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File: Esperanza — Sierrita

J. H. C.

APR 25 1973

MINERALIZATION CONTROL AT THE DUVAL SIERRITA PROPERTY, PIMA COUNTY, ARIZONA

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March 6, 1973

MINERALIZATION CONTROL AT THE DUVAL

SIERRITA PROPERTY, PIMA COUNTY, ARIZONA

METHOD OF STUDY

Data for the mineralization study was derived from pit geologic mapping, rotary blasthole assays, and development-exploration drillhole geology and assays. Pit mapping data, including rock type, structure, and mineralization occurrence, were plotted on 100-scale bench maps and 200-scale pit progress maps. Blasthole copper and molybdenum assays, spaced at 20-to 50-foot intervals, were plotted on 100-scale bench overlays, contoured, and color-coded for a visual representation of mineralization intensity and distribution. From these overlays, 200-scale pit progress maps were prepared. In addition, 100-scale copper and molybdenum three-bench composite maps were drawn outlining zones $>0.3\%$ copper and $>0.03\%$ molybdenum.

Rock type and copper-molybdenum assay data from development and exploration holes were plotted, contoured, and color-coded on 500-scale maps for alternating benches from the 3800 through the 2000. Hole spacing increased from approximately 250 feet on upper benches to about 500 feet on middle benches, and to greater than 500 feet on lower benches. From the 500 scale maps, a series of copper, molybdenum, and rock-type 200-scale cross-sections were drawn oriented both perpendicular and parallel to major mineralization trends.

GENERAL

The Sierrita-Esperanza orebodies comprise a single Laramide porphyry copper-molybdenum deposit with economic mineral concentrations occurring linearly along the margins of a Laramide quartz monzonite porphyry, both within the quartz monzonite porphyry and adjacent quartz diorite, andesite, breccia, Triassic Ox Frame

Continued ...

volcanics and Jurassic-Triassic (?) Harris Ranch quartz monzonite. Mineralization zones parallel the contact at Esperanza (northeast) and Sierrita (northwest), forming a V configuration with a < 0.1% copper core, grade increasing again to the north and east in the Lofton Peak and Anglin McGee areas. Both properties reflect the major mineralization trend of the adjacent property through minor zoning.

The predominately hypogene Sierrita orebody is composed of two major parallel mineralization zones striking N40-60W, one of which connects with Esperanza at depth. The west zone occurs primarily in quartz diorite and Harris Ranch quartz monzonite, the east zone in quartz monzonite porphyry and breccia. Significant secondary enrichment occurred only along the east and southeast perimeter in the original West Esperanza area; all secondary ore tonnage has been mined.

The Esperanza orebody consists of a major mineralization zone striking N40-55E, and the southeast end of the east mineralization zone extending from Sierrita. It occurs principally in quartz monzonite porphyry, but with significant tonnages also in andesite and quartz diorite. Mineralization in the volcanics is negligible, with the exception of local secondary enrichment. Orginally a secondary chalcocite-primary molybdenite orebody, most supergene-derived ore has been mined. The remaining portion of the orebody is predominantly hypogene.

Hypogene copper and molybdenum occur in the same general areas, with no obvious zoning relationship.

COPPER-MOLYBDENUM MINERALIZATION

Hypogene ore minerals are chalcopyrite and molybdenite. Mineralization control is

Continued ...

structural-lithological, as indicated by linear zonal geometry paralleling fault trends, contacts, and intrusions; by the association of hypogene mineralization with specific rock types, and by the predominantly fracture-controlled nature of the mineralization, minor disseminations occurring only in breccia and quartz monzonite porphyry. In these two latter rock types, economic mineral concentrations are present only in rock with extensive pre-mineral fracturing. Preference of mineralization for specific rock types was related to higher fracture intensities.

Hypogene copper is present along fractures in the quartz diorite, andesite, volcanics, and Harris Ranch quartz monzonite, occurring as fillings and in quartz veins and veinlets. The same control is present in quartz monzonite porphyry and breccia, but with additional copper present as disseminations and blebs. In the quartz monzonite porphyry chalcopyrite commonly replaces biotite, while in the breccia is present as blebs in the biotitic matrix. Disseminated mineralization is not in itself sufficient to produce ore-grade material unless associated with high molybdenum values.

Hypogene molybdenum occurs in all rock types as fracture fillings, and in quartz veins and veinlets. Disseminations are not common.

Volcanics, Harris Ranch quartz monzonite, quartz diorite, and andesite were in place and fractured prior to mineralization. The quartz monzonite porphyry and breccia may have been lightly mineralized by chalcopyrite during emplacement, followed by later chalcopyrite and molybdenite mineralization after ground preparation by fracturing. There was more than one period of fracturing as indicated by cross-cutting relationships and dissimiliar fracture, veinlet, and vein mineral associations. The most obvious example is a period of late fracturing and subsequent stilbite-anhydrite-gypsum filling which occurred after completion of sulfide mineralization.

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A study of the Sierrita pit by W. A. Rehrig and T. L. Heidrick (1972) showed mineralized fractures, veinlets, and veins to be systematic in attitude with a perpendicular pattern of N50-85E and N05-25W. The major mineral zones at Sierrita strike N40-60W, paralleling the contact between quartz monzonite porphyry and the intruded rocks. Secondary zones strike N45-60E, parallel to the major mineralization zone and related contact between quartz monzonite porphyry and intruded rocks at the adjacent Esperanza property. The major structural trend as determined from faults and dikes strikes N60-75E. In summary, the predominant trend of mineralized fractures strikes N50-85E, which parallels the major structural trend. Overall deposit zoning, however, strikes N40-60W paralleling the contact between quartz monzonite porphyry and the intruded rocks. Within this overall deposit zoning, secondary trends strike N45-60E paralleling the major Esperanza zoning trend. The minor trend of mineralized fractures striking N05-25W is not related to any obvious pit features.

COPPER OCCURRENCE AT SIERRITA - DATA FROM MINED BENCHES

General

Hypogene copper $>0.2\%$ occurs in quartz diorite, along the central quartz diorite-Harris Ranch quartz monzonite - quartz monzonite porphyry contact intersection, and in the breccia pipe. Harris Ranch quartz monzonite and quartz monzonite porphyry in general contain $<0.2\%$ copper. Secondary chalcocite mineralization was present in significant amounts only along the east and southeast perimeter as part of the original West Esperanza orebody. All secondary ore tonnage has been mined.

Quartz Diorite

Hypogene mineralization in the west and northwest sections of the pit is structurally

Continued ...

Quartz Diorite - Cont'd...

controlled by quartz diorite, which contains a N45W >0.2% copper zone generally paralleling the strike of the quartz diorite intrusion. Scattered areas <0.2% are present in this zone, increasing in frequency to the south. Concentration of mineralizing agents was by ground preparation through extensive stockwork fracturing, probably related in some degree to emplacement of adjacent quartz monzonite porphyry.

The 0.2% zone terminates to the east in quartz diorite along the quartz diorite-quartz monzonite porphyry contact, extends 200 feet into quartz monzonite porphyry on the north, terminates in quartz diorite 500 feet from Harris Ranch quartz monzonite to the northwest and 200 feet from Harris Ranch quartz monzonite to the southwest, and extends 200-500 feet into Harris Ranch quartz monzonite to the south. Overall dimension of the zone is 1200-1700 x 3600 feet.

Within the quartz diorite, a major subtrend is characterized by a series of >0.3% elongated pods striking N45-60E. The strike of these pods becomes more easterly trending to the south. They are not distinguished by large mappable features, but rather by an increase of mineralized fractures, veinlets, and veins. The largest of these zones occurs to the north adjacent to the quartz monzonite porphyry contact, strikes N45E, and measures 300x800 feet. It has been continuous with depth through five benches mined to date, with a vertical or near-vertical dip. To the south, near the center of the quartz diorite, a 50-200 x 600 foot >0.3% zone strikes N50E. Further south, a minor > 0.3% zone represented by one to four small pods on each of four benches strikes N60E for approximately 300 feet.

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Quartz Diorite - Harris Ranch Quartz Monzonite-Quartz Monzonite Porphyry Intersection

The > 0.2% quartz diorite zone extends 200-500 feet into Harris Ranch quartz monzonite to the south. Within this extension, a structurally controlled > 0.3% hypogene zone 50-100 x 900 feet strikes N65E and dips vertically. It parallels a quartz latite porphyry dike located 50-150 feet to the south, while generally trending along the Harris Ranch quartz monzonite - quartz diorite contact 100-350 feet to the north. To the west are a large number of similar-striking quartz diorite dikes paralleling the predominant structural trend in the pit, indicating a zone of structural activity prior to or during emplacement of the quartz diorite.

On the east, this zone abuts perpendicularly against a second structurally controlled > 0.3% zone to form a T. This latter zone strikes N35W along the Harris Ranch quartz monzonite-quartz monzonite porphyry contact, penetrating into quartz diorite; its extension to the southeast parallels the contact for 700 feet. Farther southeast the contact curves to the south, with the mineralization zone continuing along the original S35E strike into quartz monzonite porphyry characterized by intermixed quartz diorite, Harris Ranch quartz monzonite, and Ruby Star granodiorite. The > 0.3% zone is generally discontinuous, composed of pod-like bodies with an overall dimension of approximately 100 x 1700 feet. Dip is vertical or near-vertical as far as can be determined from available information.

The two zones forming the T are the upper expression of the main portion of the orebody, expanding rapidly in size and increasing in grade with depth.

Breccia Pipe

Hypogene copper mineralization in the east portion of the pit is structurally and

Continued ...

Breccia Pipe

possibly genetically controlled by the breccia pipe. The 0.2% contour closely follows its physical boundaries, generally within 100 and rarely over 200 feet, undulating in and out of breccia along the breccia-quartz monzonite porphyry contact. Scattered areas < 0.2% occur within the breccia. The overall dimension is 300-900 x 2800 feet. Strike is E-W, turning on the east end to S55E which trends toward the west end of the Esperanza orebody. Irregular areas > 0.3% within the 0.2% contour form an elongated zone approximately 200-300 x 1200 feet, with a strike indentical to the > 0.2% zone. A breccia extension on the northeast edge of the pipe is associated with a 300 x 1000 foot > 0.2% zone striking N-S.

COPPER OCCURRENCE AT SIERRITA - DATA FROM DEVELOPMENT DRILLING

General

Hypogene chalcopyrite occurs in two major parallel zones, designated the Sierrita Zone and Amargosa Zone. The Sierrita Zone is more extensively mineralized; the Amargosa Zone extends into and becomes part of the Esperanza orebody. Both zones converge with increasing depth on the northwest end, while to the southeast they are separated by a relatively low-grade area. Their formation may be reasonably ascribed to structural parameters. There is no secondary mineralization below the 3850 bench.

Sierrita Zone

The Sierrita Zone, as delineated by the 0.2% contour, strikes N40-60W. On upper benches it extends from quartz diorite on the northwest through Harris Ranch quartz monzonite, terminating to the southeast in or adjacent to quartz monzonite porphyry. In general, the 0.2% contour parallels the quartz diorite-quartz monzonite porphyry and Harris

Continued ...

Sierrita Zone - Cont'd.

Ranch quartz monzonite-quartz monzonite porphyry contacts, with more intense mineralization in the Harris Ranch quartz monzonite and quartz diorite. Its dimension on the 3800 bench is 600-1800 x 3800 feet. The >0.2% zone increases in intensity and areal extent with depth to merge with the Amargosa Zone on the east, covering most of the pit area.

The Sierrita Zone, as delineated by the 0.3% contour, strikes N40-60W. It increases in length with depth along the zonal strike in the form of an inverted V, plunging 25-30 degrees to the northwest and 25-40 degrees to the southeast.

Measuring 40-100 x 900 feet as presently exposed on the 3800 bench, the >0.3% zone increases to 1000 x 2000 feet by the 3500 bench. Grade increases from 0.3 - 0.4% to 0.3 - 0.8%, becoming essentially constant below the 3500 bench. Size continues to gradually increase to approximately 1400 x 4000 feet on the 2600 bench.

Beginning with the 3300 bench, the northwest end of the Sierrita and Amargosa Zones are connected by an erratically occurring cross-zone striking approximately N45E. The area between the two zones on the south is consistently characterized by low copper content of 0.1 - 0.2%.

The >0.3% zone occurs principally in Harris Ranch quartz monzonite. Its east boundary follows the Harris Ranch quartz monzonite - quartz monzonite porphyry contact, entering only occasionally into quartz monzonite porphyry. There is no contact control for the west edge. The northwest edge generally parallels the Harris Ranch quartz monzonite - quartz diorite contact, plunging 25-30 degrees northwest. Control for the southeast edge, which plunges 25-40 degrees to the southeast, may be related to the overlying Ox Frame Volcanics.

Continued ...

Sierrita Zone - Cont'd.

On upper benches, the >0.3% zone initially increases in Harris Ranch quartz monzonite along the Harris Ranch quartz monzonite - quartz monzonite porphyry and Harris Ranch quartz monzonite - quartz diorite contacts. These areas correspond to the T intersection described previously. Below the 3600 bench, the zone extends 400-1000 feet into quartz diorite. More intensively mineralized areas of 0.4 to >0.6% are generally concentrated in the central and northern sections along the Harris Ranch quartz monzonite - quartz diorite contact. Large areas <0.3% are present in the south half of the zone, apparently plunging about 40 degrees to the southeast.

