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Item 27

MEMORANDUM

April 5, 1984

TO: M. J. Mackenzie

FROM: G. Westra GJW

RE: The Sulphur Gold-bearing Hydrothermal System, Nevada

Prior to the Association of Exploration Geochemist meeting in Reno, I participated in a field trip to the Sulphur district in Western Nevada. Andy Wallace of Cordex and Steve Friberg formerly of Homestake led the tour. The Sulphur area clearly demonstrates the relationship between the paleo watertable, alteration and metal deposition. The geology of the area is described in the attached field trip guide.

The Sulphur district has recorded production of sulphur, silver and alunite. Duval conducted an extensive exploration program for sulphur in the area in the early 1960s. Cordex tested the gold potential in the mid-'70s and Homestake drilled the area in the early 1980s. Drilling has indicated the presence of a very large low-grade gold resource. Gold grades range from nil to 0.1 ounces per ton and average 0.015 to 0.02 ounces per ton. The gold is restricted to a blanket-shaped horizon and gold grades appear to decrease away from steeply dipping silicified feeder structures. Silver values up to 5 ounces per ton are also present. The Standard Slag Company is developing a small gold deposit at the northern end of the district.

Alteration and mineralization occur within a 2,000 feet thick section of coarse clastic continental sediments of the Sulphur group. The lower 1,000 feet consists of unnamed conglomerates, lacustrine tuffs, siltstones and sandstones which are overlain by the Camel Conglomerate, the dominant exposed lithology in the area. The Camel conglomerate is between 100 and 400 feet thick with an average thickness of 200 feet. The Sulphur group overlies a 6,000 foot thick sequence of silicic volcanics and volcaniclastics of the Tertiary Kamma Mountains group. The Camel Conglomerate is overlain by a variety of unconsolidated late Tertiary to Quaternary gravels which are not affected by hydrothermal alteration. The hydrothermal system was active between 1.8 and 2.1 m.y. ago based on K-Ar dating of cross cutting alunite veins.

The hydrothermal system is related to three major north-trending normal faults which cut gently east-dipping sediments of the Sulphur group. The western fault separates Camel Conglomerate from recent gravels. The central fault is well displayed along a 2-1/2 mile long silicified scarp. The northern extension of this zone splays into a broad fracture pattern that localized Standard Slags gold deposit. The eastern fault zone has a total displacement of 4,000 feet and separates Sulphur group rocks to the west from Kamma Mountain volcanics to the east. The Kamma Mountain volcanics are cut by gold- and silver-bearing quartz/chalcedony veins which may have acted as feeder structures to the overlying hydrothermal system.

Hydrothermal alteration has affected an area of 4.5 square miles. Extensive thick sinter deposits are exposed in the northwestern part of the system. Zones of solfataric alteration (acid leaching) are widespread throughout the area. The central and eastern fault zones localize quartz/chalcedony $\pm$ calcite veins and thick alunite veins.

During the first stop, we inspected the large area of silica sinter development along the northwest side of the property. Bedded sinter forms a cliff approximately 150 feet high. Predominantly opaline sinter at the surface give way to chalcedonic replacements of opaline sinter at depth. The presence of fossil reeds in the upper part of the sinter deposit proves beyond a doubt that the sinter was laid down on the paleo surface. Drilling has shown the sinter to be 150 feet thick. Anomalous gold (up to 0.1 ounce/ton) and silver values are restricted to two small (15x15 feet) "mounds" which cross cut the sinter and show evidence of brecciation and recementing by silica. The mounds also show iron oxide staining and are cut by irregular cryptocrystalline black silica veins which contain visible stibnite. The large sinter area is completely devoid of gold and silver. I interpret these sinter deposits to represent precipitates along a zone of hot spring acrtivity where the water table intersected the paleosurface. The gold-anomalous breccias represent zones of upwelling of reduced gold-bearing fluids. The situation would be somewhat similar to Waiotapu, New Zealand where gold-bearing As and Sb-rich precipitates occur in a small lake. In contrast to Waiotapu no major hydrothermal explosion breccias have been found at Sulphur and the nonexplosive nature of the hydrothermal activity may be one of the main reasons why gold mineralization is spread out over a large area instead of being concentrated in more restricted zones of high fluid flux. The main conclusion one can draw from the exposure: barren silica sinters may overlie bulk gold deposits at depth of 100 to 200 feet.

The second stop showed the silicified pyritic Camel Conglomerate overlain by grey and white intensely leached material. Gold, silver, arsenic and antimony are strongly enriched in the zone of strong silicification and pyritization beneath the paleo water table. Pyrite content ranges from 3 to 5 percent. Stibnite occurs in trace amounts. The contact with the overlying acid leach zone is very sharp and characterized by the local presence of a 4-inch zone of massive alunite. The acid leach zone consists of porous silica, kaolinite and alunite and is devoid of precious metals. A deep drillhole by Duval indicates that the zone of silica flooding is underlain by a thick zone of argillization. I estimate the zone of silicification to be between 200 and 300 feet thick. The silicified zone is cut by several 2-4 meter thick massive alunite veins that cannot be traced into the acid leach zone above. Fluid inclusions in coarse alunite crystals in these veins are vapor rich. Possibly a late boiling event produced acid waters and steam which dissolved alunite from the overlying acid leach zone and reprecipitated the alunite along major structures beneath the water table. Several of these alunite veins are enriched in silver but they do not contain gold.

At the third stop we studied native sulphur and cinnabar occurrences within the zone of acid leaching. Coarse sulphur crystals fill fractures and cement gravels suggesting a solfataric (sublimation) origin for the sulphur. Cinnabar occurs in opalized zones closely associated with native sulphur in the zones of most intense alteration and leaching. These white leached zones with sulphur and cinnabar are approximately 50 feet thick and are overlain by a zone of argillized, intensely hematite-stained gravels about 20 feet thick. The hematite-stained gravels upward grade into unaltered unconsolidated gravels which may postdate hydrothermal activity. Lateral zoning is also well demonstrated. A core area with porous vuggy opalized material with native sulphur along fractures is surrounded by a narrow zone (20 feet) of intensely silicified conglomerate. The matrix of the silicified conglomerate consists of bright red hematite-stained chalcedony. This zone grades outward into intensely hematite-stained argillized gravels and finally into unaltered unconsolidated gravels. The hematite-rich material, whether silicified or argillized, is not anomalous in precious metals.

Approximately 500 meters north of this area, Steve Fiberg showed us a brecciated silicified zone (hydrothermal breccia) associated with the central fault zone. Stibnite rosettes are common in this outcrop and the silicified zone is directly overlain by acid leach material with native sulphur. According to Steve, the antimony distribution pattern shows a much closer relation to feeder structures than mercury or arsenic.

