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Studies of Antimony Occurrence with Special Relation to its Effective Extraction, San Jose Antimony Mines, Wadley, San Luis Potosi, Mexico

J. C. Archibald Jr.

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STUDIES OF ANTIMONY OCCURRENCE WITH SPECIAL RELATION TO ITS EFFECTIVE EXTRACTION
SAN JOSE ANTIMONY MINES
WADLEY, SAN LUIS POTOSI, MEXICO
by
J. C. Archibald Jr.

22737

Professional Degree
1951
Montana School of Mines

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STUDIES OF ANTIMONY OCCURRENCE WITH SPECIAL RELATION TO ITS EFFECTIVE EXTRACTION
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J. C. Archibald Jr.

INTRODUCTION:

The author joined the staff of Cia. Minera y Refinadora Mexicana, S. A. in October, 1947 as Unit Superintendent, Wadley Unit, stationed at the San José Mines of the company. He is now General Superintendent of the same company with headquarters in Wadley in charge of the Wadley, Bernal (Querétaro), and Durango Units of the company. The mines at San José which are within the Wadley unit are the largest antimony mines in Mexico. These mines produce more than half of the antimony produced by the company from its mining operations. Since the time of the author's connection with the company, a number of changes have been made in planning of development work, handling of labor, methods of mine development, cost improvement, and other problems inherent in the successful guidance of an operation. It is the purpose of this report to record these changes commenting on the former practice, reasons for making the change, and results. It is not the purpose to give complete operating details and such details will be given only when it is believed necessary or of sufficient interest to the reader.

The problems of operating in a foreign country combined with the extraction of an ore which differs from those commonly encountered in mining operations are felt to warrant the preparation of this report. This work will be for the permanent reference of future operators of the mine and will be of value to all who may be interested in mining in Mexico as many of the labor problems would be the same.
LOCATION and ACCESSIBILITY:

The San José Antimony mines are located in the Catorce range of mountains in the State of San Luis Potosí in the eastern central part of the Mexican plateau region. They are 12 kilometers east of Wadley, a station on the National Railways of Mexico, about half way between Laredo, Texas and Mexico City. A good truck road exists between Wadley and the base of the mountains. Elevation at Wadley is 1.800 meters above sea level. At the end of the truck road ten kilometers away it is 2.100 meters and at the mines 2.600 meters. From the end of the truck road a two-kilometer jeep road has been cut up the side of the mountains for ready accessibility of the mine. Ore is lowered to the truck road by an aerial tram.

Wadley can be reached by excellent rail accommodations in overnight trips from Laredo or Mexico City. San Luis Potosí, capital of the state of that name is three hours south of Wadley along the main railway. San Luis Potosí is accessible by car over good highways from the north or west and by one airline, Líneas Aéreas Mexicanas, S.A. known as LAMSA, which has two scheduled flights through San Luis Potosí daily.

CLIMATE and VEGETATION:

The climate at San José mines is dry and healthful. Temperatures range from a low of five degrees centigrade below zero in the winter to a high of 25 degrees centigrade in the summer. (These temperatures are the equivalent of 23 and 77 degrees Fahrenheit.) Nights are always cool. Average annual rainfall is 20 inches. Most of the precipitation takes place from May to September.

Scrub oak and pine are found on the eastern slope and to some extent at the western base of the Catorce range where the rainfall is higher. Vegetation in the mine area proper consists of grass, cacti, and a semi-arid brush known locally as "gobernadora".
GENERAL HISTORY OF THE PROPERTY:

The antimony deposits were discovered in 1898 by Mayer Elsasser, an assayer at the Catorce silver mines located in the same range as the antimony mines and approximately 12 kilometers to the north. The deposits were worked by several owners and operators until 1915 when Cookson & Co., Ltd. of Newcastle, England acquired the properties. In 1947 control of the properties passed to National Lead Company, New York through purchase of the shares of the local Mexican companies.

Production of Mexican antimony has fluctuated over many years controlled by prices as low as 4.15 cents per pound in 1922 and the present high price of 42 cents per pound. Antimony is priced, f.o.b. cars, in bulk, Laredo, Texas, for refined metal 99.5% Sb. White (1) assigns a production of 174,412 tons of ore with a metal content of 57,612 metric tons of metal for the period 1898 to 1943. Since 1943 the production is estimated to have been 41,881 metric tons of ore with a metal content of 12,394 metric tons. Total production has been 70,006 metric tons of metal in 216,293 metric tons of ore and an average grade of 32.37% Sb. During recent years, grade of ore mined has been directly influenced by need for the metal. In 1947 and 1948 grade of ore from the mine was dropped to an average of 22% Sb. whereas in 1949 and 1950 the average grade was raised to over 40% Sb. Improvement in smelter techniques combined with increased value of the product has made possible and in many instances desirable the mining of low grade antimony ores.

An antimony smelter was built in Wadley in about 1920 and moved to Laredo, Texas in 1932 so as to avoid payment of United States import duty on metal which was not placed on ores and also to avoid possible expropriation of the smelter during troubled years in Mexico.

