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GEOLOGY APPLIED TO MINE DESIGN AND ORE CONTROL AT THE DUVAL CORPORATION ESPERANZA - SIERRITA MINES

INTRODUCTION

The Duval Esperanza and Sierrita open pit copper-molybdenum mines are located approximately 26 miles south of Tucson, Arizona, in the southeastern foothills of the Sierrita Mountains. They are the southernmost porphyry-type deposit in the Pima Mining District.

Initial penetration of the present Esperanza ore body was by the New Year's Eve mine, which was worked intermittently from 1895 through World War II. Duval acquired the Esperanza property in 1955 on the recommendation of Dr. Harrison A. Schmitt, consulting geologist. Pre-mine stripping began in 1957, with initial production in 1959. Additional exploration drilling developed the West Esperanza ore body, followed by pre-mine stripping in 1963 and production in 1965. Total tonnage mined thru July, 1972 was 163 million tons, including 59 million tons of ore and 58 million tons of leach. Average ore grade was 0.5% copper and 0.03% molybdenum. Present daily production capacity is approximately 25,000 tons leach-waste and 15,000 tons ore.

The Sierrita property consists of over 13,000 acres. Forty-two percent of the ore body was originally controlled by Duval through ownership of patented mining claims, with the remainder being acquired in 1968 by the purchase of unpatented mining claims. Pre-mine stripping began in 1968; production in 1970. Total tonnage moved through July, 1972 was 296 million tons. Current daily production is approximately 80,000 tons ore and 140,000 tons waste. Published reserves are 414 million tons of 0.35% copper and 0.035% molybdenum.

GEOLOGY

The Esperanza, West Esperanza and Sierrita ore bodies are part of a single porphyry-type deposit occurring along the contact between Laramide intrusives and an older volcanic-intrusive complex. Mineralization trends parallel the contact (N60E at Esperanza and N45W at Sierrita), resulting in a "V" type configuration. Within the contact-mineralization zones are subtrends paralleling the contact-mineralization zone of the adjacent property. At Sierrita, for example, N60E zoning commonly occurs within the overall N45W mineralization belt.

All rocks within the pit limits are either pre-mineral or syngenetic with the mineralization event, with quartz diorite, breccia, Harris Ranch quartz monzonite and quartz monzonite porphyry the principle hosts. Volcanics, with the exception of localized secondary enrichment, were unfavorable for ore deposition. The original Esperanza-West Esperanza ore bodies were chalcocite blankets, with accessory molybdenite. Mining has removed most secondary ore tonnage, with primary chalcopyrite and molybdenite now being the principle economic minerals. The Sierrita ore body is mainly chalcopyrite and molybdenite, with secondary mineralization confined to minor tonnages near the southeast perimeter.

Chalcopyrite generally occurs in fractures and quartz veinlets, with some disseminations in the quartz monzonite porphyry. Molybdenite is found along faults, fractures, and in quartz veinlets, very seldom disseminated. Chalcopyrite and molybdenite zones consistently occur together and/or immediately adjacent, with chalcopyrite generally preceding deposition of molybdenite. In general, the deposit is a uniformly mineralized body containing large tonnages of low-grade material.

MINE DESIGN - ORE CONTROL

GENERAL

Mine design and ore control at the Esperanza and Sierrita properties are the responsibilities of the respective engineering departments, with the geology department serving in a supporting role. The function of the geologist is, where possible, to assist in design and ore control activities where his knowledge of the deposit may result in a more efficient operation.

Long-range mine design is based on development drilling, spaced at 250 to 500 foot intervals. Yearly and monthly designs utilize the development drilling information supplemented by assay contour-rock contact map overlays supplied by the geology department. Daily ore control is based on bench blast hole assays generally spaced at 20 to 50 feet, depending on rock blasting characteristics, bench height and drill hole size. Ore cutoff is 0.32% copper equivalent, which is computed by taking total percent copper minus one-half the acid-soluble copper plus four times the total molybdenum.

Sorting, with the exception of minor alluvium or oxide separation from the chalcocite zone, is not practical due to large equipment size, relatively wide blast hole-assay spacing, high bench height, and the generally uniform nature of the deposit.