Our final stop included the Silver Camel mine area and the Devils Corral. The Silver Camel mine exploited a high grade (80-90 ounces) silver vein. The vein is encased in a one-meter wide zone of intense silicification which passes outward into less intense silicification and argillization. Silver values are contained in cerargyrite and values decreased dramatically below the water table.

In the Devils Corral a north-trending structure cuts across a zone of intense acid leaching. The structure is sealed by a barren silica cap and associated silica sinter which is 10-15 feet thick and decreases in thickness away from the structure. Relic fragments of highly silicified conglomerate with pyrite within the acid leach assemblage indicate that the water table had dropped following the formation of the massive silica-pyrite zone. In this case, acid leach material may be anomalous in gold inherited from a previous mineralization stage. To the east a 150-foot high cliff shows intense brick red hematite staining and consists of opalized silicified partly leached Camel Conglomerate. The rock also contains streaks and disseminations of red hematite. The hematite appears of primary deriviation and was not produced by oxidation of sulfides. This rock type is devoid of gold. South of Devils Corral intensely hematite-stained argillized Camel Conglomerate is exposed which is cut by thick very coarse crystalline calcite veins. This zone most likely represents a zone of mixing of cold groundwater and condensed steam enriched in CO_2.

The superposition of acid leach alteration on earlier silica-pyrite-Au-As-Sb alteration as a result of a lowering of the water table offers an explanation for the formation of structurally controlled supergene silver veins without gold. Silver would be leached from the silica-pyrite altered rock by low pH sulfate-rich solutions during the acid leaching stage. Gold is not susceptible to acid leaching and remains behind in the acid leach assemblage.

Several characteristics of gold distribution at the Sulphur geothermal system may be of interest to explorationists:

- Gold occurs in a zone of intense silification and pyrite addition directly beneath a highly oxidizing acid leach zone. This indicates that gold was transported as a thiosulfide complex.

- It is also suggests that replacement alunite deposits described by Cunningham from the Marysvale district, Utah (Cunningham, 1984) could be underlain by a gold-bearing sulfide zone.

- Where reduced fluids can reach the surface, e.g., in areas of hot spring activity, in feeder faults or hydrothermal explosion breccias, Au, Ag, As, anomalies will be found if the hydrothermal fluids contain gold.

- Native sulphur and cinnabar deposits are localized within acid leach zones (zones of solfataric alteration) characterized by opal, chalcedony, alunite, kaolinite. These deposits are most likely devoid of gold and silver. The lack of gold in the occurrences does not mean the hydrothermal system is devoid of gold.

- If significant readjustments of the water table take place while the hydrothermal system operates, acid leach alteration can be imprinted on earlier Au-Ag-Sb-As mineralization. In this case, the acid leach zones may contain anomalous gold but tend to be devoid of silver.

° None of the conclusions presented above applied to gold enargite systems. In these systems gold is transported as chloride complexes and high gold values are found closely associated with advanced argillic alteration assemblages. Gold may be found in quartz-alunite rocks, in barite and in chalcedonic and cryptocrystalline quartz. Initially it will be difficult to distinguish between solfataric alteration related to a steaming groundwater table in a meteoric geothermal system, and advanced argillic alteration related to a sulfur-rich magmatic-meteoric system. The presence of highly anomalous As, Sb, Au, Ag and Cu and the presence of Pb anomalies in the magmatic-meteoric system will help to make the distinction and to adjust the interpretation of geochemical patterns accordingly.

GW:snl
Attachment

cc: R. Chuchla

FIELD TRIP 8.
SULPHUR MINING DISTRICT

GEOLOGY AND MINERAL DEPOSITS OF THE SULPHUR MINING DISTRICT HUMBOLDT COUNTY AND PERSHING COUNTY, NEVADA

Andy Wallace
Cordex Exploration Company

Robert S. Friberg
Sierra Exploration Associates

INTRODUCTION

The Sulphur mining district, located about 95 miles northeast of Reno, is in the southwestern part of Humboldt County, and the northern part of Pershing County, Nevada (Figure 1). The district can be reached by travelling mainly gravel roads 60 miles north from Lovelock, Nevada, or alternately, 50 miles west from Winnemucca.

Hydrothermally altered rocks, dominantly volcanic, are exposed over an area of about 4.5 mi². Within this area sporadic past production has yielded sulfur, silver, alunite and mercury. Sulfur, the main commodity, has been mined intermittently since the late 1800's from both underground and open pit workings (Couch and Carpenter, 1943; Willden, 1964).

Alunite veins were discovered in 1917 (Clark, 1918) and approximately 500 tons were shipped to the west coast to be used as fertilizer (Vanderburg, 1938). Drilling projects in the 1960's and early 1970's by several companies have been directed toward developing sulfur reserves. The Silver Camel Mine area, located at the southwestern edge of the district produced about $150,000 in silver, mostly in the late 1800's (Lincoln, 1923; Couch and Carpenter, 1943). Exploration for gold and silver by several mining companies began in the mid 1970's. Currently, the Standard Slag Company is developing a gold deposit at the northern end of the district. The mine, scheduled to be on line in late 1984, will process several million tons of low grade ore by heap leach methods.