DEFINITION OF ORE:

Ore may be readily defined as a mineral or mixture of minerals which can be mined at a profit. Nearly always there are two kinds of ore. One, that is rich
enough to be shipped by itself and the other which requires some process of concentration. As will be shown below, antimony ores from the San José mines cannot be satisfactorily concentrated, therefore ore as used in the text will mean ore rich enough to be shipped. The following sections are devoted to the study of the factors involved which limit the minimum grade of ore. A short summary is given summarizing present information on concentration of antimony ores.

Antimony ore is bought by the Texas Mining & Smelting Division of National Lead Company for the smelter located at Laredo, Texas. All antimony ores are purchased on a sliding tariff which presently varies from seven cents per pound of antimony contained for 15% ore to a high of 17 cents per pound of metal contained for 65% ore. Such tariffs have been established to cause delivery of the higher grade ores in preference to lower grades. Impurities in all ores must be not more than 1/2% combined of the following substances: zinc, copper, lead, tin, arsenic, bismuth, and selenium. Prices are fob cars, smelter yard, Laredo, Texas. In this discussion where the word cents is used, it will mean United States cents.

Direct Taxes

Under the Mexican tax structure, two direct taxes are levied on ores and concentrates. The first and oldest is the production tax which amounts to 1.54 percent of the value of the ore calculated at an official price fixed monthly by the government. This official price is the average price for the metal in case lots at Laredo converted to pesos at an arbitrary exchange rate of 4.85 pesos per dollar. The tax for the month of April was 0.3665 cents per pound of metal.

The second tax is the advalorem tax applicable to all exports. This tax is 18.36 percent of the official value fixed for the purpose. The official value fixed for this purpose is the current quotation for antimony ores placed New York less freight allowance converted to pesos at 8.65 (the official exchange rate.) No quotations are published for ores under 45% antimony and the values for the ores under this assay are estimated. For the period April 21 to May 20 the export tax
in cents for ores over 55% was 4.2216 cents per pound and for ores of less than 25% was 3.0064 cents per pound. Intermediate grades of ore are priced proportionally.

Freight Rates:

Freight rates are fixed by the tariff commission of the department of roads and public works and consist of eight columns of rates which vary for shipments from Wadley to Laredo of from 12.75 pesos per metric ton to 37.35 pesos. The rate the ore takes depends upon its value which has been arbitrarily determined by the railroads as the value of the antimony content in the ore based on the official value for production tax but converted to pesos at 8.65 pesos per dollar instead of the 4.85. This means that each percent of antimony content is valued as of April at 81 pesos. Fifteen percent ore has an official valuation for freight purposes of 1,215 pesos and 65% ore 5,265 pesos. The freight rate for the 15% ore is 29 pesos per ton whereas the 65% ore takes the maximum rate of 37.35 pesos per ton. Converted to cents per pound of metal the cost is one cent per pound for the 15% ore and 0.3 cents per pound for the 65% ore.

Concentration of antimony ores:

Present methods of concentrating antimony ores are wasteful. Antimony ores from the San José mines are composed of oxide antimony minerals such as stibiconite, cervantite, or valentinite mixed with varying amounts of kermesite or the sulfide stibnite. Clean stibnite can be floated but the natural ores found in the mine have not been found amenable to flotation. Heavy media concentration has been tried with varying success and the process has not yet been applied to a commercial operation. A pilot plant operated on the property in 1947 and 1948 using jigs and tables gave an overall recovery of 35 to 40 percent of the antimony in concentrates averaging 22% from the tables and 48% from the jigs. Losses were in slimes. Concentration of antimony in low grade ores by fuming has been tried but has yet to be applied on a commercial scale. Temperature control is critical as the pentoxide
sublimes at 930 degrees centigrade and the trioxide sublimes at 1550 degrees. No adequate process has yet been devised for the satisfactory concentration of the mixed oxide ores. All known commercial methods are wasteful.

Grade limits for ore:

Grade cannot be fixed at this time for concentrating ores. Arbitrarily, the grade has been assigned as no less than 3% antimony. Shipping ores can be readily calculated taking into consideration, price offered by the smelter, taxes, freight costs, and production costs. for two extremes, 15% ore is worth at Wadley ready for shipment 2.5 cents per pound of contained metal and 65% ore is worth 12 cents per pound. Present mine average is 40% which is worth 8.5 cents placed Wadley.

GENERAL GEOLOGY MAIN MINE AREA

The San José mines are on the summit and west flank of the Sierra de Catorce which trends north-south. A number of anticlines whose axes strike N10ØE with as much as 25 degree plunge to the north are cut by faults striking N25W with both east and west dips. The west dip is the most prominent and may be the controlling one. Additional fractures are found, some strike N10ØE with a westerly dip, and others strike N60ØW with a northerly dip.

