GEOLOGY OF THE GOLDSTRIKE MINE
Elko County, Nevada

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Introduction

The Goldstrike gold mine is located 24 miles northwest of Carlin in northeast Nevada. The first development and production on the property was in 1976-77 by Pan Cana Industries who mined ore from an altered granodiorite intrusive. Since 1978 the mine has been operated by Western States Minerals Corporation in a joint venture partnership with Pan Cana Industries. Since that date the mine has been steadily expanded. Production has been by open pit from a number of deposits, the ore being treated by cyanide heap leaching.

Geologic Setting

The Goldstrike mine is located along a well defined northwest trend of disseminated gold deposits in northwest Nevada "Figure 1". This district has a total production and known reserves of approximately 15 million ounces of gold. These deposits are located on the northeastern edge of extensive Miocene volcanics of similar age to the gold mineralization. An extensive magnetic high also exists in the area of the volcanics and presumably a large shallow intrusive. Heat from this intrusive developed gold bearing hydrothermal systems along its flanks, that have been localized by deep seated northwest trending fractures.

The majority of the rocks in this area are sedimentary rocks of Ordovician to Devonian age that were deposited in the Cordilleran geosyncline. In the eastern (miogeosynclinal) part of the geosyncline the sediments were predominately limestones and dolomites with minor clastic sediments; while in the western (eugeosynclinal) part they were predominately cherts and clastic sediments with minor volcanics. These distinct assemblages, of similar age, are commonly referred to as the carbonate or eastern facies, and the siliceous or western facies of the Lower Paleozoic of Nevada. A transitional facies of the Lower Paleozoic is also recognized. These sediments were deformed in the Antler orogeny of Late Devonian age; the rocks of the western siliceous facies being thrust eastwards over the rocks of the eastern carbonate facies, along the Roberts Mountain thrust. Basin and range block faulting in the Tertiary, followed by erosion, has resulted in the removal of upper plate rocks, to form windows, which expose the lower plate rocks.

The Lower Paleozoic sediments are intruded by small stocks and dykes of Cretaceous and Tertiary age and overlain in some areas by volcanics and sediments of Tertiary age. A number of the larger disseminated gold deposits in the district, such as Carlin and the Maggie Creek/Gold Quarry deposits, are located within the windows and hosted by lower plate rocks of the carbonate or transitional facies. The Goldstrike deposit is an exception, in that the major host for the gold mineralization is the Ordovician Vinini Formation of the western siliceous facies.

Geology of the Goldstrike Mine

Stratigraphy

With the exception of Tertiary sediments, all the sediments at Goldstrike belong to the Ordovician Vinini Formation. It is composed of argillites, shales and siltstones with minor quartzite, chert and limestone. The argillites are carbonaceous(graphitic) while the shales may or may not be carbonaceous. Bedding thicknesses are generally ¼" to ½" with the exception of some thick quartzites and sandy silstones which are probably turbidites. Limestones are rare and the clastic sediments are essentially non-calcareous. Silicification of the sediments is common, particularly in the Long Lac area, which may be due to contact metamorphism by the adjacent granodiorite intrusive, as well as the later hydrothermal event. To the west of the mine area, the Vinini is covered by Quaternary/Pliocene tuffaceous siltstones and conglomerates.

Igneous Rocks

The Vinini is intruded by a stock of granodiorite to locally diorite composition, which is also locally porphyritic "Figure 2". In the vicinity of the stock, dykes and sills of similar composition are relatively common. In the mine area, the intrusive is strongly altered to clay and sericite, plus quartz and pyrite in mineralized zones. Using the potassium/argon method, biotite from the granodiorite has been dated at 121 ± m.u., or Early Cretaceous.

Dykes of quartz latite and latite also intrude the Vinini along major faults particularly those of northwest trend and in mineralized areas. These dykes are invariably altered to sericite and clay and their original composition is difficult to discern, though some remnants of K-feldspar can be seen. The latites have not been dated but are younger than the granodiorite intrusive and older than the gold mineralization.