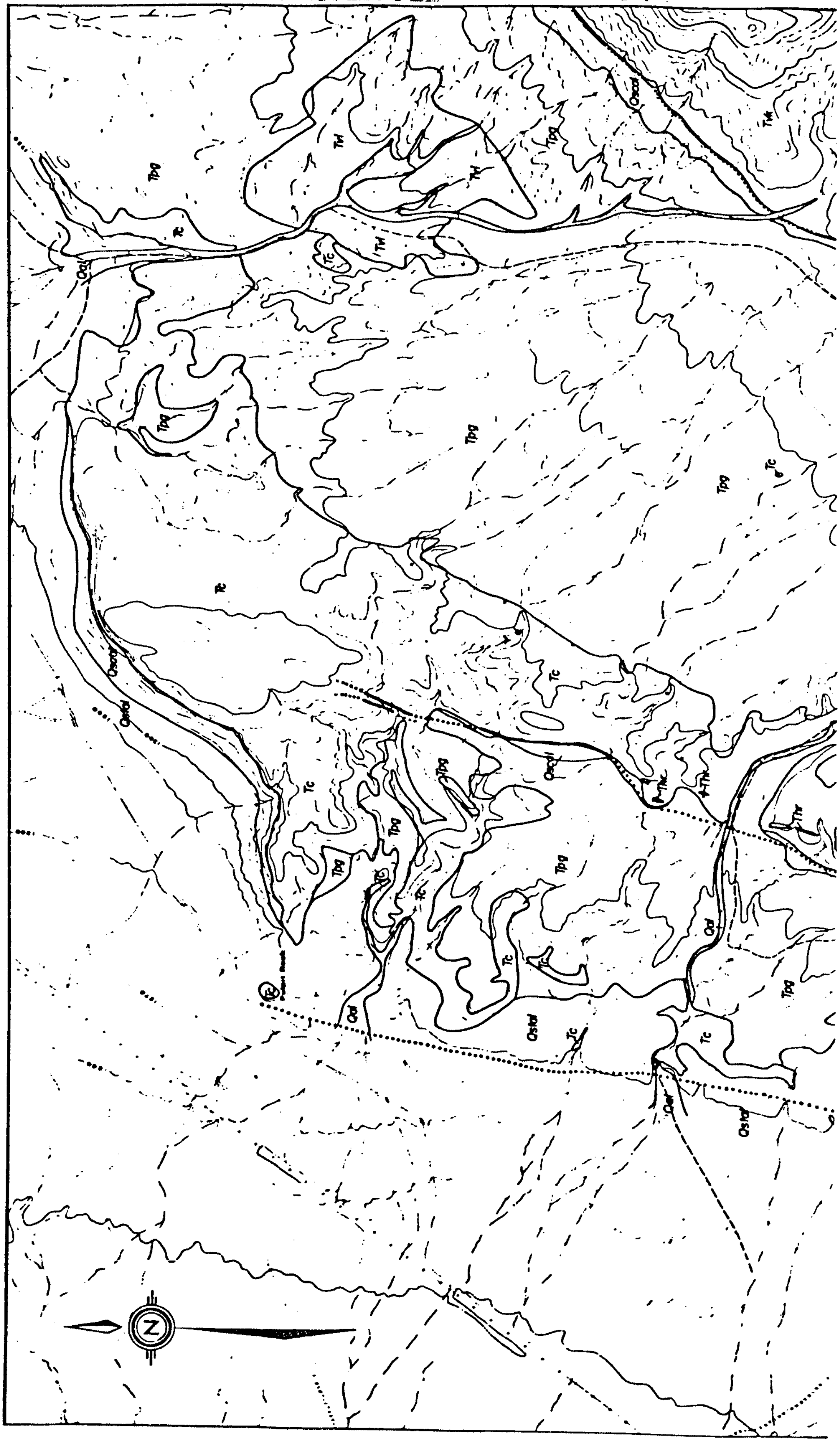
Figure 1. Index map showing Sulphur, Nevada.

STRATIGRAPHY

Rock units exposed in the Sulphur mining district are Tertiary in age (Willden, 1964). The lowermost unit, the Kamma Mountains Group, about 6000 feet thick, includes a thick section of rhyolite and latite lavas and plugs with interbedded volcaniclastic sediments. Overlying this dominantly volcanic group is a sequence of conglomerates, sandstone, lacustrine tuff and hot springs sinters. This sequence, the Sulphur Group, is considered to approach 2,000 feet in thickness. A few thin rhyolite dikes and flows occur in its upper part, all of which is highly altered over large portions of the district. Unlithified, postmineralization rocks include Tertiary terrace gravels, Quaternary-Tertiary alluvium accumulations along fault scarps, Quaternary Lake Lahontan beach gravels, and Quaternary stream gravels.

Kamma Mountains Group

Rocks of the Kamma Mountains Group crop out at high elevations in the central part of the Kamma Mountains east and southeast of the Sulphur district and a nearly complete section is exposed in the deep canyon east of the Rosebud placer deposit. The rocks are dominantly rhyolite lavas with interbeds of latite, volcaniclastic sediments, and lake bed sediments. Approximately 6,000 feet of Kamma Mountains Group is exposed in the canyon near Rosebud where the following units occur (from bottom to top):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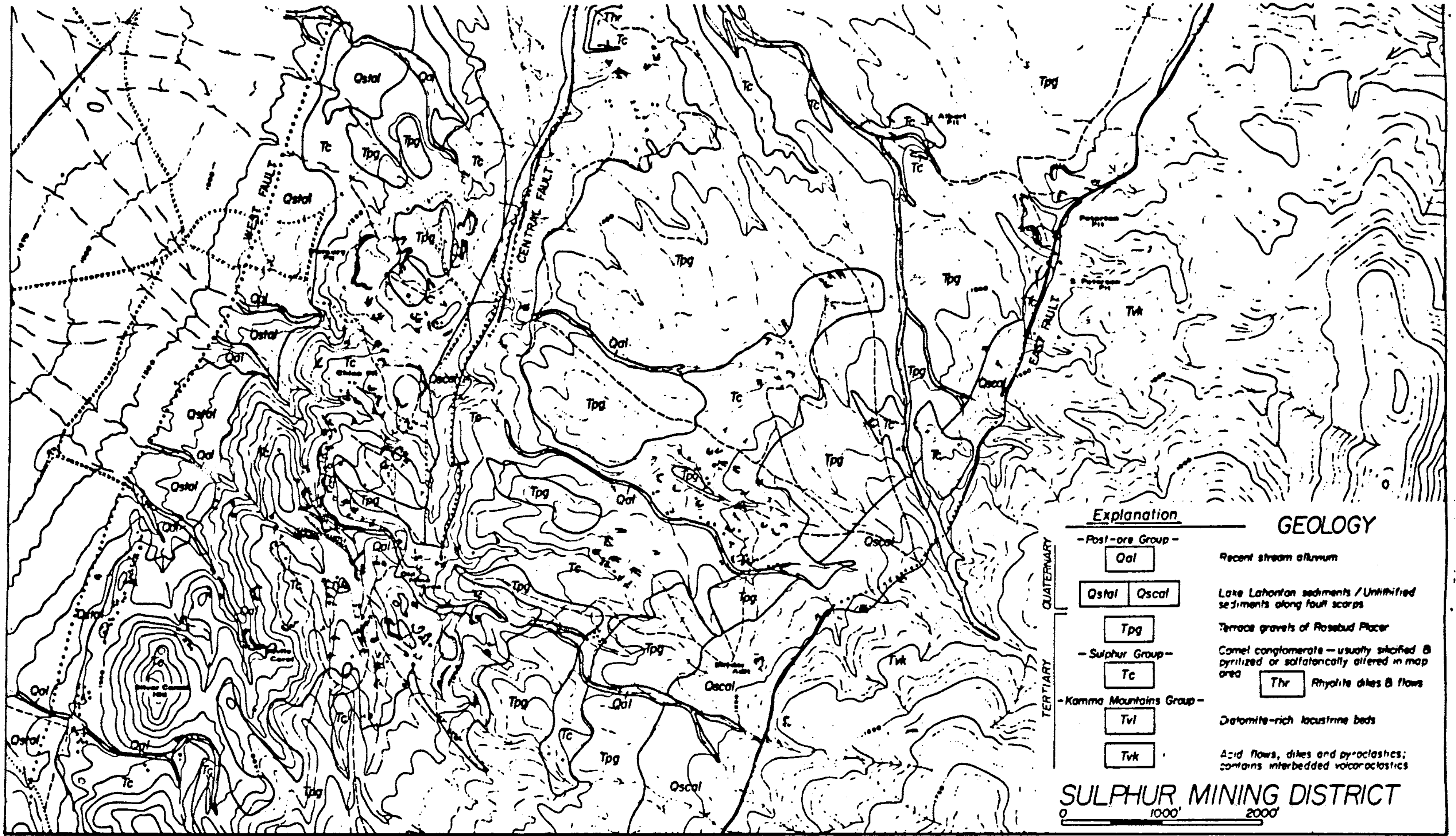