STRATIGRAPHY:

The geologic column is given in Plate I. The oldest exposed formation in the district is known as Caliza del Fondo, which is a thin bedded blue-gray limestone with some limey shale. This is conformably overlain by the Santa Emilia limestone with a total thickness of about 250 meters. The Santa Emilia limestone contains the mantos, or favorable beds for ore deposition. The San José shale overlies the Santa Emilia and is characterized by black to gray or green shale members some of which grade into limey shale. The upper portion of the formation is composed of interbedded shale and limestone. Characteristically, there is a black shale direct-
ly above the Santa Emilia limestone. The San José formation is 60 meters thick. Above the San José is what is known as the Corona limestone, which has a thickness in excess of 300 meters. The San José shale may grade into the Corona limestone. The Corona limestone is characterized by the absence of shaley members, and the presence of many chert lenses and concretions of iron oxide. Some ore has been found in this formation. All the formations described are believed to be upper Jurassic. (2)

FAVORABLE BEDS FOR ORE DEPOSITION:

The relationship of the mantos, or principal ore bearing horizons in the Santa Emilia limestone is also shown in Plate I. The word manto as applied in the San José mines, means an ore bearing horizon, presumably parallel to the bedding, which has been altered in some fashion so as to present distinct characteristics from the limestone. The Santa Emilia limestone is known to have no less than eleven mantos. Five of these are the most widely known and worked, and are now known as the upper series. The other six have been partially explored or otherwise encountered by diamond drilling at depth. Between the two series, stratigraphically, are about 180 meters of limestone which is believed to be non ore-bearing although there are isolated instances where certain members have produced ore in the vicinity of a mineralizer.

Starting at the top of the Santa Emilia limestone, there are from five to seven meters from the shale contact to what is known as the zero marker, which in turn is one meter above the first manto. Between the first and second manto are eight meters, and between the second and the bastard manto which is found only in the northern portion of the main mine area are two to three meters. The third manto is three to five meters below the bastard or about eight meters below the second where the bastard is not found. The fourth manto is six meters below the third. These five mantos comprise the upper series.

The second series begin with the fifth manto, 180 meters below the fourth. The sixth and seventh mantos are six to eight meters, each, below in succession.
In most locations there is found another bastard manto one meter and a half above the seventh. Below the seventh manto there are no less than three mantos, the upper of which is 15 to 20 meters below the seventh. One meter below it is the ninth manto and one meter below the ninth is found the tenth.

Some of the mantos are characterized by physical differences which serve to identify them. All are marbleized grading laterally into gypsum in certain cases. In most cases identification can only be made by the manto's position. The first manto is the only manto which has a strong silicified portion varying from 20 to 50 centimeters thick and found at the top of the manto. Below the silicified portion there may be up to one meter of white marble. Manto Two is identifiable by the presence of two clay marker beds about two meters above the manto which are only a few centimeters thick and separated by from 20 to 50 centimeters. This manto commonly has a distinctive odor of hydrogen sulphide when freshly broken and is from one half to two and one half meters thick. The so-called bastard manto is identifiable only by its position. It may be one meter wide. The third manto is characterized by the presence of a prominent clay marker 30 centimeters thick, one meter above the manto. The manto is commonly divided into two portions of marble separated by up to one meter of limestone. The upper portion sometimes has a silicified top ten or less centimeters thick with one to over two and a half meters of marble. The lower part of the manto will vary from one half to two meters thick. The fourth manto is generally recognizeable by its great width, sometimes exceeding five meters of marble.

The fifth manto is one to three meters thick and is commonly identified by a reddish colored marble at the top. The sixth manto is one to two meters thick and may be non-existent in certain sections of the mine. It has been exposed in several places on surface and has been cut by diamond drill holes. The seventh manto is overlain by the bastard manto which is up to one meter thick. The seventh itself is from one and a half meters to three meters thick. No commercial ore has been found in the eighth, ninth, and tenth which are 20 to 40 centimeters, ten meters,
and two meters thick, respectively. One diamond drill hole (#31) cut traces of ore in the eighth and ninth mantos.

The origin of the mantos is not known. Two theories are advanced to try and explain their formation. The first is that slippage along beds in the limestone may have permitted and encouraged subsequent recrystallization of the limestone. The second theory, suggested by White (3) is that the mantos were originally deposited as gypsum which was subsequently altered to marble. This theory has been propounded for the formation of certain similar formations in the Colorado plateau region. The facts seem to favor this second theory.

**FAULTING**

At least three separate systems of fractures are known with varying displacements. In age, the N10E fractures are the oldest. These fractures are nearly vertical, dipping slightly to the west. They show little sign of displacement. Fractures with a N60W strike and a dip to the north show a displacement of three to four meters and may have been of the same age as the N25W system. This last system shows as much as seventy meters of displacement and may have had marked scissors-like movement because in some places it is impossible to measure any movement. It would appear that the N60W fractures may have resulted from the breaking due to hinging the main break at two points with a sag in between. The two fixed points would be located, one at the north end of the San Jeronimo level at Coordinates 6080 N, 4300 E, where no displacement can be measured in the fifth manto where it is crossed by the Colorado fault, and two, at a point now eroded at Coordinates 4900 N, 5100 E. (See Plate III.)