Metamorphic Rocks

The granodiorite intrusive contains xenoliths of skarn, calc-silicate hornfels and quartzite some of which are several hundred feet in size. The skarn is composed of garnet, epidote, diopside, tremolite, calcite and quartz. Chalcopyrite, scheelite, and hematite in non economic proportions also occur and are evidently related to skarn formation and not the later gold mineralization. As there are no massive limestones of this size in the Vinini Formation, it is likely that these large xenoliths are originally limestones and quartzites, equivalent to Devonian limestones outcropping to the south at the Blue Star mine.

Structure

The Vinini Formation has generally gentle dips, except in the vicinity of faults, where it may be strongly folded, fractured and brecciated. Both the Vinini and the granodiorite are cut by both high angle and low angle thrust faults. Three main sets of high angle faults are evident; northwest, northeast and north-south "Figure 2". All these structures plus the low angle structures are pre-mineral, though there has been post-mineral movement in some cases. The extensive alteration and brecciation in some areas, such as at the Long Lac deposit, may be due to hydrothermal brecciation.

Mineralization and Alteration

Gold mineralization at Goldstrike occurs in the Vinini sediments granodiorite, latite and skarn, wherever these rocks have been sufficiently fractured or brecciated to allow access to hydrothermal solutions. The best mineralization occurs at intersection of high angle structures, but also following low angle structures "Figure 3". The ore bodies are therefore typically tabular to elongated lensoid in shape, with increased thickness and grade occurring where the low angle thrust faults are intersected by high angle structures. The northwest faults have a dominant control on mineralization, as mineralized zones are 200' - 1000' long in a northwest direction while only 50' - 200' wide across the fault zone. There may also be a lithological control on the mineralization particularly where unusually thick zones of brecciation occur, such as at Long Lac where the ore zone is up to 120' thick "Figure 4". The type of host rock is of secondary importance as an ore control, though the Vinini is the best host followed by the skarn, latites and granodiorite. The Vinini is non-calcareous, but has thin bedding and is amenable to brittle fracture. The presence of carbon in some of the Vinini sediments may also have caused deposition of gold from the ore fluids. The skarn can comprise 10-20% calcite and is therefore susceptible to replacement by hydrothermal solutions.

In general, proximity to the granodiorite intrusive appears to be a favorable environment for the localization of mineralization, probably due to faulting and fracturing at the time of emplacement of the granodiorite. Both oxidized and unoxidized mineralization occurs at Goldstrike. The oxide ore extends to a maximum depth of 300 feet, while in some areas unoxidized sulfide ore is located only 60 feet below the surface, in areas of perched water tables.

The unoxidized mineralization consists of fine-grained, gold-bearing, pyrite and marcasite disseminated through brecciated and strongly altered host rock. In the eastern part of the Long Lac area, sheared and brecciated granodiorite has been replaced by quartz, sericite and clay. Fine to very fine grained pyrite and marcasite are scattered throughout the altered host rock as single grains or very fine grained aggregates. Concentrations of pyrite/marcasite can be a few percent, up to 20%, of the mineralized rock. The higher concen-

tration of sulfides and significantly higher gold values are in areas of sericite/clay replacement rather than with the siliceous replacements. The presence of pyrite/marcasite does not necessarily imply the presence of significant gold. Pyrite generally appears to overlap marcasite in time of deposition as it is both enclosed by and occurs as partial rims on marcasite. There are at least three stages of quartz deposition, the earliest replacing the host rock followed by two stages of fracture filling. The sericite/clay alteration appears to be later than the silicification of the host rocks but earlier than the fracture fillings. Minerals observed in the quartz veinlets include barite, jarosite, variscite, chalcedony, alunite, calcite, aragonite, pyrite, marcasite, stibnite, realgar, orpiment, arsenopyrite, sphalerite and native gold. The native gold is rare in these veinlets and is very fine grained (1-4 microns). The bulk of the gold is intimately associated with pyrite and marcasite.