WEST FAULT
CENTRAL FAULT
EAST FAULT
Explanation
GEOLOGY
QUATERNARY
- Post-ore Group -
Qal
Recent stream alluvium
Qstal
Qscal
Lake Lahontan sediments / Unlithified sediments along fault scarps
TERTIARY
Tpg
Terrace gravels of Rosebud Placer
- Sulphur Group -
Tc
Camel conglomerate — usually silicified & pyritized or solfatarically altered in map area
Thr
Rhyolite dikes & flows
- Kamma Mountains Group -
Tvl
Diatomite-rich lacustrine beds
Tvk
Acid flows, dikes and pyroclastics; contains interbedded volcaroclastics
SULPHUR MINING DISTRICT
0
1000'
2000'

Figure 2.

1. Aphyric rhyolite and flow breccia, usually with well-developed highly contorted flow banding. This unit lies on volcaniclastic sediments with interbedded, sanidine-bearing rhyolite near the Sulphur deposits, but its base is not exposed in Rosebud Canyon. A vitrophyre and vitrophyre feeder dike occur at the base of the unit near the Sulphur district.
2. Epiclastic arkose, latite breccia, lacustrine tuff and minor rhyolite.
3. Flow-banded latite with prominent plagioclase phenocrysts, probably in part intrusive.
4. Biotite and hornblende rhyolite.
5. Tuffaceous siltstone and shale (lacustrine?), conglomerate with volcanic fragments, undifferentiated volcaniclastic and epiclastic sedimentary rocks.
6. Dark-colored banded, aphyric latite. Chaotic attitudes are characteristic and the unit is probably intrusive in part.
7. Undifferentiated rhyolite lava and plugs. Rich in feldspar phenocrysts near the Sulphur area where it is underlain by biotite-hornblende rhyolite.

In general, the sedimentary members of the Kamma Mountains Group thin considerably as one moves north from Rosebud Canyon into the Sulphur area. The entire group is complexly faulted in the vicinity of Sulphur. The base of the Kamma Mountains Group was not observed.

Sulphur Group

The Sulphur Group is composed dominantly of clastic units and may reach 2,000 feet or more in thickness. This is the primary rock unit exposed west of the major north-trending fault, which separates the Sulphur Group from the Kamma Mountains Group to the east.

The lowermost units of the Sulphur Group are known only from a 2,000-foot hole core-drilled by the Duval Corporation. Based on the character of the lowest unit penetrated, the hole must have almost reached the Kamma Mountains Group. This lowermost unit, which is unnamed, consists of reddish conglomerate with coarse volcanic clasts (many of which are from the flow-banded rhyolite of the Kamma Mountains Group). Overlying the conglomerate is more than 1,000 feet of lacustrine(?) tuff (also unnamed) with interbedded siltstone and sandstone. These units are pyritized and argillized.

The Camel Conglomerate is considered to directly overlie the lacustrine tuff. This contact is not exposed but has been inferred from the deep core hole by Duval. Total thickness of the conglomerate is not known but a 250 feet section is exposed at the Silver Camel Mine area. The unit is pyritized and silicified or argillized throughout the district. Two distinct lithologies make up the Camel Conglomerate. The lowermost part has abundant large fragments of Mesozoic(?) slate, siltstone, milky quartz and occasional limestone with only a few volcanic fragments. Upward in the unit, volcanic fragments increase in abundance, but older rock fragments (particularly dark silicified shale(?) and sandstone) are still present. The fragment size decreases towards the top and sandstone interbeds become much more common.

The Camel Conglomerate is overlain in the mineralized area by a solfatarically altered, heterogeneous unit variously consisting of opal breccia, highly leached sulfur-bearing breccia with opaline or chalcedonic fragments, conglomerate (usually leached or opalized) with mostly volcanic fragments, and highly siliceous chalcedonic breccia and conglomerate (produced by alteration of the above) (Figure 3). These units are often very light grey or white. The rocks seem somewhat argillized but the apparent softness is due to acid leaching on a microscopic scale and(or) the presence of abundant alunite.

This unit can be mapped separately from the underlying Camel Conglomerate, but the distinction is based principally on alteration differences. However, Wallace (1980) suggested the alteration boundary is lithologically controlled and the solfatarically altered rocks were originally finer grained, more tuffaceous sediments containing angular fragments from the underlying Camel Conglomerate.

Thick hot-spring sinter is preserved at about the same horizon along the northern portion of the district. Friberg (1980), on the basis of drill hole information, suggests that sinter is locally abundant in the solfatarically altered zone, and perhaps below in the Camel Conglomerate, in the main part of the district. The best exposures of sinter are along the range-front north of the main altered area, where the sinter is nearly 150 feet thick. The sinter pad is zoned from chalcedonic silica near its base to more opaline silica near the top where abundant silicified plant material is preserved.

Wallace (1980) mapped minor, aphyric rhyolite dikes cutting the Camel Conglomerate (Figure 2). A minor flow breccia is also interlayed with solfatarically altered rock in that area. Other workers argue that the fine, siliceous rock is an alteration effect, and not rhyolite (Friberg, 1980).

Several types of unaltered and unlithified materials of Tertiary and Quaternary age are shown on the accompanying geologic map. These overlie highly altered units and often contain altered rock fragments. Four units are mapped:

1. *Rosebud Gravel.* These gravels are as much as several hundred feet thick and can be traced several miles to the Rabbit Hole placer where they host placer gold (Vanderburg, 1936; Johnson, 1977). These gravels once covered the entire Sulphur area and contain mostly Mesozoic fragments and some Tertiary volcanic rock fragments.
2. *Scarp alluvium.* Locally thick accumulations along scarps of normal faults.
3. *Stream alluvium.* Coarse gravels along present day stream channels.
4. *Lake Lahontan sediments.* Undifferentiated material in the flats toward Sulphur siding occurring at elevations of 4,400 feet or less.