GEOLOGIC INPUT

Data used by the geology department in support of mine design - ore control activities is obtained from pit mapping, development drilling, and bench copper-molybdenum blast hole assays. With the exception of development drilling, this information is kept on 100-scale bench maps, consisting of a structure-rock type base map, an alteration-mineralization overlay, and copper, molybdenum and copper equivalent bench blast hole assay overlays. The assay overlays are contoured and color-coded to give a visual representation of mineralization distribution and intensity. Development drilling data is available from 200- and 100-scale engineering polygon bench maps, geology drill hole logs, and geologic cross-sections. We are presently obtaining a series of 200-scale copper, molybdenum and copper equivalent development drilling cross-section overlays, produced by a computer-plotter system at the Tucson office. Assay contours of previously mined benches will be plotted on the overlays, which in conjunction with the geologic base sections, will provide a better understanding of the deposit. Through the use of this data, it has been possible to more accurately define mineralization control and occurrence, with resultant application to engineering activities.

The use of development drilling polygons for long-term, large volume design is statistically valid if correct hole spacing is used. These polygons are less dependable on a short-term basis, where a single assay representing 200,000 to 800,000 tons of rock determines the ore-waste designation and grade. Obviously, the closer the sample spacing, the more accurate the estimated tonnage and grade will be with respect to material actually mined. Using this concept, a program was established in which distribution, grade and tonnage estimates are made for areas scheduled for future mining, utilizing assay data from previously mined upper benches. Under this method, actual mineralization characteristics determined from blast hole sampling at 20 to 50 foot intervals are projected vertically 35 or 50 feet, depending on bench height. When mineralization controls and/or zoning are known, the projections may be adjusted to incorporate these factors. The effect of this procedure is to represent a 250 (500) foot polygon with 50 (200) blast hole assays in place of a single development hole assay.

An ore tonnage study covering 42 DDH polygons on the Sierrita 3850 bench showed 53% of the polygons to be more accurate, in comparison to ore tonnages actually present, when using tonnages planimetered from the bench immediately above (overlay polygon) rather than DDH polygon tonnages. Only 7% were less accurate, the remaining 40% having insignificant differences. On an individual or small group basis, the overlay polygons are consistently as accurate or more accurate than indicated DDH polygon tonnage. Over the entire 11.5 million tons of the study, however, the DDH polygons gave a more accurate total tonnage figure because of the increasing mineralization with depth not reflected in the overlay. In addition to the increased tonnage accuracy, overlay polygons show mineral zoning and relative ore-waste distribution not possible with DDH polygons, except on a small scale, deposit-wide basis.

To make this information available on a continuing basis, a program was established in which monthly and semi-annual bench contour overlays are prepared for the engineering departments. Rock contacts are included on the overlays because of the effect of rock type on milling rate, grade, and blending.

SEMI-ANNUAL OVERLAYS

The semi-annual overlay is basically a pit progress map, with blast hole assays contoured for all active benches, graphically depicting mineralization throughout the pit. This map is prepared for Sierrita using copper equivalent contours at a scale of 200, corresponding to design polygon bench maps. Preparation consists of tracing the current pit progress map on mylar, with assay contours for each bench then transferred from the previously mined bench immediately above. Prior to transfer, the 100-scale office bench overlays are Xerox-reduced to 200 scale. Rock contacts are placed on the map and bench faces color-coded for rock type. By not contouring bench faces, a more visual representation of bench locations and rock distribution is achieved. Because of the relatively small map scale and its use in long-range planning, interpretation is generally not attempted unless a significant change in tonnage or grade would result. Map preparation takes about five man-days, at a total cost of $220.00.

The map is used as a supplement to design polygon maps for yearly and monthly mine planning, visually depicting ore-waste distribution, grade, zoning, and rock distribution.

Specifically, they have been used to verify location of ore-waste lines as originally determined by development drilling; to aid in averaging in crest lines where ore-waste contacts are non-linear; to adjust monthly and bimonthly designs for more accurate ore-waste ratios; and, to design for ore tonnages by rock type. In addition, these maps have outlined narrow ore zones near rock contacts which were not indicated by development drilling and, therefore, not incorporated into the mine design. Even had development drilling intersected these zones, the indicated polygon tonnage would have greatly exceeded the actual tonnage present.

MONTHLY MINING OVERLAYS

Monthly mining overlays are used to supplement development drilling polygons for monthly and weekly production planning. Copper (with rock contacts), molybdenum and copper equivalent overlays are prepared for Esperanza; a copper equivalent overlay (with rock contacts) is prepared for Sierrita. Separate metal assay overlays are given to Esperanza because of occasional blending requirements, while any blending at Sierrita is generally based on rock type, rather than grade. A scale of 100 is used to correspond with office bench maps.