Oxide mineralization has been developed from the sulfide mineralization by oxidation, usually above the water table. The gold-bearing sulfides have been altered to goethite, resulting in the liberation of the gold, which is then amenable to leaching by cyanide solution. There is very little difference in gold values between the oxide and sulfide mineralization. Assays of high grade ore may reach a maximum of 2 ounces/ton gold. Gold-to-silver ratios are high, in the range of 20:1.

Alteration at Goldstrike is intense and extensive, though approximately centered on areas of mineralization. The Vinini Formation and the intrusives have undergone sericitic and argillic alteration extending for considerable distance around areas of mineralization "Figure 2." Clay minerals are mostly kaolin with some montmorillonite. Hydrothermal carbon is associated with some deposits, but is of limited extent. Silicification of sediments and fault breccia, has resulted in outcrops of jasperoid, overlying or close to most areas of mineralization. These jasperoids are anomalous in gold, arsenic, antimony and mercury.

Studies of fluid chemistry and temperatures have not been done, but the characteristics of the gold deposits at Goldstrike are similar to other epithermal, "hot springs," disseminated gold deposits. If there is any difference to neighboring deposits such as Carlin, it is the unreactive nature of the host rocks at Goldstrike and therefore the dependence on strong fracturing for the development of ore bodies. Consequently, individual ore bodies are smaller in size than at larger neighboring deposits with calcareous host rocks, though gold values are somewhat similar.

Acknowledgements

I would like to thank all the geologists and engineers that have worked at Goldstrike and contributed to an understanding of the geology and the development of a successful mining operation. In particular, I would like to thank Charles Sulfrian and Tom Rich for help with this paper and to Russell Honea for petrographic descriptions.