Silicification is prominent on the N60W fractures, along the N25W fractures, especially the San Elias fault, (Plate II) and along some of the N10E fractures as far south as two kilometers from the main mine area.
GEOLeGIC STUDIES:

Other than the very superficial study made by White(3) no geologic studies have been made of the mine as a whole. Work is now underway under the direction of the Chief Geologist who with two assistants expects to complete the mapping of the underground of the main mine area within a few months and by mid year 1952 it is hoped most of the surface geology will have been mapped. Authorization has been received for an aerial survey to draw a topographic map of the area to be used as a basis for the mapping of the surface.

BASIS FOR PLANNING DEVELOPMENT WORK:

Present planning of development work is carried on by sectional analysis of certain portions of the mine on what is termed short-range development work and generalized visualization of the overall structure of the mine in planning long-range work. One native member of the staff has a phenomenal memory for local structure of the mine and he has been of immeasurable aid in helping to plan work. Since 1947 only about five percent of the headings started have not come up to expectations which in view of the nature of the ore deposits in the mine is excellent. As no positive reserves of antimony shipping ore can ever be measured, in one sense every development face started could be called exploration, however, the short-range work is nearly always after ore which we have reason to suppose is there, and the long-range work is going into new areas and could be termed exploration. No separation is made of them, and they are all labeled development work.

Plate II is a generalized geologic plan of the yet unmapped General level. It is offered in order to illustrate the mine structure with its pattern of strong N25W faults, (the Colorado, San Elias, and Estrellas) and the very important transverse faults running into the Colorado and San Elias faults, and the less prominent fractures with a N10E strike which show little displacement but have been the most important local mineralizers west of the Colorado fault. These are such as the Nueva Esperanza and Los Angeles faults. In addition to
the fault pattern, we have a number of folds in the limestone overlain by shales which have formed excellent traps for the antimony. Plate VII shows two views indicating, structure of the San Jose Mines. In the area directly between the Colorado and San Elias faults is a small peak known as Cerro de la Corona from which the Corona Limestone takes its name which was highly mineralized and a good producer. In summary therefore the conditions present in this main mine area are strong N25W faults, minor silicified N60W faults, a series of minor N10E fractures, adequate folding, and signs of ore above the shale capping.

DEVELOPMENT OF OUTLYING AREAS

Conditions almost identical to those summarized in the preceding section are found in an area known as Alamarcito, about three or four kilometers north of the main mine area. The N25W faulting is prominent, folding is adequate, the Corona limestone is well mineralized, but the N10E fractures have not been observed. The N60W fractures are noted in the Corona limestone with important concentrations of ore. This area is the most important area outside of the present mine workings of any of the holdings of the company in the district. It is hoped that attention can be given the detailed mapping of the area and recommendations can be made for starting to work. The author feels that the readily accessible reserves of ore in the main mine area may be limited to from two to five years depending upon the rate of extraction. As it will take at least a year to begin work in a new area such as the one under consideration here, it has been recommended that the geologic mapping be speeded up. Since January the Chief Geologist has been assisted by one man and he will be assisted by the second man within a period of thirty days.

A section illustrating the Alamarcito area has been prepared, Plate IV which shows the general structure of the range. The main structural features which may have been responsible for the ore deposition and concentration are shown with the exception of the N60W fractures which could not be represented clearly on the section. Point "A" on Plate IV represents a down dropped block similar to the
block between the San Elias and Colorada faults (Plate II). The fault block under "B" offers an excellent opportunity for finding antimony as the conditions are similar to those of the main mine area directly west of the Colorada fault. Conditions similar to those at "C" should also be favorable for the deposition of the ore. In an area to the west and north of where the section in Plate IV has been drawn, we are working along N25W fractures in the Corona limestone which are excellent producers of ore. The conditions at "C" are the same. Points "D" and "E" are on the flanks of the range of mountains and nothing is known as to the possible production of ore from similar conditions. Further south and approximately twelve kilometers east of the main mine area at a place known as Maroma, we are mining antimony ore in lesser concentrations than the main mine area in mineralized beds in what may be the Corona limestone under conditions similar to "D". No correlation has been made of the formations in this area with those which we are discussing over the main range. Point "F" cannot be checked as the surface is covered with loose valley fill. It is possible as we lose elevation, the chances for finding antimony are lessened as the ore may have had a tendency to seek the highest available points for deposition. However, good traps may be found locally and geologic work is warranted over the entire region.

ORE DEPOSITS MAIN MINE AREA

Plate III is a reproduction of the main mine workings at a scale of 1:5000. The elevation of the levels is indicated on the color chart at the margin of the map. From the Republica and San Felipe levels on up, the first series of mantos have been worked. The Soledad and San Jeronimo workings are on the second series of mantos. The workings of the first and second series are not yet connected. A brief description will be given of the levels, followed by a discussion of the larger producing areas of the mine.
DESCRIPTION OF MINE LEVELS:

Plate III shows the location of the levels and the following comments are designed to simplify the study of the map.

Plate VIII A. Shows a view of the mine taken from the foot of the mountain indicating relationship of some of the mine workings.

The San Pablo level is for the most part a new level. Principal workings are along the first manto which has been an excellent producer. The San Jose and Japon levels are interconnected and represent the oldest workings in the mine and may be considered as one. The mine offices are on this level. It is probably the third largest level of the mine.