Within the V-shaped quartz diorite intrusion, the Sierrita Zone is represented by a series of >0.3% pods which seem to align in a discontinuous zone plunging approximately 25 degrees southeast. This area abuts the >0.3% zone in the Harris Ranch quartz monzonite to form an essentially tabular zone with a VV configuration, plunging southeast 25-40 degrees.

Secondary trends strike N40-60E, corresponding to those of the major mineralization zone and related quartz monzonite porphyry - intruded rock contact at the adjacent Esperanza property.

Amargosa Zone

The Amargosa Zone, which links the Sierrita and Esperanza orebodies, is incompletely outlined by development drilling. It was originally exploited in the southern end of the Esperanza pit and later in West Esperanza because of high copper values associated with secondary chalcocite enrichment. Most secondary ore tonnage has been mined.

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Amargosa Zone

As delineated by the 0.2% contour, the Amargosa Zone strikes N45-60W paralleling the adjacent Sierrita Zone, expanding dimensionally from 400-1400 x 6400 feet on the 3800 bench to at least 2200 x 7400 feet on the 3000 bench where data is insufficient to define exact limits.

The Amargosa Zone extends from quartz monzonite porphyry and breccia on the northwest to andesite and quartz diorite on the southeast, with quartz monzonite porphyry in the center. With few exceptions, the breccia pipe is confined within the 0.2% contour, although it is not the northwest limit to the $>0.2\%$ zone. In this same general region, areas of $>0.3\%$ occur both in quartz monzonite porphyry and breccia with no preferential association.

The breccia pipe itself, as determined from pit mapping, measures 300-900 x 2800 feet. The lowest drillhole intercept is on the 2800 bench, for a continuous minimum vertical depth of 1200 feet. Actual bottom is not known due to wide hole spacing on lower benches. The pipe does, however, decrease in horizontal dimensions with depth.

Generally, areas $>0.3\%$ occurring within the $>0.2\%$ zone are not as large as in the Sierrita Zone, nor as well defined due to the wide hole spacing. A major exception occurs on the southeast end in the Esperanza pit, where a hypogene area measuring 400-800 x 1700 feet on the 3800 bench is zoned by rock type. Geologically, the area consists of a quartz monzonite porphyry core surrounded by andeside-quartz diorite, which in turn is bounded by rhyolite welded tuff. Copper grade decreases from $>0.4\%$ in the andesite-quartz diorite to 0.3-0.4% at the quartz monzonite porphyry contact, and to $<0.3\%$ near the center of the quartz monzonite porphyry. Grade increases to 0.3-0.4% as the opposite

Continued ...

Amargosa Zone - Cont'd.

andesite-quartz diorite contact is approached, becoming $>0.4\%$ upon penetration. Copper content in the rhyolite welded tuff is generally $<0.2\%$.

Secondary trends in the Amargosa Zone are less common than in the Sierrita Zone. They strike N45-55E where present, corresponding to trends of the major mineralization zone and quartz monzonite porphyry - intruded rock contact at the adjacent Esperanza property.

SUMMARY

The Laramide Sierrita and Esperanza copper-molybdenum porphyry orebodies are components of a single, structurally controlled deposit, occurring along the margins of the quartz monzonite porphyry intrusion. Mineralization is predominantly hypogene chalcopyrite and molybdenite, present economically in zones which parallel the contact between quartz monzonite porphyry and intruded rocks. Both chalcopyrite and molybdenite occur in the same general area, with no apparent zoning relationship.

Copper mineralization in the Sierrita orebody is present in two major parallel zones, the more heavily mineralized Sierrita Zone in quartz diorite - Harris Ranch quartz monzonite and the Amargosa Zone in quartz monzonite porphyry - breccia. The Amargosa Zone links the Esperanza and Sierrita orebodies.

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Structural Geology of the Sierrita Mountains, Pima County, Arizona

by

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(Abstract of talk to be given at AIME symposium on Sierrita Mts., April 13, 1973)

The Sierrita Mountains, some 25 miles southwest of Tucson, Ariz., are almost as well known for their complex structures as for their tremendous deposits of copper. Although the area near the mines has been studied in detail, range-wide structural interpretations have been few or have been little publicized, in part because of the difficulty in piecing together many small structurally complex areas that are separated from each other by large stocks or extensive deposits of pediment gravel, and in dating and correlating metamorphosed rocks. The interpretation here offered is based on the detailed map of the Twin Buttes quadrangle by John R. Cooper, augmented by my own detailed work in the Rincon and Santa Rita Mountains and reconnaissance mapping extending from the west flank of the Sierrita Mountains to the borders of Sonora and New Mexico. As a preliminary model of the structural development of a complex range, the interpretation is offered with the expectation that it will be substantially modified as the efforts to find more ore deposits continue.

The Sierrita Mountains contain many faults, both low-angle and high angle, and folds, all of which are now interrupted by large stocks. Most of the strong deformation occurred during the Laramide Orogeny, of Late Cretaceous to Paleocene age (about 90-53 m.y. (million years) ago).

Evidence for pre-Laramide deformation is scanty because it is much obscured by later deformation, whereas evidence for post-Laramide deformation is both widespread and relatively clear.

The sparse record of pre-Laramide rocks and structures in the Sierrita Mountains suggests a sequence of events much like that proposed for the Santa Rita Mountains. During the Precambrian, Pinal Schist was foliated, folded, and intruded by bodies of porphyritic granodiorite which are themselves weakly foliated. In Paleozoic time the sea invaded the area and deposited rocks in a miogeosynclinal environment. During the Triassic through Lower Cretaceous, continental conditions prevailed; from time to time magmatic activity and local relief increased markedly, but the occurrence of faulting during the interval is inferred primarily from the local record of sedimentation and from the structural record in nearby mountains.

During the Laramide Orogeny, the rocks of the area were intruded several times, were strongly compressed and thrust faulted, and were widely metamorphosed and locally mineralized. During this involved period of structural development of the Sierrita Mountains the following major events occurred:

(1) Thrust plates of regional scale were pushed east-northeastward on the Sierrita thrust fault between the times of deposition of the Demetrie Volcanics (upper Upper Cretaceous; ~75 m.y.) and the Red Boy Rhyolite (upper Upper Cretaceous; 72-73 m.y.). Some rocks of the thrust plate were folded, cut by strike-slip faults, thinned, and possibly tectonically metamorphosed. Thrust faults in the Sierrita Mountains, particularly the ones on the west side of the mountains,

resemble those in the northernmost Santa Rita Mountains and in the Rincon Mountains in that several major plates of Paleozoic and Mesozoic rocks and substantial sheets of Precambrian rocks are involved. If the thrust plates in these three mountain ranges are related, then the postulated amount of tectonic transport as suggested by evidence in the Rincons may exceed 10 or perhaps even 20 miles.

(2) Large stocks of Ruby Star Granodiorite were emplaced about 59 m.y. ago, apparently under the influence of northwest-trending pre-Laramide structural grain, also present in some nearby ranges. The widespread thermal metamorphism of the area is probably associated with this magmatic event.

(3) Scattered small stocks of quartz latite porphyry or fine-grained quartz monzonite porphyry (ore porphyry) were intruded about 55 m.y. ago along the east flank of the Sierrita Mountains. Ore fluids, which apparently were associated with or immediately followed this magmatic event, spread along faults and the margins of plutons. From these fluids, metals were deposited in various favorable host rocks close to both the ore porphyry and the available conduits.

Post-Laramide structural features include local high-angle faults and a shallow low-angle fault, as well as some small intrusive bodies. High-angle faulting occurred during several intervals, but in general is datable only as pre-late Oligocene and post-late Oligocene. Some of these faults utilized older high-angle structures, and probably some faulting is

associated with the development of high local relief southeast of the Sierrita Mountains. A plate of rock, perhaps only a few thousand feet thick and a few tens of square miles in extent, is postulated by Cooper to have moved about 7 miles northward from the high area down a gentle gradient on the dish-shaped San Xavier fault. Rocks of this glide plate include some previously thrust-faulted Cretaceous and older rocks, as well as fanglomerate containing intercalated wedges of monolithologic breccia, of landslide origin, and flows of andesite dated at 31 m.y. Rhyodacite dikes 24 m.y. old appear to postdate the gravity gliding and are penecontemporaneous with the youngest volcanic rocks occurring on the flanks of the Sierrita Mountains. The postulated area of high local relief must have been faulted down during the late Tertiary to initiate the basin now occupied by the Santa Cruz River.

A SYNOPSIS OF ALTERATION AND MINERALIZATION AT THE SIERRITA AND ESPERANZA MINES

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A SYNOPSIS OF ALTERATION AND MINERALIZATION AT THE SIERRITA AND ESPERANZA MINES

This paper, presented only as a preliminary study, is based almost entirely on field and drill hole data gathered from field mapping and drill logs, then transferred to 500-scale surface maps, bench maps, and sections. Laboratory work, including preparation and study of thin and polished sections, is necessary to provide definitive conclusions on the subject of mineralization and alteration.

Alteration found at Sierrita-Esperanza is similar to that found at other porphyry copper deposits, and includes potassic, phyllic, and propylitic zones. The alteration and mineralization sequence is far reaching, and must be considered as a large pattern including Sierrita, Esperanza, and mineralization found north of the two pits.

The alteration is characterized by potassium metasomatism with later retrograde propylitization superimposed upon it. Phyllic alteration and to a lesser extent argillic alteration are found only as remnants which were not destroyed by the retrograde alteration. The potassic alteration consists of orthoclase veining, orthoclase envelopes surrounding mineralized and unmineralized quartz veins, orthoclase flooding, and secondary biotite including fracture fillings, veinlets, replacements of hornblende, and pegmatitic masses. The suite of characterizing accessory minerals, especially anhydrite, are also present.

Commonly, secondary orthoclase is found in the quartz monzonite porphyry and Harris Ranch quartz monzonite while secondary biotite is the characteristic potassium mineral found in the quartz diorite-andesite. However, biotite does occur in the quartz monzonite porphyry and Harris Ranch quartz monzonite, and orthoclase in the quartz diorite-andesite. The potassic alteration zone forms a core which includes the northern half of the Sierrita pit, the northwestern

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half of the Esperanza pit, and an area north of the Sierrita pit.

Phyllic alteration occurs irregularly, outside of the potassic zone. Sericite, quartz, and pyrite are characteristic. Sericitic alteration is found in Esperanza, east of the New Year's Eve shaft, in the southern half of the Sierrita pit, in the Amargosa Extension of the Sierrita pit and in the mineralized area north of the pits. Argillic alteration is scarce, and no well-developed zones are presently recognized.

Two periods of propylitic alteration are recognized. Original propylitic alteration is found up to several thousand feet away from the mine area. The propylitic zone extends for at least 2,000 feet west of the Sierrita pit and 3,000 feet north of the pit. The outer limit of the propylitic zone is not known. Both propylitic facies have the same mineral assemblage of epidote, chlorite, calcite, pyrite, and minor albite.

Retrograde propylitization is found throughout the ore body in varying degrees, although it is most pronounced in the quartz diorite in the northwestern quarter of the Sierrita pit. Possibly unique to the retrograde propylitization is the occurrence of the zeolite stilbite with minor heulandite. The zeolites occur exclusively as fracture fillings and are most abundant in the central portion of the Sierrita pit. Characteristic of the retrograde propylitization are chloritized secondary biotite, epidote and epidote-calcite veins cutting earlier mineralized fractures and veins. The relationship of the retrograde alteration to the regular pattern of hypogene alteration and mineralization is most clearly seen in the potassic zone, where the potassic alteration minerals are well preserved. Orthoclase veins are offset and cut by epidote veins. Epidote veins cut through orthoclase flooded rocks. Biotite filled fractures and veinlets are cut by epidote, and some secondary biotite has been chloritized.

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The scarcity of phyllic and argillic alteration facies may be explained by the retrograde phenomena, with those facies being destroyed by the epidotization and chloritization, and by the mafic nature of the host rocks which appears to have greatly expanded the stability field, and hence the geographic extent, of biotite with respect to sericite. Some remnants of phyllic and argillic alteration may be seen in thin sections being replaced by propylitic minerals (Laine, 1972). Retrograde propylitization minerals are indistinguishable from the original propylitic suite, but the retrograde propylitic alteration undoubtedly enriches the original propylitized zone.

Ore grade at Sierrita and Esperanza is based upon copper equivalent, currently copper assay plus 4x molybdenum assay, and ore zones therefore do not follow the alteration pattern exactly. However, by using the 0.2% and 0.3% Cu. isograde, a rough correlation between ore mineralization and alteration can be made. Central to the potassic zone, a large area of <0.2% Cu. exists. This is proposed as a major portion of the barren core of Lowell and Guilbert. The >0.2% Cu. which surrounds the core includes a large portion of the potassic and phyllic zones, and is proposed as the ore shell. Areas of greater than 0.3% Cu. are usually indicative of shattered zones rather than alteration, although they do occur within the proposed ore shell.

Total sulfide content is low with an overall average from 2% to 3%. The pyrite to chalcopyrite ratio is approximately 1:1 overall. Copper mineralization occurs exclusively as fracture fillings and veinlets in quartz diorite, andesite, and Harris Ranch quartz monzonite. In quartz monzonite porphyry and in the breccia pipe, it occurs as fracture fillings, veinlets, veins, and disseminations. Disseminated chalcopyrite in the quartz monzonite porphyry is found replacing discrete specks of biotite. In the breccia pipe, it occurs as blebs in the biotitic matrix.