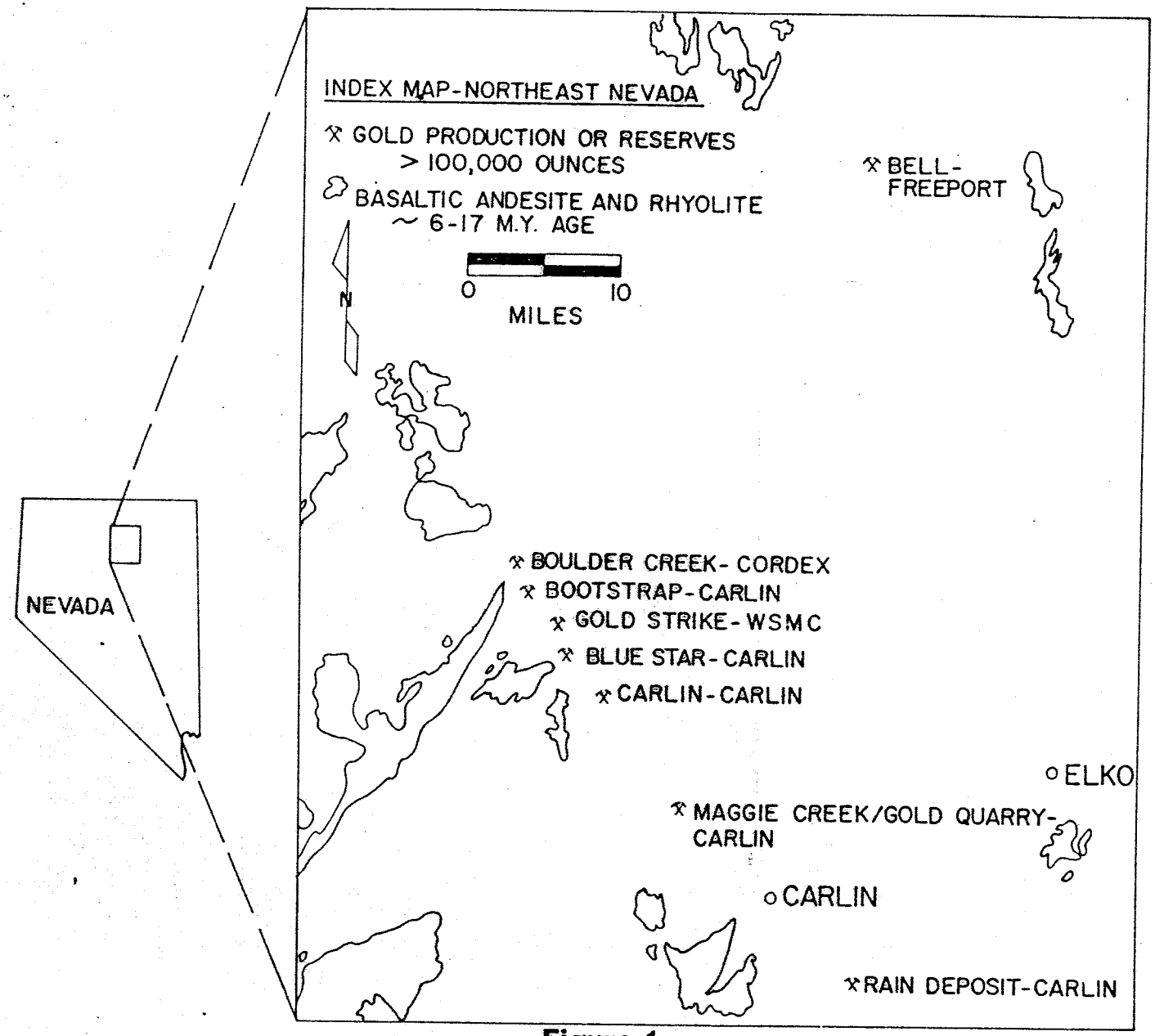

INDEX MAP-NORTHEAST NEVADA
GOLD PRODUCTION OR RESERVES
> 100,000 OUNCES
BASALTIC ANDESITE AND RHYOLITE
~ 6-17 M.Y. AGE
N
0
10
MILES
NEVADA
BELL-
FREEPORT
BOULDER CREEK- CORDEX
BOOTSTRAP-CARLIN
GOLD STRIKE-WSMC
BLUE STAR-CARLIN
CARLIN-CARLIN
ELKO
MAGGIE CREEK/GOLD QUARRY-
CARLIN
CARLIN
RAIN DEPOSIT-CARLIN

