Taylor, 1989).

The Antler Orogeny of late Devonian to Early Mississippian time thrust the western siliceous rocks over the eastern carbonate rocks; the transitional facies in the Osgoods may have moved only a short distance or not at all (Hotz & Willden, 1964). Current drill results indicate the Roberts Mountains thrust is locally present, placing Ordovician Valmy Formation over Ordovician Comus Formation rocks. The exact map and cross section pattern of the Roberts Mountains thrust at the property is one issue being addressed by current mapping and hole logging.

At least three younger orogenic events in the region complicate the geology: the Sonoma Orogeny of Late Permian to Early Triassic time: the Sevier Orogeny of Late Jurassic to Mid-Cretaceous time, and Basin and Range extension beginning in the Cenozoic and continuing to present (Hotz and Willden, 1964; Bloomstein et al., 1991; Jones, 1991; Shigehiro, 1999; Cline & Hofstra, 2000). These orogenies produced the present complex interference pattern (at a detailed scale) of faults and folds, many of which show evidence of multiple deformations, including refolding and recurrent faulting.

STRATIGRAPHY

Getchell gold deposits are within rocks that in the past have been mapped as Cambrian Preble Formation, Ordovician Comus Formation and Ordovician Valmy Formation. Exact and unequivocal correlations among the Preble, Comus and Valmy rocks are the subject of ongoing interpretation.

Informal mine nomenclature has adopted a lithologic terminology, (Berentsen et. al. 1998) based on the distribution of rock packages within and around the discoveries. Lower Sediments are black carbonaceous, siliceous mudstones and local silty limestone. Overlying the Lower Sediments are brown Middle Sediments, consisting of biotite hornfels and phyllite mudstone (often calcareous) and limestone (Shigehiro, 1999; Getchell 1998, Berentsen et. al., 1998). Lower Sediments have been correlated with Comus Formation and Middle Sediments with Preble Formation, though these correlations have been questioned (Shigehiro, 1999). The reversed stratigraphy (Cambrian Preble over Ordovician Comus) has been explained either as a thrust or an overturned fold (Shigehiro, 1999). Above the Lower and Middle sediments are basaltic flows and tuffs and interbedded sedimentary rocks including shales, cherts, and quartzites which have been mapped as the Valmy Formation (Hotz and Willden, 1964).

From the literature the Preble Formation consists of a lower phyllitic member, a middle calcareous member, and an upper phyllitic member. These are tightly folded, with a westward vergence and are evidence that the Preble Formation is a regionally metamorphosed package of rocks (Madden-McGuire and Marsh, 1991).

The Comus Formation includes calcareous rocks, argillaceous rocks, pillow basalts and mafic tuffs, and are lithologically distinct from the type-locality of Comus (Madden-McGuire and Marsh, 1991). Hotz and Willden (1964) consider the Comus Formation to be part of the transitional facies, and to be autochthonous; e.g. not moving during the Antler Orogeny.

The Valmy Formation consists of pillow basalts, radiolarian ribbon cherts, argillites, quartzites, and minor limestones. The Valmy and Comus Formations are more or less coeval and were deposited in different portions of the Ordovician basin along the continental margin. The Valmy was thrust over the Comus during the Devonian to early Mississippian Antler Orogeny. The contact between the Valmy and Comus is reported by Groff (1996) and Berentsen (1998) to be locally depositional rather than entirely structural. The nature of this contact is of continuing debate with some conflicting evidence as current exploration drilling proceeds. Better exposures of the contact can be seen in drill core. Valmy Formation thrust over Comus Formation contacts are clearly exposed in some 1999 holes.

Further north, the entire sequence is overlain by the Pennsylvanian/Permian Etchart limestone which is in both high angle fault and unconformable contact with the Ordovician sequence.

The allochthonous Farrel Canyon formation (Hotz and Willden, 1964) overlies the Etchart to the north and is overlain by Miocene volcanics.

The Cretaceous Osgood granodiorite stock and other lithologically similar and presumed correlative stocks are characterized by having associated pegmatite, aplite, and dacite dikes. There is also a suite of porphyritic andesitic dikes younger than the granodiorite suite (Hotz & Willden, 1964; Gingrich, personal communication, 1998).

STRUCTURE

The structural geology of the Osgood Mountains includes several terranes and subterrranes juxtaposed as a result of translational, compressional, and extensional tectonic movements over time (Jones, 1991). As a result, it is not surprising that faults locally show evidence of reactivation and more than one sense of motion. As with so much of the Basin and Range province, faults can be grouped into domain related, "families" of faults as follows.