STRUCTURE

The dominant fault pattern within the Sulphur district is a N.20° to 35°E.-trending system which has divided the area physiographically into two plateaus. The western fault system bounds the Sulphur Group with the valley alluvium to the west. Displacement here is unknown but could amount to several hundred feet. The central fault system is well displayed along the 2½ mile-long silicified scarp. Displacement of this steeply dipping normal fault system is considered to be from 100 feet to 300 feet. The northern extension of this zone splays into a broad fracture pattern, loosing its continuity. The eastern fault zone marks the boundary between the Sulphur Group to the west and the Kamma Mountains Group to the east. The total displacement of this fault is considered to be in excess of 4,000 feet (Wallace, 1980). Strike along this fault is moderately sinuous. The dip along this system is to the west and averages 45° to 50°. Post-mineral movement is seen by striations on native sulfur in several mine workings. Near the Peterson Pit, the eastern fault has been offset several tens-of-feet by an east-west trending left-lateral fault.

A series of west-northwesterly-trending linears occurs in the southern and northern portions of the district. These are very obscure in the field and are best defined in aerial photographs.

Numerous north-trending fractures, some with silica or alunite fillings, are common throughout the district. All are very steeply dipping and show little to no evidence of displacement. Widths of these fractures range from a fraction of an inch to more than one foot.

Bedding throughout the Sulphur Group rocks is very consistent. The strike trend follows the primary north-south structural direction. An easterly dip is common throughout and is generally less than 10°.

MINERAL DEPOSITS

Several seemingly different types of mineralization occur in the Sulphur district which, although spatially distinct and very different in alteration and metal content, are probably genetically related. Each type will be discussed, beginning with those inferred to have formed uppermost in the system.

Sulfur and Mercury Deposits in the Solfataric Zone

The most obvious mineralization in the Sulphur district is the native sulfur that formed near the surface as small pods, matrix material, and along fractures and faults in the solfatarically altered or acid-leached rock. Rarely, sulfur occurs below the solfataric zone along faults in the upper part of the Camel Conglomerate. Crystals larger than 0.5 in. are also found within workings that cut the eastern fault zone. Sulfur is currently forming encrustations at the surface of a small natural vent which is emitting hydrogen sulfide. This gas is also being expelled from several of the holes drilled in 1974. Sulfur has been mined predominately from the acid-leached gravels that are now composed mostly of opaline silica.

Cinnabar occurs in minor amounts in several of the sulfur pits as horizontal streaks along bedding. Less often, it is found as blebs within sulfur pods or coating sulfur crystals. It is only associated with the acid-leached rocks, generally within solid opaline silica layers. Trace cinnabar occurrences are found in several resistant opal/chalcedony outcrops that have formed along the central fault zone. Thin black coatings of metacinnabar can be seen on exposed surfaces.

The solfatarically altered rock is almost everywhere intensely leached, particularly where it is sulfur bearing, and has undergone a complex alteration history. Below the zone of weathering the unit is often soft owing to intense leaching and the sporadic presence of fine alunite. X-ray patterns of the leached rock indicate it is composed mostly of opaline silica replacing fragments and coating cavities. Pods of massive opal as well occur locally. At least some of the massive opal was precipitated prior to the leaching.

For the most part, the acid-leached rocks retain their original textures. Although the alteration occurred very near the surface, these rocks are for the most part not true spring sinters or surficial deposits, but represent near-surface replacements of pre-existing clastic and lacustrine sediments. Although erosion may have removed most of the surficial hot spring deposits, layers of opaline and chalcedonic material, which include opaline replacements of straw grass and reeds, are preserved in the northern part of the district. Friberg (1980) reports gold, silver, and antimony mineralization in this sinter, particularly along its more chalcedonic lower portion.

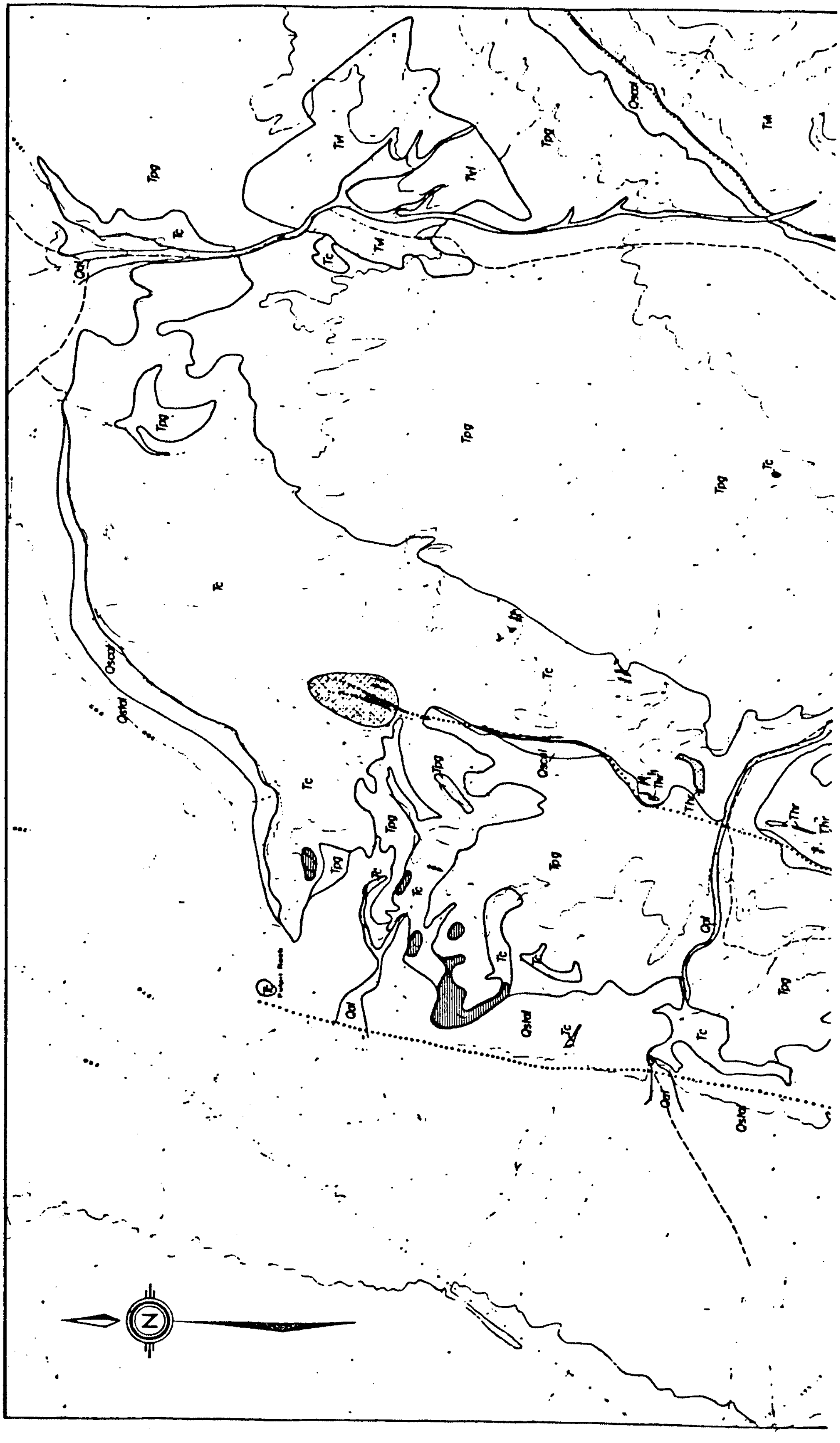
Several flat-lying zones of massive, white, chalcedonic breccia are present in the solfataric zone. These zones are interlayered in the more typical leached material. The origin is questionable, but the chalcedonic zones may have formed during periods of a high water-table fluctuation which encroached upward into the acid-leached zone, and deposited chalcedonic silica.