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Molybdenite occurs in fractures as coatings, in crystalline rosettes in open fractures, in quartz veins, and rarely as disseminated grains. Molybdenite mineralization is younger than the copper mineralization with molybdenite veins cutting chalcopyrite bearing veins. The pattern formed by the molybdenite zones roughly follows the copper mineralization trends. Ore deposition must have occurred directly after the intrusion of the quartz monzonite porphyry, and the formation of the breccia pipe.

The alteration-mineralization pattern evolved at the Sierrita-Esperanza deposit differs from the model of a typical porphyry copper deposit of Lowell and Guilbert in the two major respects of shape and retrograde alteration.

Pre-ore shattering and contact effects are the prime factors in the localization of mineralization and alteration at Sierrita-Esperanza. The mineralization-alteration pattern developed in an elliptical northwest-southeast elongated shape, following the contact of the quartz monzonite porphyry with the pre-ore country rock. Mineralized fractures have preferred orientations at NNW and ENE. Ore zones trend NW at Sierrita, and ENE at Esperanza. Shattering is most pronounced in the Harris Ranch quartz monzonite and in the quartz diorite-andesite, and good ore zones exist in those rock types. Shattering in the Harris Ranch quartz monzonite and the quartz diorite-andesite is due to the intrusion of the quartz monzonite porphyry. Shattered zones in the quartz monzonite porphyry located near the breccia pipe appear to have formed with the pipe. Other shattered zones in the quartz monzonite porphyry are found along zones of structural weakness that trend from the breccia pipe into the southwest end of the Esperanza pit. Shattering in the breccia pipe is probably due to cooling and release of pressure within the pipe, and the renewed intrusion of quartz monzonite porphyry. Ore zones are coincident with the shattered areas within these rocks. The Triassic Ox Frame volcanics were resistant to shattering. No hypogene ore occurs within them.

Continued....

SEQUENCE OF MINERALIZATION

The following is proposed as the sequence of mineralization and alteration at Sierrita-Esperanza:

1. Secondary orthoclase, biotite, and sericite, with quartz, pyrite, and chalcopyrite were earliest minerals deposited. Purple anhydrite is also given an early relative age due to its intimate occurrence with the chalcopyrite and pyrite. Original propylitization is contemporaneous with the potassic metasomatism. Molybdenite occurs alone, with quartz, and with pyrite and quartz. Rare fluorite is thought to be associated with the molybdenite. Galena, sphalerite and calcite occur with some chalcopyrite and pyrite in veins found in the eastern portion of Sierrita and scattered throughout Esperanza.

2. Retrograde alteration consisting of epidote, chlorite, K-feldspar, calcite, pyrite, and possibly marcasite occurred after the main mineralizing period. Stilbite can be grouped with the retrograde alteration, but is definitely post retrograde epidote and chlorite. Pink anhydrite and gypsum are post stilbite. The anhydrite is possibly hydrothermal, and gypsum probably represents a supergene environment.

Recommendations for further studies in the area of alteration and mineralization are as follows:

1. A detailed thin and polished section analysis of alteration and ore minerals to delineate specific relationships.

2. A study to define pyrite to chalcopyrite ratios and total sulfide content which will hopefully delineate a pyritic core and halo.

Continued...

3. An analysis of cross-cutting relationships between mineralized and unmineralized veins. This would give more specific information as to the relative stages of mineralization.

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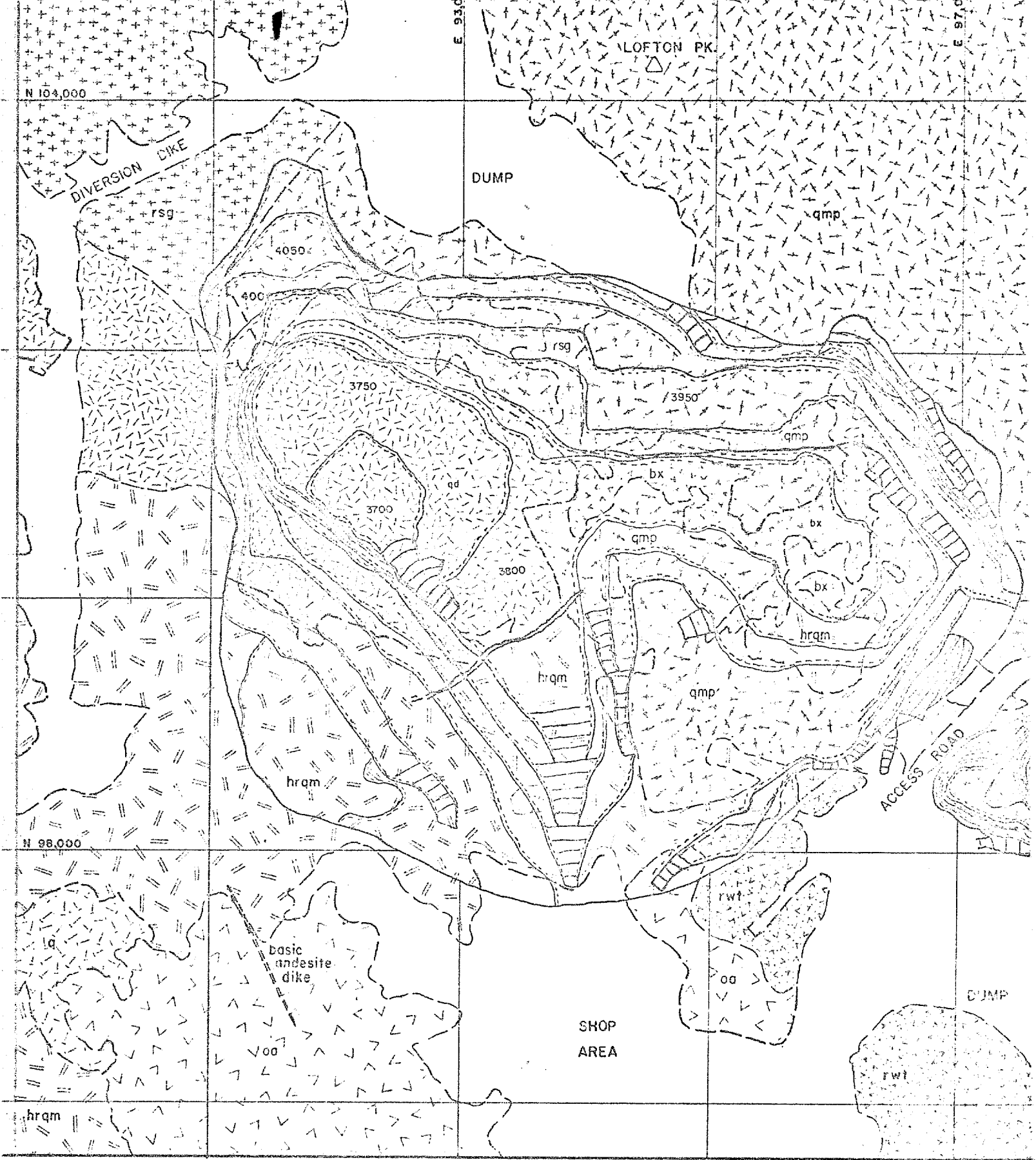

EXPLANATION

- Qal — Alluvium, waste dumps, etc.
- Aplite
- bx — Breccia Pipe
- qlp — Quartz latite porphyry
- qmp — Quartz monzonite porphyry
- rsg — Ruby Star granodiorite
- oa — Oxframe andesite
- gd — Biotite quartz diorite
- hrqm — Harris Ranch quartz monzonite
- rwt — Oxframe rhyolite welded tuff
- q — Quartzite

DUVAL SIERRITA CORPORATION

SIERRITA PIT GEOLOGY

SCALE : 1" = 1000'	DATE : APRIL 1, 1973
GEOLOGY BY: RAM, AHJ, BLW, DWL, FWM, CAO, CDI	DRAWN BY : RLL , ATD, VHT

DUVAL SIERRITA CORPORATION

SIERRITA PROPERTY
SAHUARITA, ARIZONA

VISITORS'
INFORMATION

SIERRITA PROPERTY

The Sierrita property consists of over 13,000 acres, which includes property rights for water field, tailing disposal and rights of way for pipelines and a railroad spur. Included in this total acreage are 143 unpatented mining claims which were purchased by Duval. Approximately 58 percent of the Sierrita ore body was acquired in the purchase of these claims. The remaining 42 percent of the ore body was controlled by patented mining claims owned by Duval. Duval has transferred these patented claims to the Sierrita property.

EXPLORATION AND PRELIMINARY DEVELOPMENT

A total of 178 test holes has been drilled in order to delineate the Sierrita ore body and to test proposed waste dump areas. Some of the tests were drilled to check certain holes drilled by another mining company, which had previously drilled 60 core tests in the area.

GEOLOGY

Rock types within the ore zone consist of quartz diorite, quartz monzonite, and quartz monzonite porphyry. Metallization, partly syngenetic, consists of chalcopyrite and molybdenite with minor amounts of sphalerite, galena and magnetite. There is no enriched blanket in the Sierrita ore body. Dominant structural trend is NE to ENE.

ORE RESERVES

The exploration and preliminary development program delineated an ore body of 414 million tons with an average copper content of 0.35% (seven pounds) and an average molybdenum content of 0.036% (0.72 pounds). Engineering pit design indicates that a total of 634 million tons of waste must be handled prior to and during the mining of the 414 million tons ore reserve. This total of over a billion tons of ore and waste, which will be mined, represents more than twice the tonnage excavated in the construction of the Panama Canal.

Continued...

MINING

It is anticipated that the eventual perimeter of the Sierrita open pit will encompass an area of approximately 460 acres. As presently designed, the pit will ultimately reach a depth of 1850' below the highest elevation of the pit area prior to mining. Such an ultimate depth will represent a distance of almost one and a half times the height of the Empire State Building.

One hundred and twenty-six (126) million tons of waste was removed during the pre-mine stripping period prior to the startup of the mill. A daily average of 200,000 tons per day was mined during the pre-mine stripping period. The mining of ore and waste will be conducted on this scale for an initial six-year production period, after which the scale of mining operations will be somewhat reduced as less waste will be handled.

Mining is accomplished by establishing a series of levels or benches. Each bench is approximately fifty (50) feet high. The large power shovels are provided digable material by blasting the various benches. To blast a bench, rotary drills drill holes 59' in depth and from 9" to 12¼" in diameter.

The blast holes which contain water are loaded with a gelatin explosive called slurry. The holes which are dry are loaded with ammonium nitrate and fuel oil.

A typical blast consisting of forty (40) holes requires 76,000 lbs. of explosive to break 200,000 tons of rock. This is enough material to keep one electric shovel in production for approximately four (4) days.

MINING EQUIPMENT AND FACILITIES

The mining equipment features eight (8) power shovels of P & H manufacture equipped with 15 cubic yard buckets and 38 electric wheel haul trucks of 120-ton capacity along with 8 150-ton electric wheel haul trucks. These shovels and trucks are of the largest presently used in the copper mining industry. In addition seven rotary

Continued

MINING EQUIPMENT AND FACILITIES CONTD

blast-hole drills (three 60-R, three 45-R, and one CP 750), 16 dozers (three D-9, seven D-8, and six rubber tired), and numerous other units; such as 4 motor patrols, 2 forklifts, 3 cranes, 4 water trucks 4 personnel buses and miscellaneous small trucks supplement the operation. Service facilities consist of two modern shops, steam cleaning pad, change room, and offices.

Because the power shovels and haul trucks represent the largest of these machines used in the industry, some pertinent facts concerning these units are of interest:

Power Shovels

1. The weight of each shovel is approximately 450 tons.
2. Shovels are rated at 750 HP and are electrically powered by 4160 volt AC current.
3. When loaded the 15 cubic yard bucket contains approximately 23 tons.

Haul Trucks

1. The truck fleet consists of 14 from KW Dart Company and 32 from Westinghouse Air Brake Company.
2. The truck engines are 12-cylinder diesels, rated at 1000 HP. and 1325 HP.
3. The engine drives the electric generator, which supply power to electric motor assemblies in the rear wheels.
4. Trucks have a rated capacity of 120 tons and 150 tons and weigh approximately 75 tons and 92 tons empty.
5. Fuel tanks hold 450 gallons of diesel oil; the engines use one gallon per mile under full load conditions and level haul.
6. Truck tires are constructed of 48-ply; stand nine feet in height, and weigh 3000 pounds.
7. The expected life of each truck is 5 to 7 years after which replacement is anticipated.

Continued...

PLANT FACILITIES

Stearns-Roger Corporation of Denver, Colorado, was the engineering construction contractor that designed and built the Sierrita concentrator and associated facilities. The concentrator, which has a designed capacity of 80,000 tons of ore per day, and the associated facilities are estimated to cost 100 million. This capacity will be greater than any single copper-molybdenum concentrator in North America. The construction of plant facilities was completed in the first quarter of 1971.

CRUSHING

Primary size reduction of the mined ore is achieved by two 60" x 89" gyratory crushers located near the south perimeter of the Sierrita open pit and adjacent to the main haulroad. The crushers have a total operating capacity of 5,000 tons per hour, reducing the mine ore to about 85% minus 6". The crushed ore is transported by a 54" belt conveyor system to a 40,000-ton coarse ore open storage - an overland distance of about 2½ miles.