The mineralized Getchell fault is currently a basin-and-range extensional fault, and has been active since the Cretaceous emplacement of the Osgood Mountains stock. The eastern margin of the stock is locally controlled by this fault. Kinematic indicators on the fault show early right-lateral, strike-slip motion, rotating through oblique motion to later normal motion (Berentsen et al., 1996; Boskie, 2000). The Getchell fault strikes approximately N to NW parallel to the range front, dips eastward, and is the dominant structure on the property. Orebodies occur both in the footwall (Getchell Main Underground) and in the hanging wall (both Getchell Main Underground and Turquoise Ridge) of the Getchell Fault. It is also a master fault to a series of steeply-dipping north-striking faults east of and antithetic to it (Berentsen et al., 1998).

Another group of faults strikes northeast and dips steeply northwest, as marked by the Turquoise Ridge fault and fracture zone. Several Turquoise Ridge orebodies are present within and along the fault and nearby parallel faults and fractures. These high-angle normal faults cut the granodiorite stock and offset gold mineralization, indicating reactivation of the fault after gold mineralization (Shigehiro, 1999). High grade portions of the orebodies in the Getchell Main pit are at the intersections of these northeast faults with the Getchell fault. However, the Northeast faults truncate orebodies in the Getchell Underground Mine (Tretbar, 2000). These NE shears accompany a regional set of N30°E folds and fractures interpreted to date from the Antler Orogeny (Berentsen et al., 1996).

A later set of N35°W folds and faults is interpreted to date from a Jurassic event (Berentsen et al., 1996, 1998). This set, along with the northeast faults, acted as pseudo-conjugate faults during later deformation. The intersections of the folds created domes which locally control gold mineralization.

A series of low angle breccia zones may correlate with thrust faults (Berentsen et al., 1998) or tectonized stratigraphic units. For the most part these do not outcrop; they are known from mine workings and drill holes.

A set of E-W folds, fractures, and minor faults (Boskie, 2000; Tretbar, 2000) truncate and offset some orebodies in the Getchell Main Underground.

Dacite dikes and sills associated with the granodiorite stock intruded several of the faults and fracture sets. In particular, the low-angle shears and the higher angle pseudo-conjugate NE and NW structures (Berentsen et al., 1998) often controlled the intrusion of dikes and sills.

Boskie (2000) documented three folding events which predate most of the surface-exposed faults. The oldest has northerly-trending fold hinges. The second has east-trending fold axes, plunging moderately (30-40°) to the east, and reclined. This generation of folding is better-developed, and more obvious. The third generation trends NE to NNE, also plunges moderately, and are upright. Additional work will correlate these folds with regional deformation events.

GOLD ORE DEPOSIT GEOLOGY

Getchell gold deposits are associated with north-south, northeast and northwest high angle faults and fracture zones particularly where the mineralized high angle faults cut across favorable lithologic units and low angle fault and fracture zones. The best ore grades and continuities are in areas where all these features intersect, particularly in the hinges of NE and NW trending faulted anticlines. With this array of gold controls, the orebodies resemble the map and cross sectional patterns typical of composite structural and stratigraphic oil traps within oil fields in faulted sedimentary basins.

Gold in the deposits is typically submicroscopic with the best grades associated with very fine grained, auriferous, arsenical pyrite that often grows on barren, premineral pyrite grains (Cline and Hofstra, 2000, Bowell et.al., 1999). Younger realgar and orpiment (see below), for which Getchell is famous, generally carry only trace quantities of gold.

Fault controlled ore-grade material is sometimes loosely described as “grey ore” (e.g. Powder Hill orebody at S Turquoise Ridge) and is not associated with carbonaceous alteration. More often, high grade ores are black and highly carbonaceous with abundant very fine grained pyrite and arsenical (auriferous) pyrite. The arsenical pyrite sometimes exhibits megascopic orthorhombic cross sections and resembles marcasite.

TURQUOISE RIDGE MINE

The Turquoise Ridge Deposit includes four main orebodies about 3,500 feet east of the Getchell Main pit in a down faulted structural block east of the Getchell fault. From south to north they are Powder Hill, Shaft Zone, A Zone and N Zone. The mutual geologic relationships among these orebodies continues to be defined as development and exploration drilling continues. The orebodies cluster within a north-dipping (15 degrees) mineralized zone that is now about 3,500 feet north-south and 2,000 feet east-west in plan view, through a vertical range of about 3,000 ft.

Host rocks are correlated with the Comus Formation and include mudstone, calcareous mudstone, carbonaceous and calcareous silty limestone, calcarenite and breccia. In addition, some ore grade intervals are present along mineralized faults that cut interbedded pillow basalt. Dacite and dacite porphyry dikes often control the distribution of ore grade gold particularly where they are cut by high angle mineralized faults.

GETCHELL UNDERGROUND

Getchell Underground Mine deposits are typically within or very near the Getchell fault. Past open pit mining developed orebodies within the fault and within its hanging wall and footwall. Underground production and current reserves are in the footwall of the fault in metamorphosed equivalents of the Comus Formation. The 194 orebody at the north end of the present Getchell Underground workings is about 800 feet into the footwall of the Getchell fault and consists of mineralized breccias at fault and fracture intersections. Cross cutting relationships within the orebody indicate several generations of breccia, the youngest being developed in a cave collapse environment. Cave fill sediments are not completely lithified and are occasionally ore grade since they include ore grade fragments that apparently collapsed and were deposited on the cave floor (Tretbar, 2000).