Pyrite-As-Sb-Hg-Au-Ag in Silicified Camel Conglomerate

Alteration of the Camel Conglomerate below the acid-leached material consists of dense silicification and pyritization which grades outward through zones of bedding-controlled, less dense silicification and weak silicification into argillization. Widespread antimony, arsenic and mercury are found in the intensely silicified and pyritized zones with locally anomalous gold and silver values. The alteration probably took place while the Camel was very porous, perhaps even unlithified, as all the rock fragments are coated with microscopic quartz crystals. There are still open vugs (only partially filled with quartz) present and many have a very late opal/chalcedony lining. Traces of fine, disseminated adularia, fluorite, and an unidentified low relief mineral (perhaps a zeolite) were also noted in the vugs.

Pyrite, the dominant sulfide mineral, occurs throughout most of the silicified portions of the Sulphur Group rocks. It always occurs with massive chalcedony and/or silica flooding; however, silica deposition is not always accompanied by pyrite. Several stages of pyritization have occurred in the Sulphur district. The first, a pervasive microcrystalline pyrite, is intimately associated with cryptocrystalline to microcrystalline silica that has flooded the clastics. Silica and pyrite deposition was contemporaneous throughout sections which range up to several hundreds of feet in thickness. Framboidal aggregates of both pyrite and marcasite occur within this sequence. A second pyritic episode formed visible, individual subhedral to anhedral pyrite grains not exceeding 0.05 inches in size. Later pyrite occurring in seams comprise the last stage of pyritization and is not as common as the first two types. Total pyrite content averages 3% and can exceed 5% over extensive areas. Surface exposures of this highly silicified and pyritized rock are characterized by a dark greenish color due to the oxidation of the finely disseminated pyrite.

Stibnite and stibiconite (antimony oxide) are found in trace to moderate amounts over widespread areas within the Sulphur Group and in the sinter. They range from very fine needles, sometimes intermixed with cryptocrystalline silica, to moderate-sized radiating crystals in hydrothermally brecciated zones. Thin stibnite encrustations that appear to have formed from surface emanations of antimony-rich waters are seen in the sinter zone in the northwest portion of the district. Many of the very fine grained antimony-bearing siliceous veins are dark brown in color and require close examination to identify the stibnite and stibiconite blades. At least three other antimony-bearing minerals have been identified in polished section and scanning electron microscopy: berthierite (iron-antimony sulfide), valentinite (antimony oxide) and bournonite (lead-copper-antimony sulfide). Tripuhyite, a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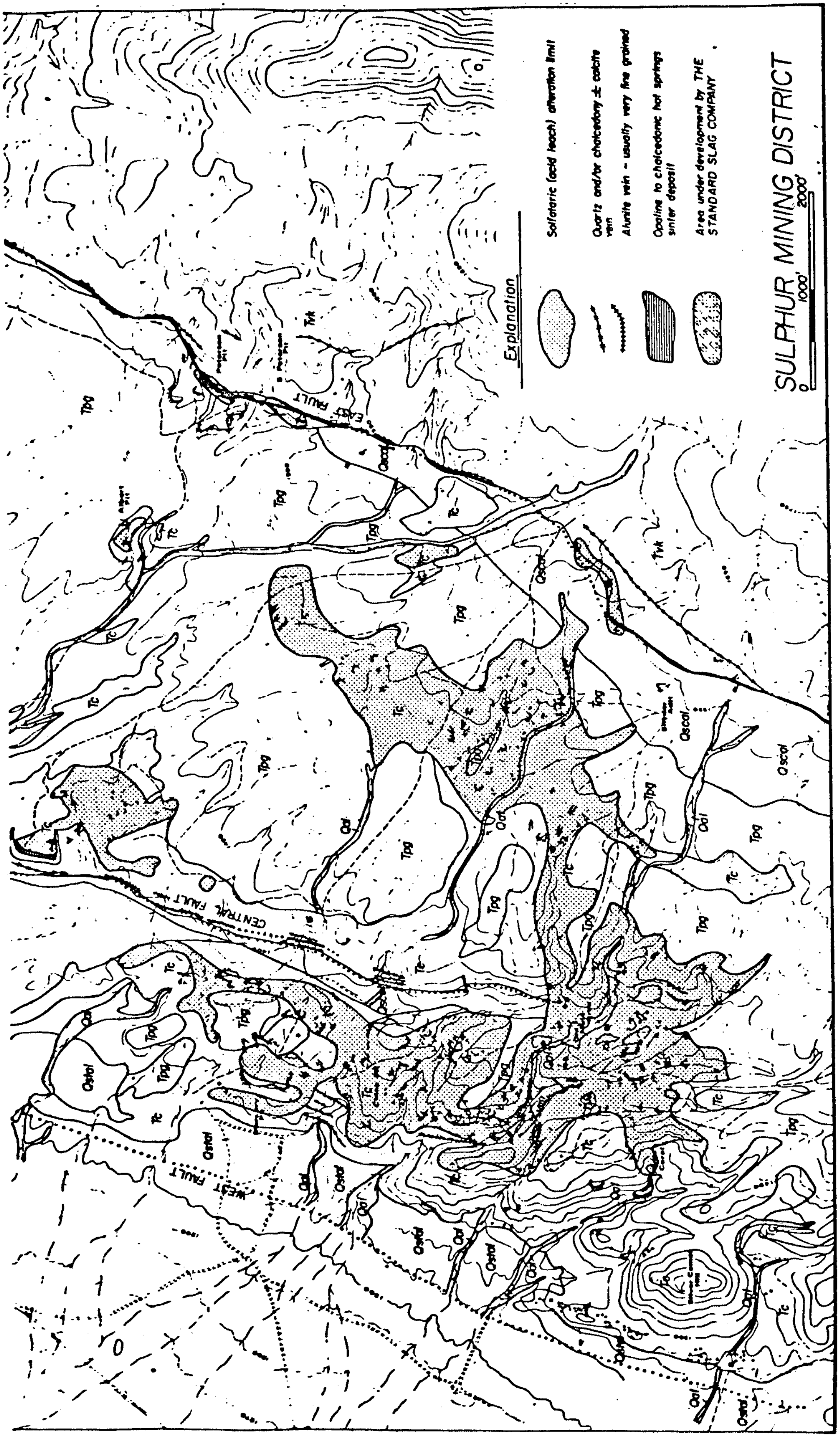