Feeder belts under the coarse ore pile collect the ore to feed the fine crushing plant. Ore is first fed to four vibrating double deck scalping screens ahead of four 13 x 84 hydrocone secondary crushers. The secondary crusher product is again screened and the oversize material is further reduced by ten 5 x 84 hydrocone tertiary crushers operating in a closed circuit system consisting of a 3000-ton surge bin feeding the crushers and vibrating screens. The finished product, essentially all minus 3/4", is transported to a 72,000-ton live capacity fine ore bin located in the concentrator building.

CONCENTRATING

The process of flotation is used to concentrate the copper and molybdenum minerals. To accomplish this, the crushed ore must be further reduced by grinding it to achieve

Continued

CONCENTRATING CONTD

mineral liberation to effectively concentrate it by floating these mineral particles. Copper and molybdenum are concentrated simultaneously and then separated.

The ore from the fine ore storage is wet ground in sixteen 16½' diameter by 19' ball mills driven by 3,000 horsepower synchronous motors. The ball mills operate in a closed circuit with cyclone classifiers. The ground ore in an ore-water slurry and conditioned with regents is floated in flotation machines to a rough concentrate of copper and molybdenum minerals. The rougher concentrate is reground in two 11' diameter by 15' regrind ball mills that are operated in a closed circuit with cyclone classifiers. The rougher concentrate is floated and refloated to a final concentrate. A total of 662 flotation machines is used in the copper-molybdenum concentration. Tailings from the flotation process are thickened before disposal in four 350' diameter rake thickeners and the water is recovered from the slurry for re-use in the process. The concentrates are thickened in 100' diameter thickeners.

The combined copper-molybdenum concentrate is floated to separate the two products. The pulp is first steamed and then conditioned with regents before flotation. In the first flotation, the copper minerals are depressed and the molybdenum floated. The copper concentrate is the tailings from this flotation and after thickening in a 125' diameter thickener, it is filtered in four drum filters and loaded in open gondola railroad cars for transporting to the smelter. The molybdenum is concentrated more by floating it in cleaning and re-cleaning stages. The final molybdenum concentrate is filtered, dried, and stored for packaging for marketing as molybdenum sulfide or for roasting it in two 23½' diameter multiple hearth roasters. The roasted product, molybdenum trioxide, is packaged and marketed as technical molydic oxide.

PRODUCTION

The Sierrita property will produce an annual average of 150 million pounds of copper during the first five year of operation and 170 million pounds thereafter. In addition, the property will produce approximately 13 million pounds of molybdenum and 650,000 ounces of silver annually. With Sierrita's production, Duval Corporation will rank fourth in U. S. copper mine production and will be the second largest producer of molybdenum in the U. S.

EMPLOYMENT

Peak employment during construction at the Sierrita property was 1,800. The average permanent employment during production will be 1,370.

UTILITIES

Power and gas will be supplied by Tucson Gas and Electric Company. Power requirements are expected to be approximately 60,000 kilowatts or 40 million kilowatt hours per month. This amount of power would supply an average city of 100,000.

Gas requirements are expected to be some 50 million cubic feet per month with all but a fraction of the gas being utilized in roasting molybdenum sulphide concentrates into the oxide form.

Water requirements for the operation will be on the order of 15,000 gallons per minute with most of this amount being used in the milling operation. This water will be pumped from wells along the Santa Cruz River basin belonging to the Sierrita property. To secure this advantageous site with its water rights, a 5900-acre ranch, which was part of an original Spanish Land Grant, was purchased.

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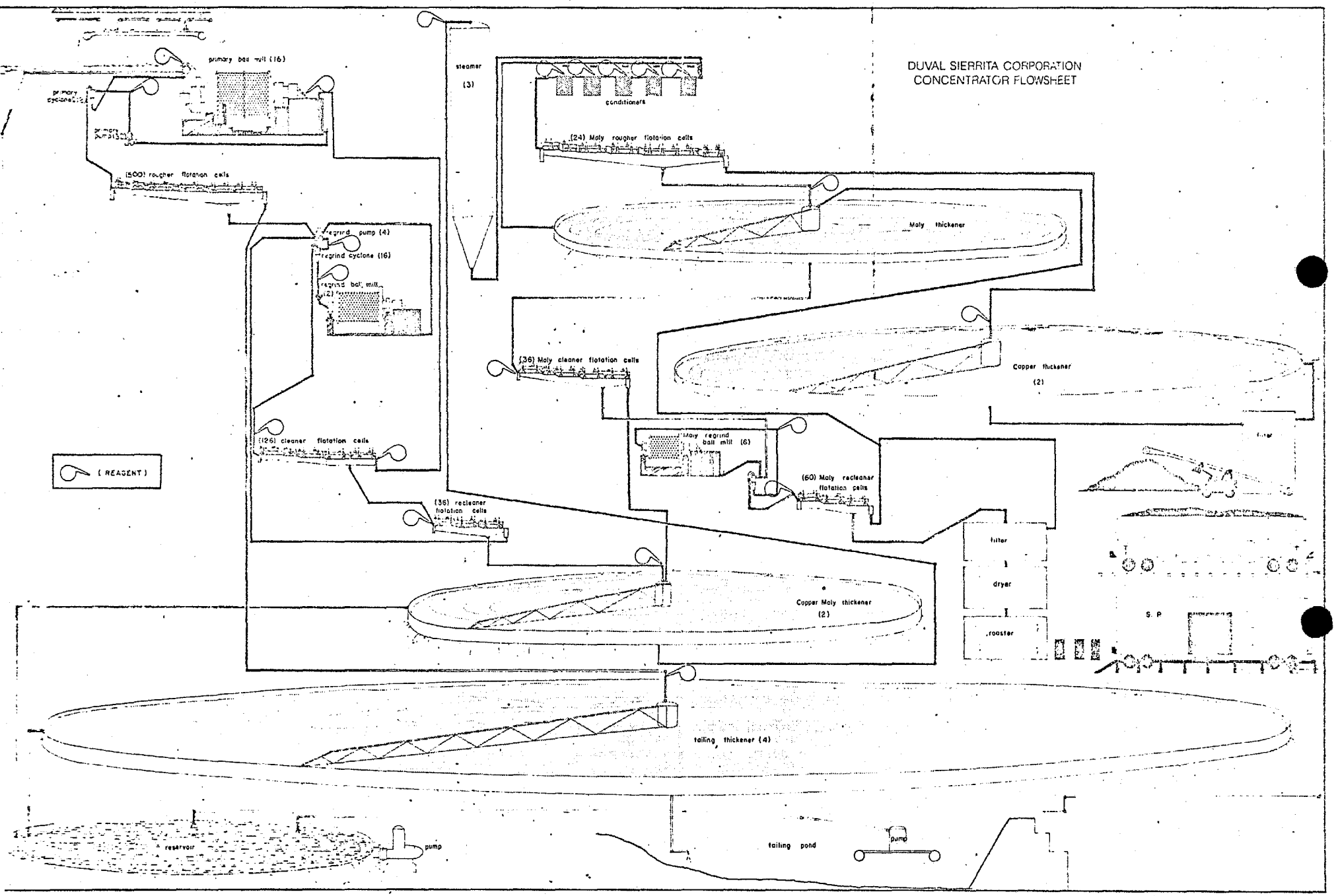
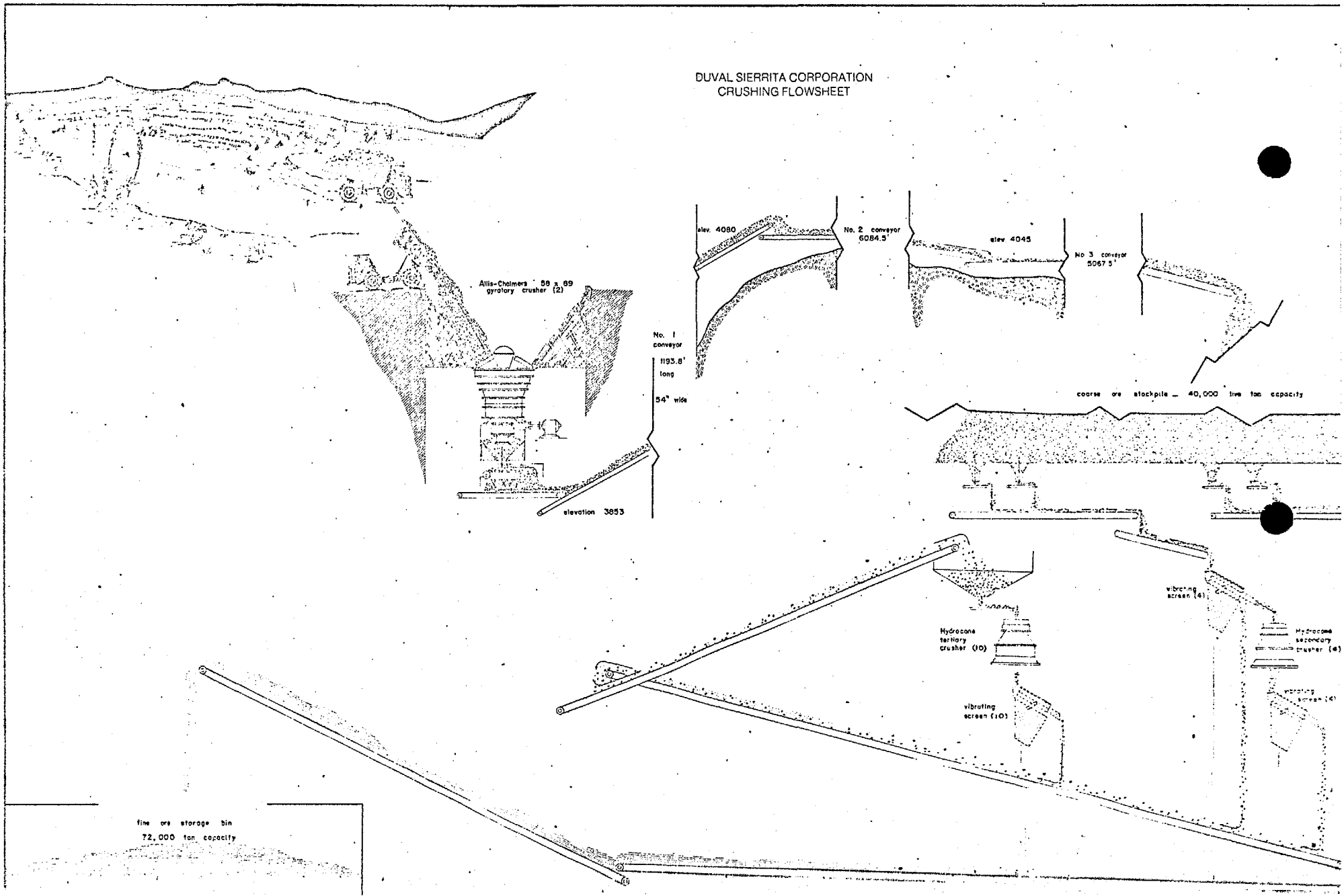
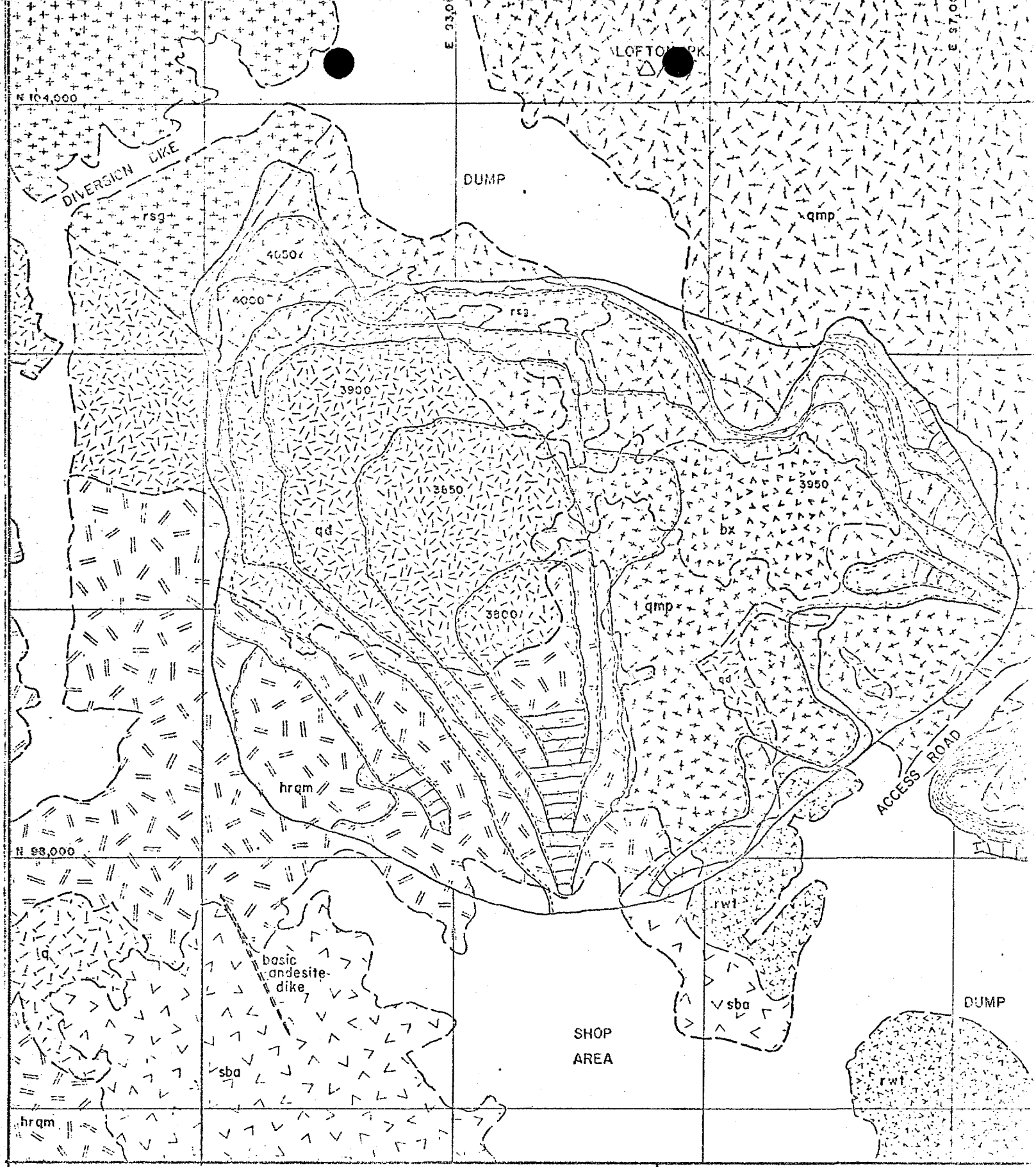