Figure 1

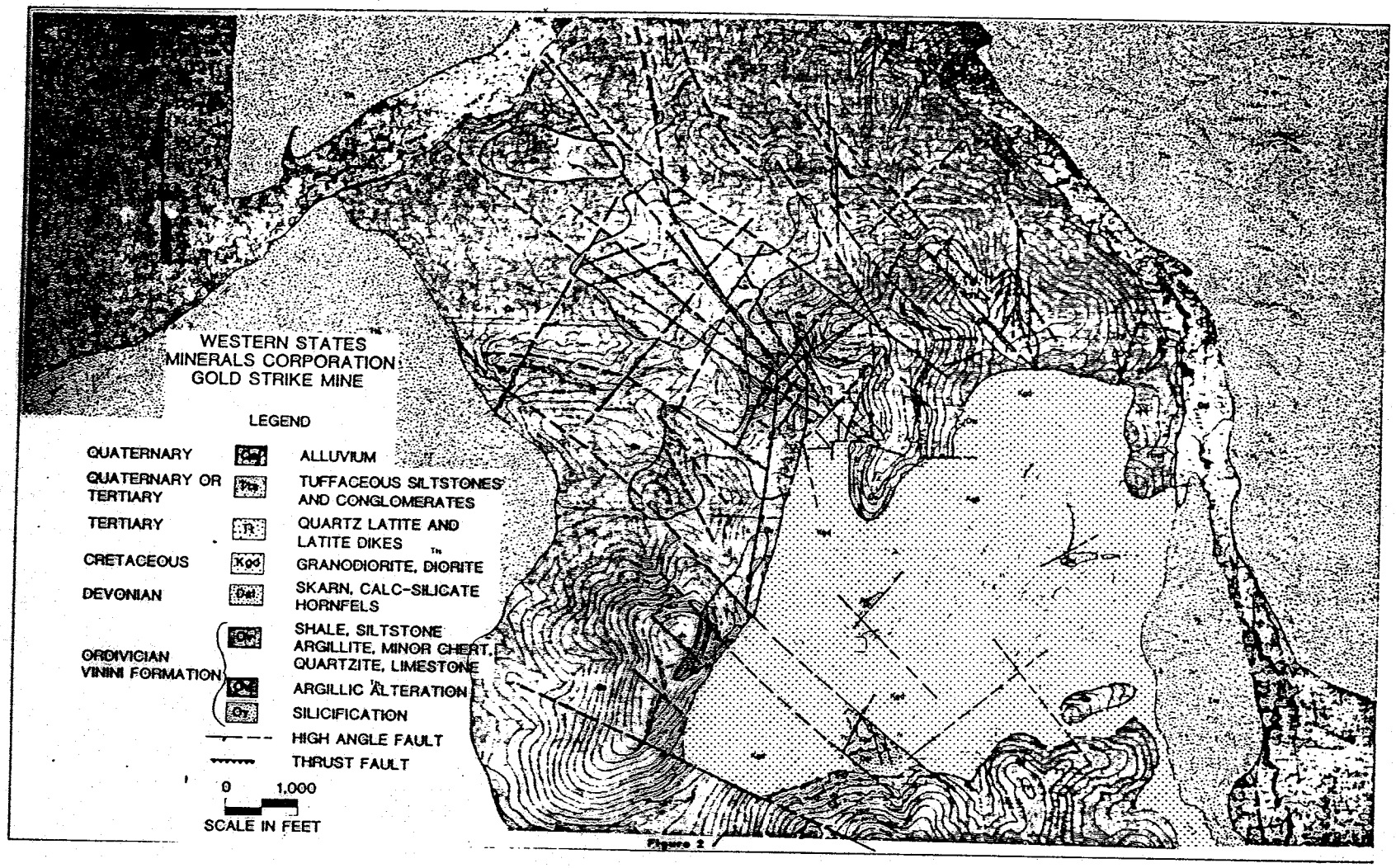