San Elias de arriba and San Elias Intermedio are short levels driven on or to the San Elias fault. The San Juan level is an intermediate level on the Colorada and San Elias faults and on the first and second mantos. The Nueva Esperanza level was driven along the Nueva Esperanza fault.

The second largest level in the mine is the San Pedro level in spite of the fact that it is an intermediate level. The General and San Antonio levels should be considered as one and together are easily the largest of the mine. Principal haulage is through the General level. The buscon ore which will be discussed further on in the paper is brought out and delivered on the General level. The compressors and mine shops are located on this level as well.

The Colorada level and San Elias de Abajo are also connected. Up until 1946 the Colorada level was known as the first sublevel as it was not holed through to surface until that time. The second sublevel is in two parts and it is expected will be connected together this year.

The Violin level is a new level to explore the Los Angeles fault. San Felipe is a level driven in about 1932 to 1936 to look for extensions of bonanza ore in the second and fourth mantos of the mine known as Santa Emilia. The new Republica level is being driven to undercut the second sublevel.
Another new level is the Soledad driven in 1948 for exploration of the fifth manto. The Santa Fe level is a short level on the seventh manto which is interconnected through workings on the manto to San Jeronimo. San Jeronimo is on the seventh and fifth mantos. Sixty meters below San Jeronimo is a new low-level crosscut which will be used for testing the continuations of the San Elias and Colorada faults and the lower members of the second series.

DEPOSITS IN MANTOS:

It is estimated that sixty to seventy percent of the production of the mines has come from mantos, principally the first and fourth. It is not yet known whether the other mantos of the upper series have produced less because they have been ignored or whether the first and fourth were the most receptive to ore deposition. It is the author's opinion that this last is the case. From imperfect data it would seem that the first and fourth offer the greatest possibility for finding ore in the upper series. Present programs are endeavoring to test this supposition by stressing work on the second manto and to a certain extent on the third. A discussion of this will be found under general development program page 33. With reference to the lower series, where even less data is available, the impression is that the seventh manto is the most productive although the fifth manto was very productive in the Soledad area and perhaps has not been sufficiently tested to determine its potency. Generally speaking, for all mantos, the ore tends to be found towards the top of the manto but in several instances the ore has been found towards the bottom of the manto. This seems to be truer of the fourth and seventh.

Inconclusive results from three test stopes run on the first, third, and fourth mantos give the following ratios of shipping ore to milling ore for each of the mantos: 1 to 65, 1 to 106, and 1 to 250. These results are not to be compared as the stope on the fourth manto was merely started and then stopped.
because the demand for antimony was reduced. Material mined from each manto was over 3,000 tons for Manto One, 2,200 tons for Manto Three, and less than 300 tons for Manto Four. As will be shown later on in the text, the stoping system offers a means of testing the potentialities of each manto.

DEPOSITS IN FRACTURES:

The fractures and faults mined to date are the northeasters (N10E), the strong northwesterns (N25W) and the transverse fault (N60W). Experience to date shows that the northeasters (especially the Nueva Esperanza fault) are the most consistent producers of shipping grade antimony ore. The northwesterns show a spotty distribution for which an attempt was made to correlate the localization to some structural condition. Plate V, is a study of the manto intersections with the Colorado fault and the projection of the position of the mantos to the east and west of the fault are shown with the actual position of the concentrations of bonanza ore and the approximate positions of the low-grade milling ore in which some shipping ore is found. Not all of the fault has been entirely explored and it now looks as though the shale rather than the mantos may be the controlling limit to the localization of the milling grade ores, which are shown as containing pockets of shipping grade ores. The upper limit to these ores seems to be where the fault is composed of shale on both sides. This may be, because through the shale, the broken and fractured zone is much reduced and did not favor ore deposition. The reasons for the deposition of the bonanza pockets and their limitation to the points where they are found are even less explainable on the intersection of the mantos with the fault. It is the author's opinion that when the geology of the mine is mapped it will be shown that the intersection of the N10E fractures with the Colorado fault was instrumental in localizing the good ore.

Only recently has attention been placed in the mining of ore from the N10E faults. The Nueva Esperanza fault since 1948 has produced about five percent of the mine's production in an area two hundred meters long by fifty meters high.
Work is being started to look for ore in a parallel fracture west of the Nueva Esperanza fault known as the Barones fault. East of the Nueva Esperanza fault is another N10E fracture which was instrumental in the formation of the ore in first manto on the San Pablo level which should be investigated more thoroughly. Ore in this type of fault is concentrated in those places where the fault is the most open. Where the fracture is tight, no ore, sometimes not even a trace of ore, can be found.

The transverse fault system in itself has produced ore in only one or two isolated cases, but it has been shown that the mantos are most productive in the immediate vicinity of the fault. This has been proved on the San Antonio level near the number 25 shown on Plate III as well as on the Colorada level between the same number 25 and number 22, and on the second sublevel at point 25.

In conclusion, the best producers of shipping ore seem to be the N10E fracture systems which are not controlled in any way by the presence or absence of mantos. The transverse system has been instrumental in the localization of bonanza ore bodies in the upper series of mantos. The second series has not been investigated. The N25W faults are strong producers of low grade milling ore running from three to nine percent antimony but do not produce much shipping ore except under the influence of local controls such as may be the intersection of the N10E fractures.