The mining overlays show assay contours and rock contacts for bench areas scheduled to be mined the following two-month period. Preparation consists of plotting two-month mining lines and bounding bench faces with DDH assays, upper bench assay contours, and rock contacts plotted within the mining lines on each active bench. Bench faces are color-coded for specific rock types. Mineralization controls, secondary and oxide mineralization, zoning and other information which could be of benefit are noted. The maps are distributed by the first of the month. Preparation takes approximately seven man-days, at a cost of $280 per set.

Contours are designated as either being traced from the bench immediately above or as definite, probable or possible when interpolated. Although generally traced directly, established zoning trends may be incorporated into the contours, with the degree of certainty indicated by the type of contour line.

Monthly overlays, in conjunction with development drilling and active bench face assays, are used extensively when preparing the weekly mining schedule. They help to determine drill pattern locations for the most probable areas of ore or waste, depending on immediate or anticipated needs. In conjunction with face grab samples, they may be used to determine if marginal grade areas should be taken as ore or waste. This may occur, for example, when blast holes are extremely wet, contaminating the sample, or for any other reason in which assays may be considered unreliable. A third application is the determination of whether an area showing an unexpected change from ore to waste, or waste to ore, can be expected to return to its original grade. The overlays are useful in indicating possible development drilling polygons which may be erroneous. The slide shows an area at Sierrita where development drilling indicated an ore polygon of 0.68% copper equivalent. When mined, over half of this polygon was waste. Assay contours from the bench above closely correspond to actual mined tonnage figures, as well as indicating correct ore-waste spatial relationships. In some areas, the mineralization zoning is consistent to the extent that, as in Esperanza, the point at which copper increases from 0.3% to 0.4% can generally be located within 30 feet.

BENCH COMPOSITE OVERLAYS

The third type of map in use is a bench composite overlay outlining ore zones from four upper benches previously mined. Ore zone outlines are color-coded for bench identification, with areas containing more than one bench of ore indicated by color and symbols. A separate overlay outlines general areas and approximates the percentages of ore and waste which have been present on the upper benches. These overlays are used primarily to check areas on the monthly and semi-annual overlays for vertical consistency.

MISCELLANEOUS APPLICATIONS

Geological information has been utilized at Esperanza and Sierrita in cases not related to the previously discussed overlays. At Sierrita, a spotty ore zone not originally recognized was shown to be vertically continuous; expanding in areal extent and grade with depth into a major section of the ore body. Location of a temporary crest line at Esperanza was based on information which showed the ore cutoff to be along a near-vertical intrusive-volcanic contact.

A study of the southwest end of the Esperanza pit indicated primary copper mineralization control to be basically a function of rock type with consistent zoning patterns. Using this information, it was possible to point out specific polygons in which grade and/or tonnage was in error due to drill hole location, with respect to zoning or anomalous assays. Both cases are shown in the slide, where one hole is located near the edge of a high-copper zone, and a second in a small anomalous high-copper area. This information was used in calculating mine design figures for the next year's budget. In an adjacent section of the pit, a small, relatively high-grade chalcocite zone was shown to be controlled by an Alaskite intrusion in the volcanics. Using assay contours from three upper benches, the ore zone proved to be vertical and continuous with depth. Rotary development holes were located and drilled on the active bench, based on the probable outline of the zone.

In West Esperanza, copper assay contours from three upper benches were used as an aid in location of the most probable high-grade copper zones in an area that showed decreasing grade and tonnage with depth. A second application in this area involved the use of an assay overlay to supply information about possible ore tonnage which might be encountered by an access cut into a large ore zone.

A different and more direct application of geology as an aid to ore control involved color-sorting of oxide-chalcocite zones in the West Esperanza area. Pit mapping showed the chalcocite extending approximately six feet into the brown oxide zone. This information was utilized by the engineering department in establishing a color-sorting procedure to attempt to maximize copper recovery and grade.

IN CONCLUSION

Data supplied to the engineering departments, derived from pit mapping, development drilling, and bench blast hole assays has resulted in a more efficient operation. With the aid these geological tools provide, a more accurate forecast for mine design schedules is possible. Also, production is improved due to information made available on ore zoning, which aids in scheduling; and, rock types and hardness, which affects blasting and milling operations. The continued use of the maps and overlays by the ore control staff testifies to their usefulness.

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