OUTLYING DEPOSITS

Summer Camp, Hansen Creek and Section 13 open pit resources exhibit similar fault and fracture dominated controls with some stratabound components. Summer Camp and Hansen Creek pits have been mined in the past for oxide deposits along the hanging wall of the Getchell fault and along intersecting NE fracture and fault sets and some low angle faults. Host rocks are generally tectonized Comus? carbonaceous mudstone and calcareous mudstone which have been strongly silicified after decalcification. Section 13 resources are exposed exclusively in drill holes and are fault controlled with a projected stratabound component in cross section within tectonized mudstone and altered and tectonized siltstone in the Valmy Formation.

GOLD MINERALIZATION

There have been at least two episodes of gold mineralization (Groff, 1996; Cline & Hofstra, 2000), a minor one after the emplacement of the granodiorite stock around 83 Ma, and the main mineralization much later, during Eocene time. There may have been as many as five mineralizing episodes (Groff, 1996), but only these two contributed substantial gold.

Tretbar (2000) has made a particularly interesting contribution to determining the age of gold deposition. He worked with galkhaite, $(Cs,Tl)(Hg,Cu,Zn)_6(As,Sb)_4S_{12}$, a rare mercury sulfosalt that is found at the Getchell Mine. It contains Rb but not Sr, and is therefore a good candidate for Rb/Sr dating. The resulting age is 39.5 ±3 Ma. The notable feature of this date is that it is a direct age of gold deposition, not an upper or lower boundary. Galkhaite contains gold up to 117 ppm, as sub-micron inclusions or lattice constituents. In addition, it occurs in higher-grade ore, concentrated along ore-waste contacts and structural intersections, and is frequently enclosed within gold-bearing silica. Thus it is part of an ore-forming event, not a pre-ore or post-ore event.

Gold occurs in two major associations on the property: micron to sub-micron inclusions in quartz, and chemically held gold in arsenian pyrite (Bowell et al., 1999). The first is most common in near-surface ore (especially from the open pits) and in veins; the second in deeper refractory ore. Gold also has been found - rarely - as discrete free grains in breccias in the Getchell Main Underground Mine (Bowell et al., 1999).

The Turquoise Ridge deposits were formed deeper than the Getchell Underground deposits, as well as occurring at greater depth below the present erosion surface (Berentsen et al., 1996; Groff, 1996). TR and GU deposits therefore have slightly different mineral paragenesis, fluid compositions, temperature and pressure of formation.

Shigehiro (1999) and Cline & Hofstra (2000) outline the following sequence of alteration and mineralization events synthesized for the property:

Pre-ore fluids associated with the emplacement of the stock dissolved carbonate, preparing the rock for later mineral deposition. The pre-ore fluids deposited quartz-pyrite veins with very low gold. Temperatures and compositions of these fluids were highly variable: (120 to >360°C; 1% to 21 wt% NaCl).

Main ore-stage fluids contain CO_2, allowing them to continue to dissolve carbonate in host rock, and H_2S, allowing them to transport gold. These fluids had moderate salinity and temperature (180 - 220°C; 4% - 5 wt% NaCl), with a pressure of around 330 bar (corresponding to >1.2 km depth). Reactions between sulfur in the fluids and iron in the host rock caused gold-bearing pyrite to precipitate in the prepared pore spaces. The range in isotopic values in ore-stage fluids imply that they are not purely magmatic, but have a deep metamorphic and/or magmatic origin, variably diluted with evolved meteoric fluid.

Later ore-stage fluids did not react with host rock as extensively; instead, coarse realgar and calcite precipitated in open space in response to cooling. These fluids had temperatures of 115 –155°C, with salinity similar to the main ore-stage fluid; they had less CO_2 than the main ore-stage fluid. Stable-isotope composition implies that late ore-stage fluid was diluted with variably-exchanged meteoric water (Cline & Hofstra, 2000). Cline and Hofstra (2000) suggest that the main ore stage was the mid-Tertiary event, significantly separated in time from the pre-ore ground-preparation event.

A post-ore event deposited coarse calcite in open fractures, probably from much later meteoric water.

The Getchell property is famous for its arsenic sulfides. Orpiment grew late in the main-ore stage, probably as it was cooling. Realgar grew in the late-ore stage, after orpiment (Groff, 1996; Shigehiro, 1999; Cline & Hofstra, 2000).

A feature of the Getchell deposits that is not yet fully incorporated into this geochemical picture is the strong spacial association between gold and hydrocarbons (Berentsen et al, 1996).

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