OTHER DEPOSITS:

In a number of instances, the most notable of which have been near the transverse fault system and close to the San Elias fault, large deposits of antimony have been found against the shale. It is believed that study of the occurrence of these deposits will furnish guides for finding more bodies similar to them. As has already been mentioned in the text, some beds both below and above the first series have been found to contain ore in minor quantities. These deposits have almost always been connected with the N10E fractures such as the case on the San Pedro level west of the point marked 9 on Plate III where a bed
under the fourth manto was found to contain ore. In the San Pablo area the zero marker above the first manto contained ore in connection with a NLOE fracture. These cases seem, so far, to be the exceptions rather than the rule, and a systematic search for them on present information may prove to be non economic. The mapping of the mine may indicate what procedures can be followed to test other likely areas.

THEORY OF ORE DEPOSITION:

Twelve kilometers north of the San Jose mines on the main mountain range are the Catorce silver mines which were a rich producer of silver up to 1910. Directly east of the range and at its base nearly eighteen kilometers away from the San Jose mines are the mines known as Santa Maria de la Paz and the former Kildun operation of the American Smelting and Refining Company. These had values principally in silver with lead and copper. Smaller mines near them have been mined for lead. Southeast of the San Jose mines at the place known as Maroma twelve kilometers away, are small deposits of silver with some lead with nearby antimony deposits. Scattered over the range south of the San Jose mines are occurrences of antimony which are as much as twenty kilometers away. West of the mines and across the valley forty kilometers away, small isolated occurrences of antimony and lead ores are found. Mercury has been found in minor amounts in the San Jose mines and to the south.

It is evident that there is a mineralized zone in which the San Jose mines are situated no less than thirty kilometers long north-south and fifteen kilometers wide east-west with outlying mineralization thirty kilometers further to the west. It is natural to suppose that the source of the ore was in or near the mineralized zone. Igneous rocks are found about nine kilometers south east of the property between the San Jose mines and Maroma. Igneous rocks are also found in Catorce. It is not known how close igneous rocks may outcrop to the south. The source of the ores most probably was a deep-seated batholith of which the Maroma and Catorce igneous rocks probably are phases. The igneous rock at Catorce is described by Bake(4) as two kinds, one a basalt or basic andesite plug and the other a quartz
monzonite occurring in porphyry dikes within the mine. The igneous rock exposed at Maroma is a coarse grained quartz monzonite or granodiorite.

White (5) states "the antimony-bearing solutions for the most part came up the major faults and fractures until their progress was impeded by the relatively impermeable shale overlying the limestone. The solutions then migrated on up the faults on the limbs of the intersecting anticlines to the anticlinal axis. At these points further migration upward was possible only to a slight extent through the nearly impermeable shale. Most of the migration then took place in the mantos on the anticlinal axes with the direction of movement away from the faults". This theory would limit the extension of the mine to the north unless more fractures bearing antimony could be found to the north as feeders on the downward pitching axes of the anticlines. (It will be remembered that in general the anticlines plunge 20 degrees to the north).

Barton (6) has indicated to the author that he believes there may have been two important foci located at the intersection of the transverse fault with the Colorado and San Elias faults. (See Plate II), at coordinates 5750N,4600E, and 5600N,5000E. He feels that either one of these or both were the main channel for the introduction of the antimony to the present mine area. He has suggested that the antimony may have come from the north, coming along the axes of anticlines at depth to come up along the two foci into the main mine area.

No attempt has been made to draw up a detailed theory of the ore deposition at the San Jose mines. The author feels that detailed studies would have to be made to determine the mineral sequence and whether there were not at least two stages of ore deposition. It has been suggested by Brown (7) that ore minerals may have been deposited as vapors rather than by hydrothermal means. Stibnite offers itself more readily to this theory in view of its low boiling point. Nearly all, if not all, of the antimony seems to have been deposited as stibnite and subsequently altered to the various oxide forms. In most cases the ore was not transported from its original site during or after the time it was oxidized.
The writer feels that the source of the antimony was an igneous body, probably underlying the Sierra de Catorce and that the antimony was transferred as vapor in the form of antimony sulphide to its present location. The means of transportation were fractures of all three classes mentioned i.e. N10E, N25W, and N60W. Until the importance of the silicification that is present in some localities is fully weighed, the most important single localizer and/or transportation medium must be the system of fractures with a N10E strike.

ORE EXTRACTION

The following sections are devoted to a discussion of all the important factors entering into the extraction of ore. They will cover labor, costs of development by hand and machine driven faces, diamond drilling, and other items entering into direct costs.

BUSCON SYSTEM

Over many years a system of mining antimony ore with what may be loosely termed in English "lease" has been perfected. These men who mine the ore are known as "buscones" one individual being a "buscon". The system is therefore known as the buscon system.