Explanation
Solfataric (acid leach) alteration limit
Quartz and/or chalcedony ± calcite vein
Alunite vein - usually very fine grained
Opaline to chalcedonic hot springs sinter deposit
Area under development by THE STANDARD SLAG COMPANY
SULPHUR MINING DISTRICT
0
1000'
2000'
EAST FAULT
CENTRAL FAULT
WEST FAULT
Tpg
Tc
Tvk
Qal
Qscal
Qsal

Figure 3.

rare iron-antimony oxide, has been identified as occurring with the alunite veins.

Other minerals identified that have been identified in polished section and SEM, occurring in trace amounts are: tiemannite (mercury selenide), barite, uranophane, native selenium and an unnamed lead-tin-antimony sulfide.

Gold and silver are found in trace to significant amounts in silicified conglomerates throughout much of the district. Better-grade gold mineralization is related to vertical, highly siliceous zones and also, at least in one area in the northwest, to a pyritized sinterous layer. Silver is found to occur both in the siliceous and alunite veins as well as secondary cerargyrite in fissures. Silver production came from the Silver Camel Mine where secondary silver values cease at moderately shallow depths (several tens-of-feet to approximately 300 feet). This probably correlates to the ancient Lake Lahontan water table. The silver to gold ratio is higher within the southern half of the district and lower in the northern half. With very few exceptions, no gold or silver values are found within the acid-leached horizon. Maximum gold and silver values are 0.2 ounces per ton and 60 ounces per ton, respectively.

Veins Cutting the Camel Conglomerate

Two types of veins occur along the north-trending normal faults cutting the Camel Conglomerate. Nearly pure alunite veins up to 6 feet in width were discovered in the early 1900's (Clark, 1918). The alunite is usually fine grained and contains pods of opal, and has occasional silver values. Crustiform quartz ± calcite also occurs as veins in the Camel, often in the same fractures as the alunite veins. Where the alunite and quartz veins occur together the quartz veins coat the walls of the fracture, having formed earlier than the alunite. Near the alunite, the calcite component of the quartz veins has been removed.

Although rhyolite dikes can occupy the same structures, the alunite appears to have been emplaced as an open-space filling in the silicified conglomerate, rather than by replacement (Wallace, 1980). The alunite veins are difficult to trace upwards into the acid-leached rocks. Often they pinch out both upward and laterally, passing into open cracks in the silicified Camel Conglomerate.

Calcite veins up to 5 feet thick form large, well developed scalenohedrons immediately southeast of the Devil's Corral. Large massive black-tinted calcite and gypsum veins have formed at several locations along the easterly fault. Dark grey opal veins up to 1 foot in width cut portions of the poorly lithified clastics in the northwest portion of the district.

Chalcedonic Quartz Veins in Kamma Mountains Group

Several silicified fault zones in the rhyolites of the Kamma Mountains Group carry silver and gold values with spotty high-grade silver. The veins are epithermal, with both open-space quartz fillings and white chalcedonic replacements of rhyolite. The better values occur in scarce patches of bluish "live" silicification colored by fine pyrite.

ORE GENESIS

In our opinion, the Sulphur district offers a unique chance to examine, at the surface, different levels of ore deposition now juxtaposed by block faulting. The following is an attempt to explain in a general way the geologic relationships observed in the Sulphur area, drawing heavily on the work of others in active geothermal areas (for example: Schoen, and others, 1974; White, 1968). Although the various Sulphur ores probably formed in the same hydrothermal system, they are grossly different because they were deposited in two contrasting environments separated by the water table. The lowest level of ore deposition is represented by the epithermal quartz veins in the volcanic rocks of the Kamma Mountain Group. Similar veins are probably present at depth in the volcanic rocks under the main part of the mineralized area. When the circulating hydrothermal fluids encountered the more porous, overlying Sulphur Group (particularly the Camel Conglomerate), the fluids deposited quartz and metals in much wider zones of silicification and pyritization below the water table.

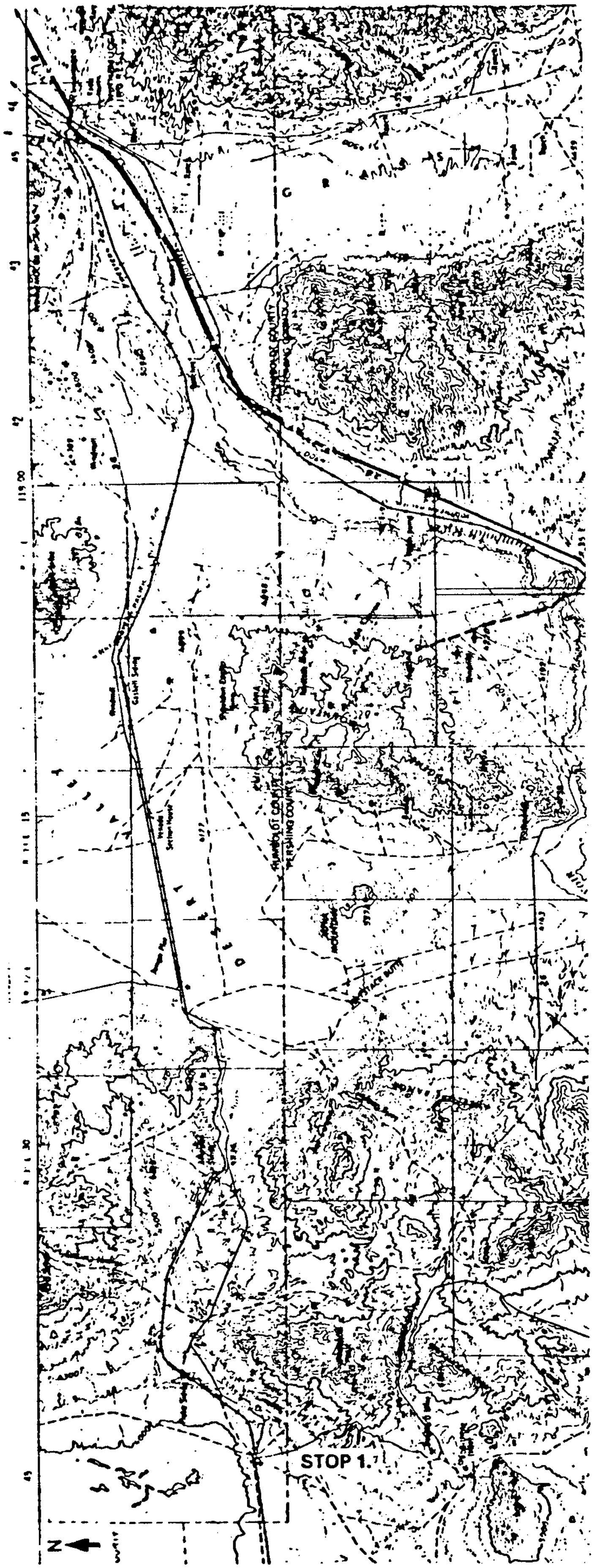
Boiling at that water table produced H_2S (and mercury) bearing vapors, which upon condensation and oxidation in the overlying solfataric zone produced sulfuric acid, native sulfur, and cinnabar. This would place the boiling water-table at the time of ore deposition along the contact of the Camel Conglomerate and solfataric zone. The water table reached the surface in the northwest portion of the district, producing siliceous sinter from the hot springs activity.