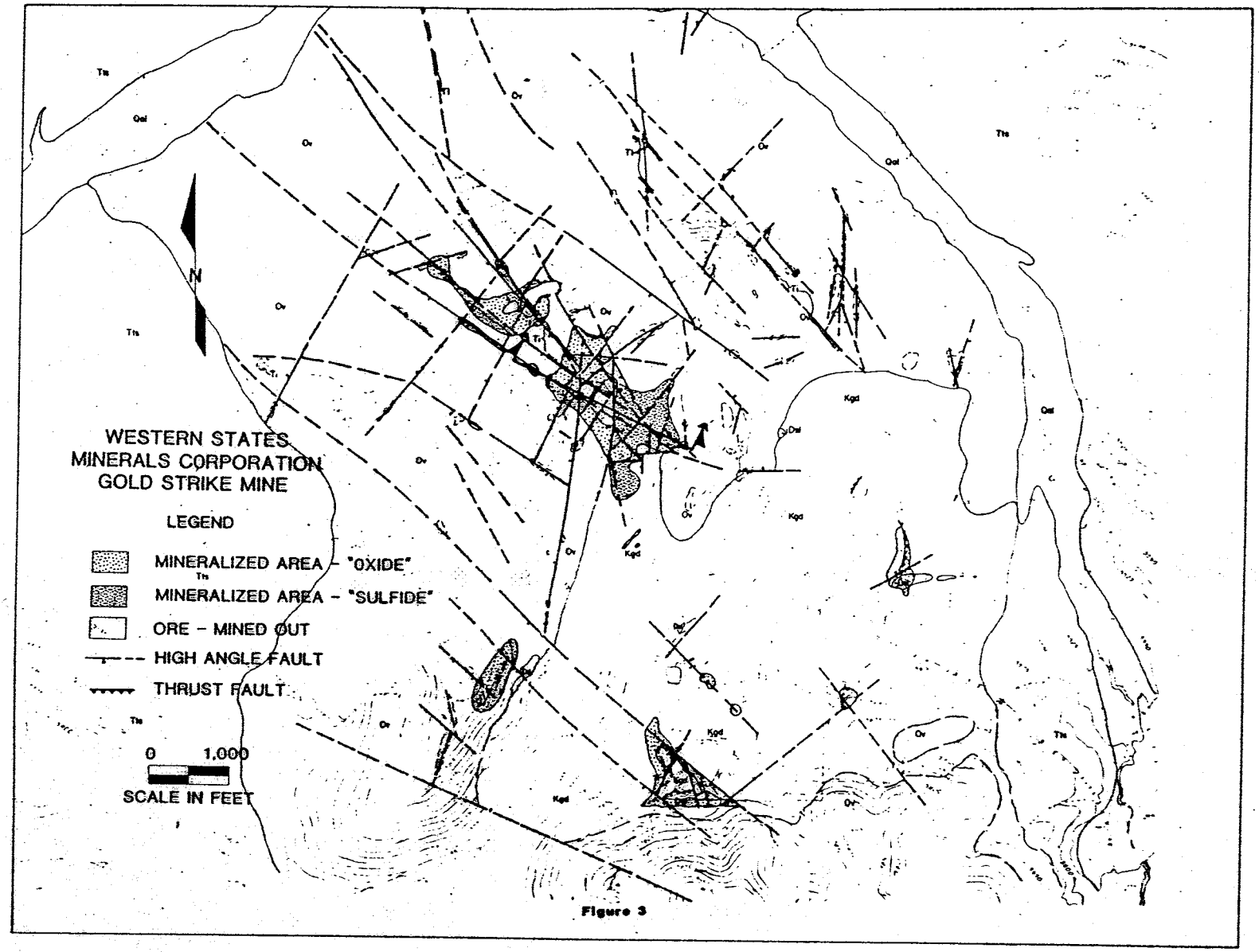