The buscon

As is true of nearly all Latin American countries, the labor laws are more favorable to labor than is true of American law. This is specially true where there exist a labor contract with a union. The labor law provides for separation pay when an employee or worker is dismissed without cause. Cause is difficult to prove, so that it generally means that to dismiss a man, means you must pay him off. His dismissal pay amounts to three months salary plus the equivalent of 20 days salary per year of employment. Maximum dismissal pay is two years salary. The law also provides for indemnization for professional diseases and injury or death. Interpretation of the law by the courts has nearly always been in favor of the worker. The company can discharge a man if he has more than three
unexcused absences in any thirty day period.

The buscon occupies a very peculiar position in that the department of labor does not recognize them as coming under the labor laws. On the other hand, the labor department attempts to class them all as workers. By definition, the buscon must be an independent contractor working with his own tools, mining ore for sale to anyone he may choose to sell to. He works the hours and days that he wishes.

In actual practice the buscon works in the company's mines, requesting and obtaining written permission to work as a buscon. He requests permission to work in some place of his own choosing and he has the rights to mine ore from there provided he does not abandon the work for more than two weeks. He often starts to work Thursday and does not leave the mine until Friday night when he removes the ore he has mined from the mine to the "Metalera" where the ore is received. He cleans up the ore by cobbing and jigging if necessary in order to meet certain grade requirements. Plates VIII B, and IX A and B are illustrative of this.

He is paid depending on grade from 200 pesos per ton to 25 pesos per ton for the lowest classes of ores. He may make as little as 15 to 20 pesos per week or as much as 1,000 pesos in a week. He pays for his own blasting supplies, steel, etc.

He pays a royalty of 2.70 to 4.50 pesos per ton.

Special aids to buscones

In order to aid the buscon to make a living, the company has made certain concessions to him. The most important aid is that he is able to purchase from the company 20 kilos of corn each week at a cost of 18 centavos per kilo. (With this corn and some beans he can support himself and seven more which is an average family). This represents a loss to the company of 10.40 pesos per week per buscon at the present price of corn. In order to buy the corn the buscon must deliver a minimum amount of ore each week varying with the class, but which must contain in metal content more than 20 kilos of antimony. We buy this ore from him and he buys the corn from us if he so desires.
Rather than increase prices paid for ores when material costs rise, we have fixed the cost of explosives, steel, hammers, ore sacks, carbide lamps, etc. as of April 1948. The company makes available to the buscon medical care and medicines at cost or free depending upon the circumstances of the case.

Limitations to the buscon system.

As the buscon is a free worker, he works when he pleases if he believes it to be to his advantage. Therefore if he can make more preparing ixtle fiber for the market he will not work in the mine. If the faces available are not showing ore enough to his liking he will not work. He is legally free to sell to whom he pleases and occasionally he will take ore from the mine to sell to outside buyers who often pay two or three times what we pay for the ore. This is discouraged as much as possible.

Advantages of the buscon system.

The early operators at the mine found that antimony ore could not be mined for company account as cheaply as it could be mined by buscones. The reasons are obvious, the miner on company account is given a fixed wage no matter how much he does, the buscon can make as much money as he cares if he can find the ore. Therefore the buscon system is the only system that will work to the advantage of both the man and the company. This system has spread to antimony mining in general all over Mexico.

Under the system the company is not legally liable for payment for termination of work or for incapacitations or deaths. In practice the company assumes the liability for incapacitations due to accidents and to a lesser extent for professional diseases such as silicosis. The reluctance of the company on this last point is that most of the buscones who are affected by silicosis have worked in other mines where they acquired most of the disease.

The buscon chief.

A buscon chief makes daily rounds of the buscon workings. He is paid by the company and is a practical geologist who aids the buscon in following the ore.
He is authorized to distribute free of charge up to four boxes of dynamite and up to one hundred pesos in cash aids each week. By a judicious use of the dynamite and money and with the prior approval of the mine superintendent he is able to stimulate the work of the buscones in areas or at points where there is not otherwise sufficient ore to interest the buscon.

WORKERS ON COMPANY ACCOUNT

The company must maintain a staff of men such as carmen, development crews, diamond drillers, mechanics, etc. who are on a weekly wage. These men have a minimum wage of five pesos per day, and according to law if they work six days must be paid the seventh as well. Therefore their wage is 35 pesos per week. Drillers, compressor men, mechanics, etc. make slightly higher wages, maximum being the double or 70 pesos per week. The company men have the right to buy 15 kilos of corn per week at 25 centavos per kilo which amounts to a present loss to the company of 6.76 pesos per man per week. In addition the company men and buscones may purchase the prime articles such as beans, rice, chile, etc. at cost at a company operated store.

A system of contracts and bonuses for tramming, development, etc. adds to the earnings of each man and stimulates their work, guaranteeing lower costs per unit of work. In the case of development headings, one contractor sub contracts his helpers with approval of the mine superintendent. Generally there is one contractor per face as the contractor is expected to work. The contractor receives 40 percent of the bonus over days pay as a result of the contract price and the men receive the other 60 percent. This is distributed by the company to avoid having the contractor pocket all the surplus. These company men observe days of work but not hours as they are so independent that they will not begin work at a fixed hour but neither do they leave at a fixed time. Earlier practice had been to contract directly with a contractor with no control over the men he hired or the rates he paid the men and the system was not to the best advantage of the company or the man. It was changed to the present system. There is no union.