The alunite veins cutting the Camel Conglomerate present a problem in interpretation. At first they were thought to represent feeders for acid fluids into the overlying solfataric zone (or perhaps return conduits for acid condensate moving downward to the water table). However, this is difficult to envision if the mineralization above and below the water table was synchronous, because the alunite veins cut previously silicified Camel Conglomerate. It is possible is that the alunite veins were emplaced by vapor-dominated fluids late in the mineralization period. As the system became sealed by the broad silicification of the Camel Conglomerate, fluid pressures might build below that horizon. Fracturing along the northerly faults would release that pressure, perhaps resulting in "flashing" and rapid upward flow of boiling fluid. Fluid inclusion data from alunite veins at Alunite Ridge near Marysvale, Utah, which are similar to the more coarse-grained parts of the Sulphur district alunite veins, indicate that they were emplaced by a vapor-dominated system (Cunningham and others, 1978).

SUMMARY AND CONCLUSIONS

Host units for ore deposits in the Sulphur district include a thick sequence of Tertiary volcanic rocks (Kamma Mountains Group) overlain by approximately 2,000 feet of coarse clastics and lacustrine tuff of the Sulphur Group. Unlithified Quaternary and Tertiary gravels blanket much of the area. North-trending Basin and Range normal faults are the only structures of importance.

The partially eroded mineral deposits are believed to represent a fossil hot spring or geothermal system. The deposits inferred to form lowermost in the system are siliceous veins cutting the rhyolites of the Kamma Mountains Group. The veins pass upward into broad zones of silicification and pyritization in the originally porous clastics of the Sulphur Group. The uppermost part of the Sulphur Group contains sulphur and mercury in rocks that were thoroughly leached, probably by acid condensate above a boiling water table. Economic amounts of gold and silver formed along and near the major north-trending structural zones during this phase. Nearly pure alunite veins probably formed late in the development of the system, and may have been emplaced by a vapor-dominated fluid.



ROAD LOG.
WINNEMUCCA TO SULPHUR

Mileage:
Cum. Inc.

0.0 0.0 Begin at junction of U.S. Highway 95 and Sulphur-Jungo Rd. Turn left and proceed west toward Sulphur, Rabbit Hole, and Scossa. The traverse will be in a portion of Nevada poorly known geologically. The only published geologic mapping to date has been at 1:250,000 scale (Tatlock, 1969) except for larger scale mapping of a few mining districts. On the basis of the reconnaissance mapping most outcrops in the region belong to one of the following units:
(1) Cretaceous granodiorite similar in age and gross composition to the Sierra Nevada batholith,
(2) The Jurassic-Triassic Auld Lang Syne Group, consisting of many thousands of feet of clastic rocks with a few lenses of limestone and dolomite not yet subdivided in this part of Nevada, or
(3) Tertiary volcanic rocks. The Tertiary section locally reaches several thousand feet in thickness. Most of the volcanic rocks are siliceous lavas and ash-flow tuffs, but basalts are locally abundant, especially at the top of the section. Radiometric age determinations are scarce, but from regional considerations most of the volcanic rocks are probably of Miocene age. Several major volcanic centers are present but none have been studied in detail. General references to the geology include Willden (1964), Tatlock (1969), and Johnson (1977).

5.6 5.6 Road to Western Turf Farm.

5.7 0.1 The road runs westerly along the base of an east-west line of hills beginning with Winnemucca Mountain on the east, the low Krum Hills, and Blue Mountain on the west. The East Range lies at 9:00 and the Sonoma Range at 5-6:00 in the distance. Workings seen north of the road for the next few miles are precious metal prospects on quartz veins and shears, in the area known as the Ten Mile district.

6.4 0.7 Windmill.

10.2 3.8 Road to Golden Amethyst Mine in Ten Mile district.

12.2 2.0 Intersection. Keep straight ahead.

16.2 4.0 Blue Mountain (at south end of the Slumbering Hills). Hills at 9-10 o'clock are the Eugene Mountains. Both ranges are mostly rocks similar in lithology to the Auld Lang Syne Group, locally intruded by Mesozoic plutons.

29.2 13.0 Numerous irrigated potato farms like the one on the right ahead have sprung up in the Winnemucca area in the last decade. The Winnemucca area is now known as a major center of potato production, mostly from the Paradise Valley area north of town.

40.6 11.4 Jungo siding on the Western Pacific Railroad. Road to right leads to the Bottle Creek Mercury district.

41.7 1.1 Cross railroad tracks.

46.7 5.0 For the next few miles we will see numerous prospect pits for placer gold in a large area called the Sawtooth district. The district has produced only about $12,000. Much of the gold supposedly occurs at a depth of only 8-24 in. (Vanderburg, 1936). Roads to right and left lead mostly to placer workings. Keep straight ahead.

55.9 9.2 Road to Mandalay Springs. Keep straight ahead.

57.9 2.0 Sulphur district on left. Continue to Mercury Pit area for stop 1.

ACKNOWLEDGEMENTS

The authors wish to express their appreciation to the Cordex Exploration Company, the Homestake Mining Company and The Standard Slag Company for their assistance during the writing of this paper. The opinions expressed herein, however, are those of the authors.

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