DUVAL SIERRITA CORPORATION
CONCENTRATOR FLOWSHEET
primary ball mill (16)
primary cyclone
primary pump
(500) rougher flotation cells
steamer
(3)
conditioners
(24) Moly rougher flotation cells
Moly thickener
regrind pump (4)
regrind cyclone (16)
regrind ball mill (2)
(36) Moly cleaner flotation cells
Copper thickener
(2)
(126) cleaner flotation cells
Moly regrind ball mill (6)
(60) Moly recleaner flotation cells
(36) recleaner flotation cells
filter
dryer
roaster
Copper Moly thickener
(2)
S. P
tailing thickener (4)
reservoir
pump
tailing pond
pump
(REAGENT)

DUVAL SIERRITA CORPORATION
CRUSHING FLOWSHEET





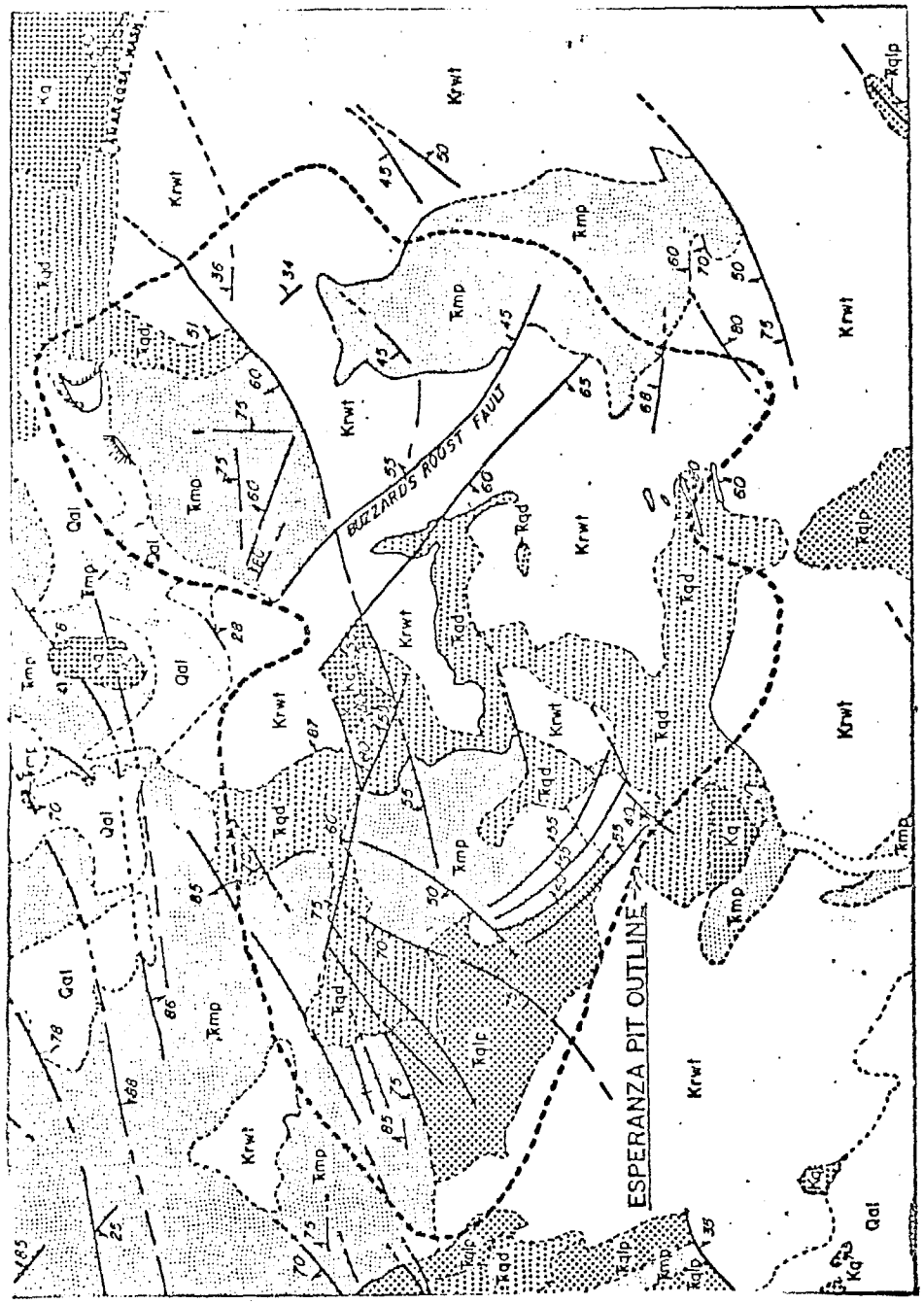
EXPLANATION

- Qal — Alluvium, waste dumps, etc.
- [illegible] — Aplite
- bx — Breccia Pipe
- qlp — Quartz latite porphyry
- qmp — Quartz monzonite porphyry
- rsg — Ruby Star granodiorite
- sba — Silver Bell (Demetrie) andesite
- qd — Biotite quartz diorite
- [illegible] — Harris Ranch quartz monzonite
- rwt — Oxframe rhyolite welded tuff
- q — Quartzite

DUVAL SIERRITA CORPORATION

SIERRITA PIT GEOLOGY

SCALE : 1" = 100'	DATE : 11-30-71
GEOLOGY BY: RAM, AHJ, DLW, DWL, EWM, CAO, CLI	DRAWN BY : RLL, ATD



Because the power shovels and haul trucks represent the largest of these machines used in the industry, some pertinent facts concerning these units are of interest:

Power Shovels:

1. The weight of each shovel is approximately 450 tons.
2. Shovels are rated at 750 HP and are electrically powered by 4160 volt AC current.
3. When loaded, the 15 cubic yard bucket contains approximately 25 tons.

Haul Trucks:

1. The initial purchase of 28 electric wheel trucks was evenly divided between KW Dart Company and Westinghouse Air Brake Company.
2. The truck engines are 12 cylinder diesels rated at 1000 HP.
3. Engines drive DC electric generators, which supply power to electric motor assemblies in the rear wheels.
4. Trucks have a rated capacity of 120 tons and weigh approximately 75 tons empty.
5. Fuel tanks hold 450 gallons of diesel oil and the engines use one gallon per mile under full load conditions and level haul.
6. Truck tires are constructed of 48 ply, stand nine feet in height and weigh 3000 pounds.

PLANT FACILITIES

Stearns-Roger Corporation of Denver, Colorado has been awarded an engineering construction contract to build the Sierrita concentrator and associated facilities. The concentrator, which will have a designed capacity in excess of 60,000 tons of ore per day, and the associated

facilities are estimated to cost $84 million. This capacity will be greater than any single copper-molybdenum concentrator in North America. The construction of plant facilities is expected to be completed in the third quarter of 1969.

PRODUCTION

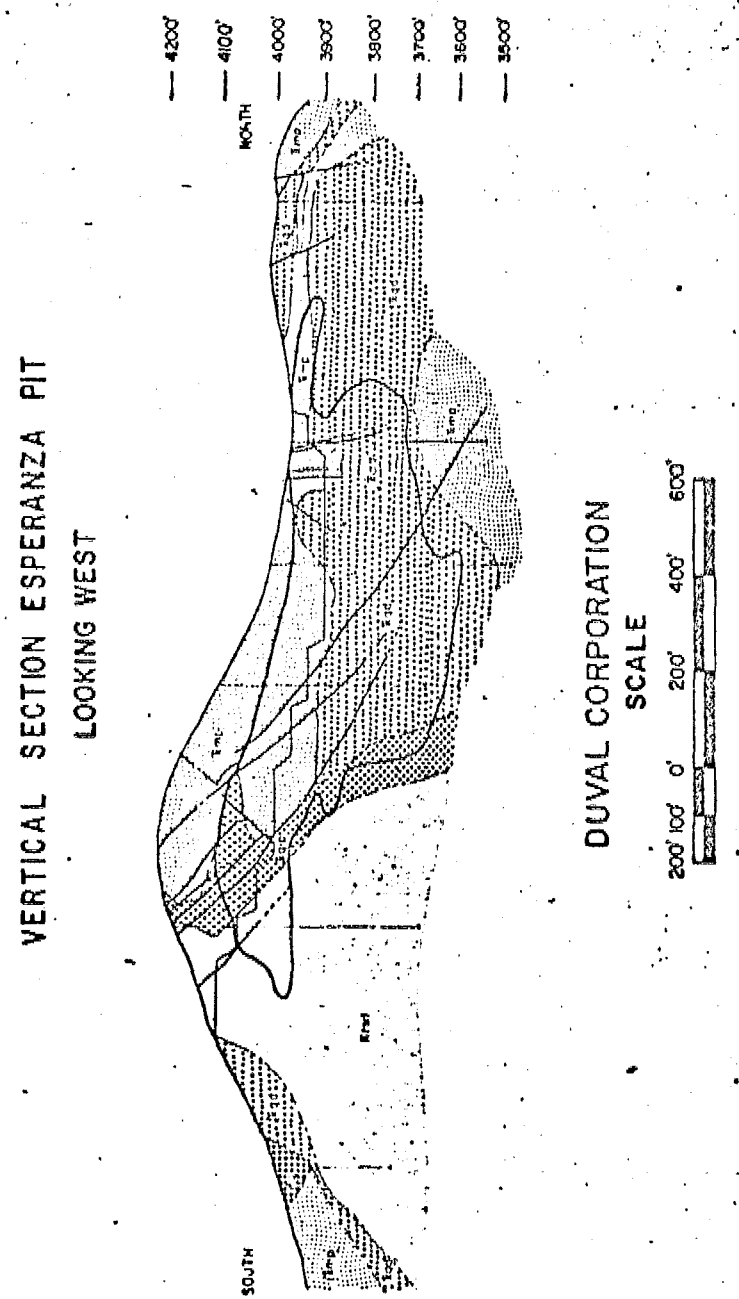
The Sierrita property will produce an annual minimum average of 114 million pounds of copper during the first five years of operations and 136 million pounds thereafter. In addition, the property will produce approximately 12 million pounds of molybdenum and 455,000 ounces of silver annually. When Sierrita reaches full production, Duval Corporation will rank fourth in U. S. copper mine production and supply approximately 14 percent of the free world's molybdenum.