WESTERN STATES
MINERALS CORPORATION
GOLD STRIKE MINE
LEGEND
QUATERNARY
ALLUVIUM
QUATERNARY OR TERTIARY
TUFFACEOUS SILTSTONES AND CONGLOMERATES
TERTIARY
QUARTZ LATITE AND LATITE DIKES
CRETACEOUS
GRANODIORITE, DIORITE
DEVONIAN
SKARN, CALC-SILICATE HORNFELS
ORDIVICIAN VININI FORMATION
SHALE, SILTSTONE ARGILLITE, MINOR CHERT, QUARTZITE, LIMESTONE
ARGILLIC ALTERATION
SILICIFICATION
HIGH ANGLE FAULT
THRUST FAULT
0
1,000
SCALE IN FEET

Figure 2


WESTERN STATES
MINERALS CORPORATION
GOLD STRIKE MINE
LEGEND
MINERALIZED AREA - "OXIDE"
MINERALIZED AREA - "SULFIDE"
ORE - MINED OUT
HIGH ANGLE FAULT
THRUST FAULT
0
1,000
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N

Figure 3

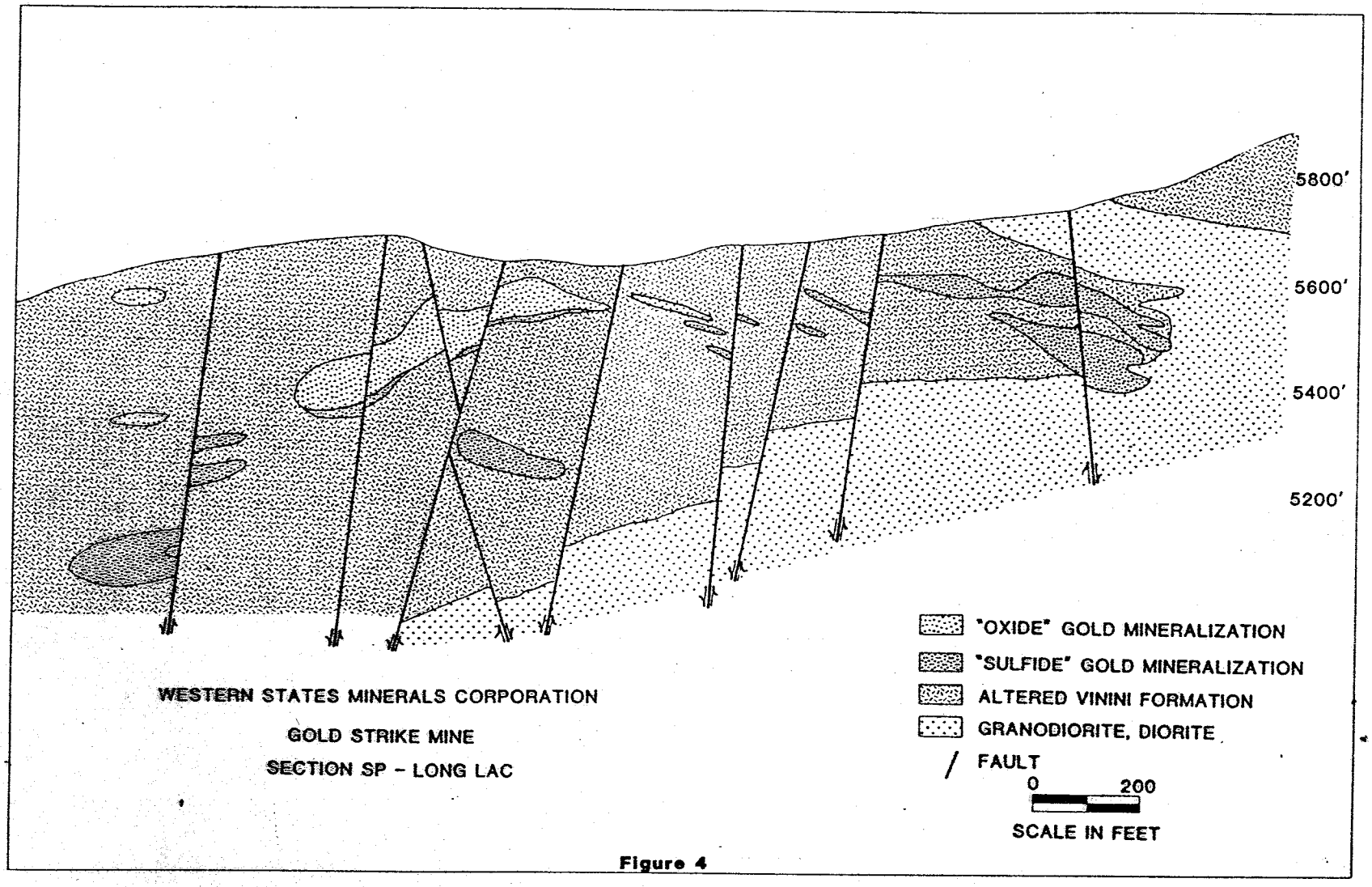
5800'
5600'
5400'
5200'
"OXIDE" GOLD MINERALIZATION
"SULFIDE" GOLD MINERALIZATION
ALTERED VININI FORMATION
GRANODIORITE, DIORITE
FAULT
0
200
SCALE IN FEET
WESTERN STATES MINERALS CORPORATION
GOLD STRIKE MINE
SECTION SP - LONG LAC

Figure 4