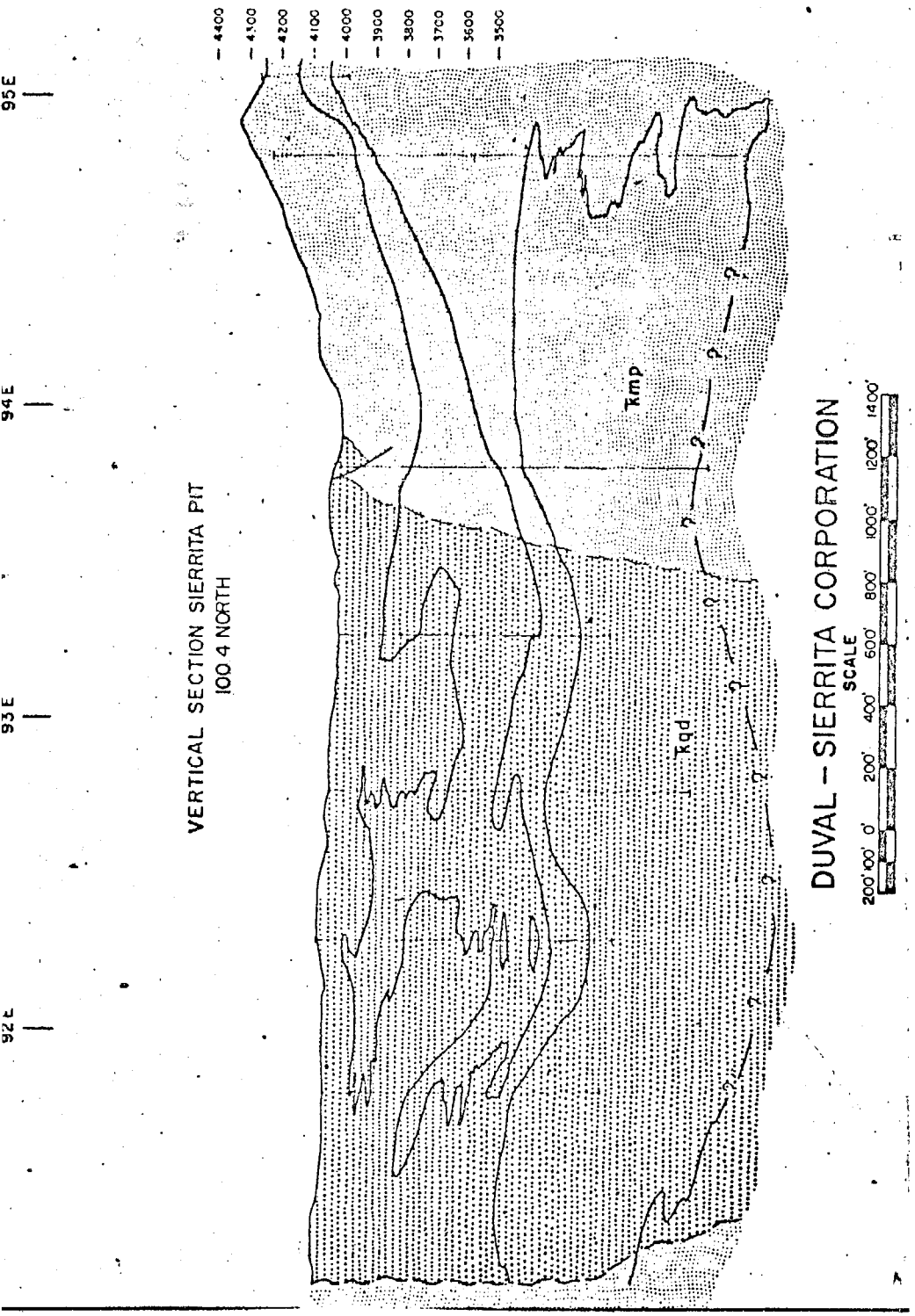
EMPLOYMENT

Peak employment during construction at the Sierrita property is expected to reach some 2,800. It is estimated, average permanent employment during production will be 1,100.

UTILITIES

Power and natural gas will be supplied by Tucson Gas and Electric Company. Power requirements are expected to be approximately 60,000 kilowatts or 40 million kilowatt hours per month. This amount of power would supply an average city of more than 100,000 population.

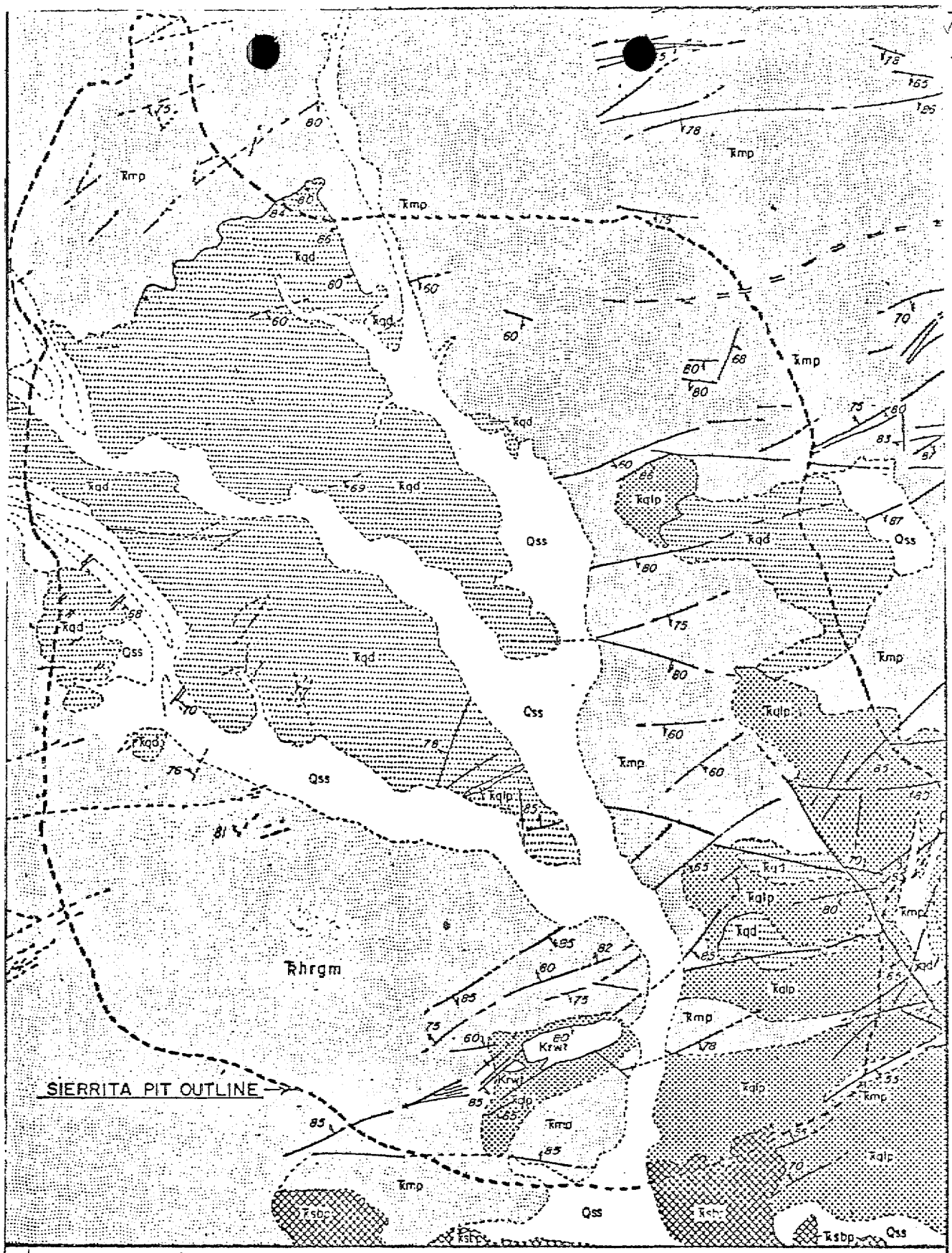




Gas requirements are expected to be some 50 million cubic feet per month with all but a fraction of the gas being utilized in roasting molybdenum sulphide concentrates into the oxide form.

Water requirements for the operation will be on the order of 15,000 gallons per minute with most of this amount being used in the milling operation. This water will be pumped from wells along the Santa Cruz River Basin belonging to the Sierrita property. To secure this advantageous site with its water rights, a 5900-acre ranch, which was part of an original Spanish Land Grant, was purchased.

JHC file



Frank Mack

EXPLANATION

Bob Mertz

- Qss — Quaternary stream sediments
- Krwt — Rhyolitic welded tuffs (includes flows, breccias)
- Ksbp — Silverbell andesite porphyry
- Kqd — Quartz diorite
- Kmp — Quartz monzonite porphyry
- Kqlp — Quartz latite porphyry

Fault or shear showing dip — Inferred fault — Contact showing dip — Inferred contact

J. H. C.

JAN 30 1969

DUVAL - SIERRITA CORPORATION

200' 0 200' 400' 600' 800'

-7-

-8-

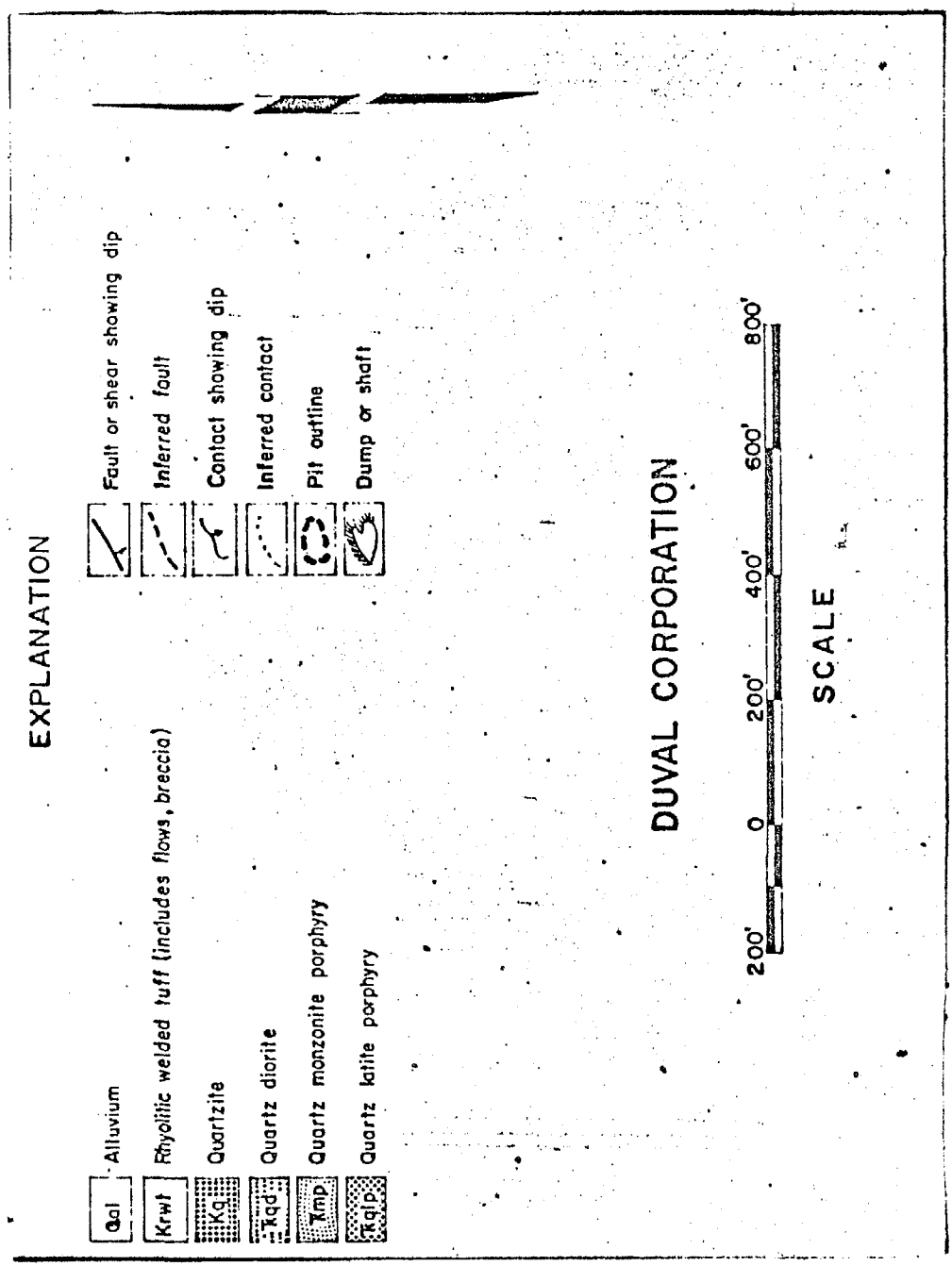
MINING

It is anticipated that the eventual perimeter of the Sierrita open pit will encompass an area of approximately 460 acres. As presently designed, the pit will ultimately reach a depth of 1850 feet below the highest elevation of the pit area prior to commencement of mining. By comparison, the Empire State Building is only two-thirds as tall as the pit will be deep.

The mining plans provide for the removal of 105 million tons of waste overburden before the commencement of ore mining operations. A daily average of 200,000 tons per day will be mined during the pre-mine stripping period. Thereafter, the mining of ore and waste will be conducted on a scale of approximately 235,000 tons per day for the initial six-year production period, after which the scale of mining operations will be somewhat reduced as less waste will be handled.

MINING EQUIPMENT AND FACILITIES

The mining equipment features six power shovels of P & H manufacture equipped with 15 cubic yard buckets and an initial order of 28 electric wheel haul trucks of 120-ton capacity which will be expanded to 40 by the completion of pre-mine stripping. These shovels and trucks are of the largest presently used in the copper mining industry. In addition, six rotary blast hole drills, 11 dozers and numerous other units such as motor patrols, fork lifts, cranes, water trucks, personnel buses and miscellaneous small trucks supplement the operation. Service facilities consist of two modern shops, steam cleaning pad, change room and offices.



Geology - Esperanza and Sierrita

ESPERANZA

Rock types within the ore zone consist of cretaceous welded tuffs, quartz diorite, latite, quartz monzonite porphyry. Hypogene metallization is syngenetic with rock type formation and consists of chalcopyrite, pyrite, molybdenite with minor sphalerite, galena and magnetite. Favored hypogene ore host is quartz monzonite porphyry. Supergene (chalcocite) metallization zone averaged 125 feet thick. Dominant structural trend is NE to ENE.

SIERRITA

Rock types within the ore zone consist of quartz diorite, quartz monzonite, and quartz monzonite porphyry. Metallization, again partly syngenetic, consists of chalcopyrite and molybdenite with minor amounts of sphalerite, galena and magnetite. There is no enriched blanket in the Sierrita ore body. Dominant structural trend is identical to that of Esperanza, which is NE to ENE.

THIS PAMPHLET EXCERPTED FROM "AIME" FIELD TRIP 3 PAPER.

SIERRITA PROPERTY

The Sierrita property consists of over 13,000 acres, which includes property rights for water field, tailing disposal and rights of way for pipe lines and a railroad spur. Included in this total acreage are 143 unpatented mining claims which were purchased by Duval Corporation. Approximately 58 percent of the Sierrita ore body was acquired in the purchase of these claims. The remaining 42 percent of the ore body was controlled by patented mining claims which were part of Duval's Esperanza Property. Duval has transferred these unpatented and patented mining claims to the Sierrita property.

EXPLORATION AND PRELIMINARY DEVELOPMENT

A total of 137 test holes have been drilled in order to delineate the Sierrita ore body and to test proposed waste dump areas. Some of the tests were drilled to check certain holes drilled by another mining company which had previously drilled 60 core tests in the area.

ORE RESERVES

The exploration and preliminary development program delineated an ore body of 414 million tons with an average copper content of 0.35% (Seven pounds) and an average molybdenum content of 0.036% (0.72 pounds). Engineering pit design indicates that a total of 634 million tons waste must be handled prior to and during the mining of the 414 million tons ore reserve. This total of over a billion tons of ore and waste, which will be mined, represents more than twice the tonnage excavated in the construction of the Panama Canal.

DUVAL SIERRITA CORPORATION

SIERRITA PROPERTY

ORGANIZATION

Resident Manager	S. H. Martin
Mine Superintendent	A. P. Holzworth
Chief Mine Engineer	F. H. Buchella, Jr.
Chief Mine Geologist	R. A. Metz
Safety Supervisor	D. L. Gidak
Chief Accountant	S. C. Polasek
Purchasing Agent	J. K. Peters
Personnel Relations Supervisor	S. L. Vaughn

VISITOR'S INFORMATION PAMPHLET

DUVAL SIERRITA CORPORATION

GEOLOGY DEPARTMENT

ROBERT A. METZ, CHIEF MINE GEOLOGIST

A. HARVEY JAMES, MINE GEOLOGIST

BOB GALYON, DRAFTSMAN

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

March 1967

FILE MEMORANDUM

DUVAL's PROPOSED SIERRITA OPERATION

Duval has come up with a very large ore reserve at Sierrita compared to our estimate of 1964. With an improved copper price and a U.S. Government loan, the outcome appears now attractive. Basic data is itemized below:

	Tons	% Cu	% MoS_2
Ore Reserve:	425,000,000	0.33	.055
Waste - ore ratio:	2 to 1		
Milling rate:	60,000 tpd		
Milling recovery:	Cu-90%, MoS_2-85%		
Operating costs per ton:			
Mining			$ .54
Milling			.36
Total direct cost			$ .90
Indirect			
Mining, Milling, Taxes			.28
Total operating			$1.18
Net smelter value per ton ore at $.39 Cu,$1.55 Mo			$2.70
Net operating profit per ton			$1.52
Capital Investment	$142,000,000		
Life Operation	20 years		
Return on investment	14% (present value method)		

J.H.Courtright

JHC:lab

Expl drill hole spacing? ?
depth of leached cap?

J. H. C.
JAN 15 1968

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

January 15, 1968

W.E.S.
JAN 18 1968

To: J. H. Courtright

From: R. B. Cummings

Notes on Trip to Duval's
Esperanza and Sierrita Properties

On January 5, 1968 Charles Zimmerman and I visited the Esperanza property of Duval Corporation and were shown around the Esperanza and Sierrita properties by Mr. Bruce Wilhelm the resident (?) geologist at Esperanza.

At the time of our visit shovels were being assembled for the stripping of the Sierrita property. According to Wilhelm 100 million tons will be stripped. The ore body at the present time is a little over 400 million tons.

Pre-mine stripping ratio?

The Sierrita ore body lies to the west of the Esperanza ore bodies. According to Wilhelm the Sierrita pit will eventually connect with the West Esperanza pit. The ore body occurs in a broad undulating basin. Examination of the intrusive outcropping in the basin shows that it weathers to a crumbly punky mass. This may be the cause for the basin.

The ore body occurs in quartz diorite and quartz monzonite. The monzonite makes up only a minor part of the ore. It does not outcrop in the ore zone. We examined the quartz diorite in outcrop and from a dump of an old shaft (windmill). The rock had a fresh unaltered appearance. Lynch in Geology of the Porphyry Copper Deposits (p. 274) quotes Cooper as saying: "K-feldspar and quartz rim and embay the other minerals and are largely or wholly of replacement origin." Thus, contrary to what field examination might reveal, the rock is altered - probably by an introduction of potassium, silica, and sulfides. It seems strange that the plagioclase in the rocks has not been affected.

The mineralization occurs as pyrite, chalcopyrite, and molybdenite (this deposit is unusual in that approximately one third of the value comes from the molybdemum) in thin seams and fractures, quartz veins, and very fine grained

disseminated particles. As the last occurrence was the least common it appears as if fracturing was of primary importance in localization of the mineralization. Fresh sulfides are abundant on the surface. Little oxide copper was seen. Wilhelm thinks that a rhyolite capping at one time covered the diorite and protected it from oxidation.

The northern edge of the ore body is apparently quite sharp with a number of minor extensions while to the south the cover quite deep and the boundary is more gradational. Wilhelm claimed that there is a primary mercury dispersion anomaly on both ends of the deposit.

Wilhelm was not at liberty to give any figures on the grade of the deposit but some rough estimates were calculated from figures given in a January 4, 1968 issue of the Tucson Daily Citizen. In these calculations the following was assumed:

1. The price of copper is 38¢ per pound
2. The price of molybdenum is $1.61 per pound
3. The price of silver is $2.00 per ounce
4. The smelting and transportation charge for their copper concentrate will be seven cents per pound. This means that Duval will receive income on their copper at 31 cents per pound.
5. The mill recovery is 90% on copper and 85% on molybdenum.

mining .70
milling .50
indirect .45
1.65
interest .50
2.15

The grade of the ore is calculated to be .36% .32 copper and .034% molybdenum (.057% MoS_2). The value of the ore is $2.91 per ton and the total value of the deposit is $1,205,000,000. (using copper at 31 cents per pound).

2.80
.15
65

With a total ore body of 414 million tons and a mill capacity of 60,000 tons per day this will be the biggest operation in Arizona. It will be interesting to see how this low grade operation will succeed.

The Esperanza ore body appears to be quite complex in comparison with the Sierrita ore body. There are at least six different intrusive rocks in the mine area. Four of these are good host rocks. These are quartz monzonite, andesite porphyry, quartz latite porphyry and quartz diorite. The quartz monzonite porphyry is the best host for both hypogene and supergene mineralization.

The hypogene mineralization occurs mainly as chalcopyrite, pyrite, and molybdenite. These minerals occur in thin veinlets and disseminations. The later occurrence seems to be the most common. The total sulfide content is approximately three per cent.

Supergene mineralization was present in the form of ~~chalcopyrite~~ and covellite. The chalcopyrite blanket was evidently thin (less than 100 feet) and is now mined out. We did not have the opportunity to see any good capping but Wilhelm said that the capping over the best supergene mineralization was jarositic in nature and was more yellow and orange than the reddish hematitic capping over the less productive rhyolite welded tuffs.

The main effects of the hydrothermal alteration has been the formation of K-feldspar, quartz, and sericite. The K-feldspar is quite abundant in the quartz monzonite and appears as pink, coarse-grained, subhedral to euhedral crystals. Quartz occurs in veins and as a thorough impregnation of the rock. Sericite occurs mainly with quartz in veins and at least from my observations is not overly abundant. In places where the quartz monzonite contains secondary K-feldspar and biotite it takes on the appearance of a fresh rock. The alteration at Esperanza appears to be less intense than that at Silver Bell. This impression arises from the fact that fewer quartz-sericite veins and a smaller total amount of sericite was observed at Esperanza.

The structure at Esperanza is quite complex. As mentioned earlier there are six different intrusives recognized in the mine area. These rocks intrude Cretaceous volcanics and sediments. The major structural trend strikes northwest. Although no linear structures can be mapped in this direction the mineralization and structural alignments do trend to the northwest. Faulting has exerted a major control on the primary mineralization and on secondary enrichment by providing channelways for upward and downward movement of solutions. The most important set of faults for this purpose strikes to the northwest. In a like manner north-south, east-west, and northwest joints have affected mineralization. Wilhelm pointed out a large breccia pipe about 1000 feet south of the mine in the quartz latite porphyry. Evidently the pipe shows copper staining but has not been drilled out yet.

It is interesting to note the similarities in the structure at Silver Bell. Both have a complex history of intrusion, a major northwest structural trend and a northeast trending fracture pattern which has greatly influenced ore localization.

The present mill capacity at Esperanza is 15,000 tons per day. The ore grade is approximately 0.51% copper and 0.028 MoS_2 with a cut-off of 0.4% copper equivalent.

These figures leave one with the impression that the deposit is on the marginal side.

Robert Cummings

Robert B. Cummings

RBC:kc

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

March 28, 1967

PERSONAL/CONFIDENTIAL
Mr. K. E. Richard, Chief Geologist
American Smelting and Refining Company
120 Broadway
New York, N. Y. 10005

Dear Ken:

Enclosed is a recent estimate on Duval's Sierrita property. Referring to the last page, you will note the large increase in tonnage with a minor drop in the grade of the moly as compared to our report of 1963. Presumably the additional ore was found in deeper drilling, although some additional ore may have been found between the original Sierrita orebody and Duval's pit.

Of principal note is the 11% return based on 40¢ copper for the first 5 years and 38¢ copper for the ensuing 15 years. Actually, this return should be shown as something just under 15%, since 11% is after interest on capital.

I have not attempted to calculate it, but at 36¢ copper and $1.55 moly the return would probably be 12% or over.

Yours very truly,

J. H. COURTRIGHT

JHC/kw
Enclosure

No copies

February 8, 1967

JHC

MEMORANDUM FOR MR. T. A. SNEDDEN

Financial Outcome Estimates
of Duval's Sierrita Property

JHC file

An operating outcome, a year-by-year financial outcome and a rate of return on investment calculation were performed on the Duval Sierrita property from information obtained from Messrs. C. E. Nelson, T. A. Snedden, K. A. von den Steinen, N. L. Weiss and R. F. Welch.

This report summarizes the results obtained from these calculations: The ultimate result being that the rate of return on Duval's investment is estimated at 11%.

The investment consists entirely of borrowed money, the sum of which is $142,000,000. A G.S.A. loan of $85,000,000 and a commercial loan of $57,000,000 make up these capital expenditures.

Along with the government loan comes a guaranteed copper price for the first 5 years of production. The guarantee assures Duval of an average copper price of about 40¢ per pound copper (Connecticut Valley price).

The terms of the agreement are shown in this table:

Current Cu Price	Cost Sub-Price	Tons of Cu to G.S.A.
36¢ or under	50¢	85,000
37¢	47-1/2¢	89,473
38¢	45¢	94,400
39¢	42-1/2¢	100,000
40¢ or better	40¢	106,250

If the current price of copper remains at 38¢ per pound, the government will buy 94,400 tons of copper at 45¢ per pound spread evenly throughout the five-year period. The remainder of the production, which amounts to 193,600 tons, will be sold at the market price of 38¢ per pound. This amounts to an average price of about 40¢ per pound. If the price of copper should vary through this period, an adjustment is made, as shown in the table.

The proposed production rate will be 60,000 tons of ore per day at a waste to ore stripping ratio of 2.0 to 1.0. The mine life is estimated to be 20 years.

From this production rate it is estimated that during the first 5 years at an average ore grade of 0.31% Cu and 0.55% MoS_2, there will be produced 115,600,000 pounds of payable copper per year. During the remaining 15 years of mine life, there will be produced 130,600,000 pounds per year from an average grade of 0.35% Cu.

Other information given was that the Cu recovery was expected to be 90% with a concentrate grade of 29.4% Cu. The MoS_2 recovery was estimated at 85% with an MoS_2 concentrate grade of 90% MoS_2. The mining cost was estimated at 54¢ per ton ore and the milling cost, as calculated by Mr. N. L. Weiss, at 36.2¢ per ton ore.

The government loan was assumed to have an interest rate of 6% and the commercial loan a rate of 6-1/2%. Both loans will be paid off within nine years from start of production.

From the given information, it was possible to calculate the plant working days to be 354 per year, which in turn reveals an ore reserve of 425,000,000 tons.

A two-year construction or pre-production period was assumed, and the distribution of capital expenditures to be distributed 1/3 the first year and the remainder the second year.

Even though any one of the copper prices could have been chosen from the table and provided the same results, the current price was set at 39¢ for the first 5 years and 38¢ for the remaining 15 years. A molybdenum price of $1.55 per pound was assumed throughout the mine life.

The indirect costs were determined by calculating the percentage of Mission's direct costs that make up its indirect costs. This same percentage was then applied for this estimate but it did not include the sales tax on Cu and MoS_2 concentrates and property taxes on ore reserves. These had to be calculated separately because they are a function of the concentrate grades and the tonnage and grade of the ore deposit as well as the tax district, respectively.

The operating outcome calculations show the net smelter value per ton of ore for the first 5-year period to be $2.65. For the remaining 15 years, the value is $2.74 per ton of ore. These figures include $.87 for molybdenum.

After operating costs, these figures are reduced to $1.46 and $1.55.

After taxes and general administration, the financial outcome cut these figures to $1.06 and $1.12.

The cash earnings, after interest is paid on the loans, bring these figures to a final average value of $0.73 and $1.09 for an overall cash flow of $1.00 per ton ore for the entire 425,000,000 tons.

A rate of return of 10-1/2% was calculated by assuming a copper price of 37¢ instead of 38¢ for the last 15 years. A change in copper price doesn't change the cash earnings of the first 5 years.

Attached to this report is a sheet showing the comparison of Bear Creek's and Asarco's outcomes that were calculated in 1963, and also this outcome as described. This 11% rate of return on investment may seem unreasonably high for a deposit with such a low grade of copper but three major factors together make this possible: (1) the high guaranteed and assumed prices of copper; (2) the molybdenum content that raises the copper equivalence grades to .46% Cu the first 5 years and .51% the remaining 15 years; and (3) the low milling costs due to autogenous grinding.

Carl E. Williams

Carl E. Williams

CEW:dh
Attachment

DUVAL's SIERRITA PROPERTY
SUMMARY OF ESSENTIAL BASIC DATA

		First Five Year Period	Remaining 15 Years
1. Ore Reserves - Tons	425,000,000		
2. Grade of Ore:			
% Cu		.31	.34
% MoS_2		.055	.055
3. Mill Recovery %:			
Cu		90	90
MoS_2		85	85
4. % Mineral in Concentrates			
Cu		29.4	29.4
MoS_2		90.0	90.0
5. Pounds of Cu paid for per ton crude ore*		5.4	6.1
6. Pounds of Mo paid for per ton crude ore		.56	.56
7. Tons of Ore Treated:			
Per day		60,000	60,000
Per month		1,771,000	1,771,000
Per year		21,250,000	21,250,000
8. Price of Cu used in outcome (¢)		**42.5 and 39.0	38.0
9. Price of Mo used in outcome ($)		1.55	1.55

10. Life of Operation - 20 years

11. Total waste tonnage (after pre-mine) - 850,000,000

12. Ratio of waste to ore - 2.0 : 1

13. Copper and MoS_2 Concentrates Production:

	FIRST 5 YEARS		REMAINING 15 YEARS	
	Tons Cu Conc.	Tons MoS_2 Conc.	Tons Cu. Conc.	Tons MoS_2 Conc.
Per Day	570	31.2	643	31.2
Per Month	16,805	920	18,973	920
Per Year	201,658	11,038	227,679	11,038
In Total			4,423,475	220,760

14. Pounds of Payable Cu and Mo Production:

	FIRST 5 YEARS		REMAINING 15 YEARS	
	Pounds Cu	Pounds Mo	Pounds Cu	Pounds Mo
Per Day	326,550	33,620	368,920	33,620
Per Month	9,633,330	991,620	10,883,330	991,670
Per Year	115,600,000	11,900,000	130,600,000	11,900,000
In Total			2,537,000,000	238,000,000

15. Estimated Capital Costs - $142,000,000

* Smelter deductions are deducted.

** First 20,000 tons of payable Cu per year @ 42.5¢
Remaining 36,800 tons of payable Cu per year @ 39.0¢

...UVAL's SIERRITA PROPERTY
...MMARY OF ESTIMATED OUTCOME

60,000 tons per day	First 5 Years	Remaining 15 Years
Head Assay: % Cu	0.31	0.35
% MoS_2	0.055	0.055
% Cu equivalence (Mo + Cu)	.46	0.51
Operating Costs: (per ton ore)		
Mining (¢)	54.0	54.0
Milling (¢)	36.2	36.2
Total Direct Costs (¢)	90.2	90.2
Indirect Costs: (per ton ore)		
Mining (15% of Direct Mining Costs)	8.1	8.1
Milling (20% of Direct Milling Costs)	7.2	7.2
Sales Tax on Cu and MoS_2 Concentrate (1.5% of Net Smelter Return)	4.0	4.1
Property Tax on Ore Reserves	9.0	9.0
Total Indirect Costs (¢)	28.3	28.4
Total Operating Costs ($)	$1.19	$1.19
Net Smelter Value: (per ton ore)		
Cu	1.78	1.87
Mo	.87	.87
Total	$2.65	$2.74
Operating Profit per ton ($)	1.46	1.55
Operating Profit per year ($)	30,970,760	32,929,650
*Income after taxes per ton ($)	(Average) 0.73	1.09
*Income after taxes per year ($)	(Average) 15,527,430	23,076,650
Pounds Copper paid for per ton crude ore	5.4	6.1
Pounds Mo paid for per ton crude ore	0.56	0.56
Pounds of Cu equivalence paid for per ton crude ore	8.0	8.9
Cost per pound of payable copper:		
Operating Costs (¢)	21.8 ~~22.2~~	19.4
Smelting and Freight	7.1	7.1
Total Direct Costs (¢)	~~29.3~~ 28.1	26.5
Depreciation	6.1	5.4
General Administration	1.1	1.0
Total (¢)	36.5 36.1	32.9

*Also less general administration and interest on loans.

DUVAL's SIERRITA PROPERTY

	BEAR CREEK's OUTCOME	ASARCO's OUTCOME	DUVAL's OUTCOME
ORE RESERVES	170,000,000 tons	113,000,000 tons	425,000,000 tons
ORE GRADE	% Cu .34 % MoS_2 .071	.312 .065	.31 and .35 .055
STRIPPING RATIO	1.9 : 1	2.33 : 1	2.00 : 1
METAL PRICES USED	$/lb Cu .31 $/lb Mo 1.400	.30 1.325	42.5, 39.0 and 38.0 1.550
MINE LIFE	28.4 years	16.0 years	20.0 years
DAILY PRODUCTION	20,000 tons ore	20,000 tons	60,000 tons
% RECOVERY	Cu 90 MoS_2 88	90 88	90 85
% Cu IN CONC.	29.0	29.45	29.4
% MoS_2 IN CONC.	90.0	89.20	90.0
CAPITAL INVESTMENT	$33,350,000	$33,350,000	$142,000,000
COSTS:			
MINING	¢/TON 64	73	54.0
MILLING	" 50	55	36.2
INDIRECTS	" 30	40	29.0
	$1.44	$1.68	$1.192
RATE OF RETURN	14.5%	7.0%	11.0% 15.0%

MR. [illegible]

READ AND RETURN

PREPARE ANSWERS ___ HANDLE ___

FILE ✓ INITIALS ___

J. H. C.
NOV 20 1963
T. A. S.

NOV 20 1963

A. C. H.
NOV 21 1963

November 19, 1963

Mr. Harry Burgess, Vice President
Kennecott Copper Corp.
161 E. 42nd St.
New York, N. Y.

Sierrita-Lofton Peak Orebodies -
Twin Buttes District, Pima County, Ariz.

Dear Sir:

This will confirm our telephone conversation of this morning during which I advised you that Asarco is not interested in carrying on further with negotiations on your subject properties.

We have greatly appreciated the cooperation shown by Mr. Walthier and his staff at Bear Creek's office in Tucson. The data they provided Mr. Courtright enabled him and his staff to arrive rather quickly at opinions on certain critical aspects of the evaluation of your orebodies.

Yours very truly,

KENYON RICHARD

cc: EMcLTittmann
RDBradford
CFBarber
FGHamrick
CHNelson
JHCourtright A/M

Mr. T. M. Walthier
Bear Creek Mng. Co.
2601 N. First Ave., Tucson, A/M

J. H. C.

NOV - 4 1963

W.E.S.

NOV 4 1963

November 1, 1963

MR. [illegible]

READ AND RETURN

PREPARE ANSWERS ..... HANDLE

FILE ✓ INITIALS

CONFIDENTIAL MEMORANDUM FOR -

Mr. E. McL. Tittmann

Sierrita-Lofton Peak Property
Twin Buttes District - Pima County, Ariz.

Attached is copy of a letter by Mr. Courtright in which he analyzes results of a drilling program carried out by Bear Creek on the west and northwest extension of Duval's Esperanza mine. Mr. Courtright's analysis is based on study of a report prepared by Bear Creek's Tucson personnel which includes several outcome estimates.

This is a very low grade orebody. Mr. Courtright's critical figures include 134.1 million tons ore grading .34% Cu and .071% MoS_2, with a waste:ore ratio of 1.63. From this, he roughly estimates a present value return of 14.6% for nineteen-year life. Initial capital is estimated by Bear Creek at $33.3 million. At first glance, this would seem to be a startling outcome for such low grade material. Along with other favorable features, however, the principal reasons for this outcome are due to the relatively high molybdenite content and the high milling recovery of both the copper and molybdenite. Mr. Courtright tells me that in a very preliminary way, and again based only on study of the Bear Creek report, Norman Weiss believes these estimated recoveries are probably valid.

Kennecott wants to "sell their position for $1.5 million." They have outstanding property options and purchases totaling $2.3 million spread over several years. This is equivalent to about $10,000 per claim.

With this possible favorable outcome, the proposition should not be ignored. On October 30, I had a talk with Mr. Harry Burgess and Mr. Bob Atkinson of Kennecott. In answer to my direct questions, Mr. Burgess stated that they, too, were surprised at their various outcome calculations (and checked them in a number of ways among their different departments.) Next, he stated that Kennecott had decided to try to sell their position because they have a great deal of low grade ore at Ray and, therefore, would not consider putting this Sierrita-Lofton Peak orebody into production until some time in the future. In order to put it on the shelf, the high property payments make the proposition unfavorable on a present value basis. Incidentally, Kennecott claims to have spent $7-800,000 to date on the exploration phase.

Sierrita-Lotton Peak Property

They have a payment of $67,500 due this November 25. Beginning December 1, 1963, $1,860 is due monthly on another parcel. The most important payment consists of $187,000 due on March 17, 1964. They are negotiating a 90-day extension on that. On November 29, 1963, $7,500 is due on another parcel. Until March 17, 1964, their total option payments are $82,440.

It is my recommendation that we should check into all of their data carefully. This would involve: -

1) Checking their drill core and carefully analyzing the distribution of chalcopyrite and molybdenite in the mineralized zone,
2) [illegible]
3) Making a preliminary estimate of mining feasibility, and
4) Checking their capital estimates.

I suggested to Mr. Burgess that, for an option on all property and data, Asarco might be willing to take up a $20,000-part of their option obligations up to, but not including the large payment due on March 17, 1964. This would give us time to check their data thoroughly and if the business still appeared to be favorable, there would also be time to do a certain amount of our own drilling. I told Mr. Burgess that our people would probably choke upon any agreement to take up all of their option payments, particularly the large one due on March 17, 1964, until we had had ample time (many months) to check their data and to drill. He did not seem willing to retreat on this point, however, and thought that that and following option payments should be taken up by Asarco.

Mr. Burgess stated that he would immediately instruct his Bear Creek people, particularly Mr. Walthier, head of their Tucson exploration office, to make all detailed information available to us. I believe by now, Mr. Courtright already will have made moves to obtain the drilling results and other detailed information in Bear Creek's Tucson office. This material done will have considerable value to our other exploration efforts in the southwest. Frankly, Mr. Courtright and I and others have made reconnaissance studies of this ground a number of times in past years, and from surface observations alone, we did not suspect anything like the high moly values which Bear Creek has obtained in their drilling. Their milling data and other detailed information would also be of general usefulness to us, I should think, but we probably should not go that far until an option agreement either is completed or

Mineralia-Lofton Bank Property

nearly so.

I would like to have authorization to negotiate an option with Kennecott, the principal obligation on Asarco's part being the $20,000 which would hold the option until at least March 17, 1964 and possibly longer. The details of these negotiations would best be handled between Mr. Courtright and Mr. Walthier, and possibly Mr. Paul Baile, President of Bear Creek.

A copy of the Bear Creek report is available in my office if you care to review it. It seems to me that the chief gimmick in the favorable outcomes is that a slight drop in the relative market values for Cu or Mo would wipe out the whole thing as an apparently favorable business proposition. On the other hand, with established operating staffs and office already in the district, Asarco is in a more practical position to operate there than Kennecott. I should also mention that after reviewing Mr. Courtright's letter just before leaving for Africa, Mr. Pollock commented that "this doesn't look very fat."

Kenyon Richard

att.
cc: RBradford
GFarber
FGLamrick
CHMelson
RRichter
HLCoodenough
HMeiss (All confid. w/att.)

RJPope
RRCourtright)
TAHodden)A/K w/o att.

GPPollock, S. A. w/att.

Aa. 16. 20. 19C

AMERICAN SMELTING AND REFINING COMPANY
Tucson Arizona

October 29, 1963

MEMORANDUM TO MR. J. H. COURTRIGHT:

RHENIUM CONTENT AT LOFTON PEAK
PROSPECT, SIERRITA MOUNTAINS
PINA COUNTY, ARIZONA

An off-the-cuff remark by Mr. Jack Clark, while Clark, Saegart and I were checking the mineralization around drill hole M-31, Lofton Peak Prospect, suggested that rhenium was present in the area.

Rhenium determinations were conducted on the MoS_2 concentrate during some of the metallurgical testing. Apparently the MoS_2 concentrate contains 80 ppm of rhenium. This value is quite low according to the values suggested by the U.S.B.M. R.I. 6246. (See my memorandum dated October 21, 1963, on: Rhenium -- A Possible Geochemical Tool in Copper-Molybdenum Porphyry Exploration.)

A geochemical survey was not conducted for rhenium over the Lofton Peak-Sierrita prospects. The testing for rhenium by Bear Creek in the laboratory was apparently of random nature and the 80 ppm value may not be representative of the entire deposit. Also, the 80 ppm value was not a "firm" number but was stated that the Lofton Peak determinations were similar to what was found at Bingham Canyon, Utah, which is said to be around 80 ppm rhenium in the molybdenite concentrate.

JAMES D. SELL

JDS/jk
cc: JHCourtright/3 extra