Similarly the tramming from chutes is contracted as wherever possible the
work is contracted.

DEVELOPMENT BY HAND AND MACHINE

Both hand and machine driven faces are being employed at the mines. The sections that follow show a comparison of present costs with earlier costs.

Hand driven faces

The usual crew of men in a hand driven face consists of four drillers, a mucker, and a steel changer. The contractor is generally the steel changer or he may be one of the drillers. Average advance per week varies from one and a half meters to as much as six meters in certain soft ground. The average would be considered two meters or .056 meters per man shift. Costs for hand drilling with company men are from 80 to 125 pesos per meter.

A new system has been employed which works out to the advantage of the buscon and the company in that the company through the buscon chief contracts a certain number of meters of work to be done in a certain place, generally from five to twenty meters. If, and as is generally the case, the working face strikes ore, then the buscon remains in possession of the working face at the end of the contract. By this system costs of from 40 to 80 pesos per meter are obtained as compared with the former costs of 80 to 125 pesos per meter.

Machine driven faces

There is available a combined air capacity of 1785 cubic feet of air which at the mine elevation is probably equivalent to 1460 feet of air. Airlines are four and three inch with some two inch. Off two inch lines not more than two machines are used and generally five or six machines are the maximum run off the three and four inch lines. Two and a half and three inch machines are the sizes generally in use, although the company owns two three and one half-inch machines. The two and a half are generally jackhammers, some of which are mounted, with seven eighths inch hexagon shanked drill steel. The three inch machines are equipped for one inch quarter-octagon drill steel with no shank. The three and a half inch machines are equipped for one and a quarter inch round lugshanked drill steel. Detachable bits are used with all machines.
The usual crew for machine drilling is the contractor who is the driller with helper and two carmen who work on the opposite shift to clean out the face. Advance is five to twelve meters per week averaging six or .25 meters per man shift. Costs vary from 60 to 80 pesos per meter for the labor and explosives. Average overall costs ran as high as 210 pesos per meter but now run approximately 185 pesos per meter. Careful selection of the men, combined with the policy of paying the bonuses over days pay directly to the men, plus insistence in good mining practices have shown marked improvement in costs notwithstanding the fact that all materials have steadily been going up in value. Dynamite has increased nearly 30 percent in value since 1948 based in dollars and in pesos has more than doubled because of the increase in the peso exchange rate. Machine parts, etc. are also priced in dollars and have increased as much as 25 percent. The comparison of costs in 1948 as compared with March 1950 is $ 8.04 as compared with $ 6.58 dollars per foot. These costs include cost of air, direct supervision, rail, etc.

EXPLORATION WITH DIAMOND DRILLING

Diamond drilling was stopped in October of 1949 and started again in March 1951. The stoppage was due to the reduced demand for antimony. Three machines are available for drilling, two 500-foot machines with air motors and one 1000-foot machine with gasoline engine for surface work. Diamond drilling costs in 1948 were 32.61 pesos per meter or $ 1.45 dollars per foot. In 1949 costs were $ 1.34 dollars per foot.

Diamond drilling has been found to be of little value as far as finding ore is concerned. Its best use at the San Jose mines is in determining structure. A program of diamond drilling was undertaken in the first manto on the General level to try and find ore in the manto. Fifty holes were drilled with a total depth of 589.6 meters from mine stations located within a block one hundred thirty meters long and fifty meters wide at a cost of 19,228 pesos. Assuming a width of 1.3 meters the tonnage in the block would be about 22,000 tons. Cost per ton of low-grade ore was therefore nearly a peso per ton for the drilling alone. Of the holes drilled only two showed sufficient ore to go after and
Production was five thousand kilos of 45% ore or 2.25 tons of metal. The cost of finding this ore was therefore 56.6 cents per pound of metal which was uneconomic.

One of the greatest problems encountered in the drilling is the almost immediate loss of water. Core recovery is good, averaging over 35 percent in all types of drilling, and generally over 95 percent in most holes. Because of the frequent loss of water, it was common practice to continue drilling until close to the end of the shift, when quick-setting cement would be injected into the hole so that the hole could be drilled out and the next shift started with return of water. The good core recovery did not require the return of the sludge. Under the direction of our Chief Geologist and as a suggestion of his, we are trying Aquagel and mica to see if drilling can be maintained without the serious loss of water previously sustained. Results which are only tentative as of the date of this writing indicate that these two substances may prove a boon to our shortage of water for drilling purposes.

TEST STOPING

As a suggestion of Mr. G. M. Wiles, Manager, Mining Department, National Lead Company, test stopes were started on low grade ore with three main purposes in mind, the first, to determine stoping costs on the flat mantos should a mill ever be built, the second, as a means of sampling blocks to obtain ratios between shipping ore and milling ore and the third, to determine assays of the milling ore in the mantos so as to be able to fix reserves. Production of shipping ore to milling ore was in a ratio of slightly under one ton of shipping ore for each 100 tons of milling ore. Under the buscon system, the ratio is about one to one. With our present development program the production of shipping ore to all material removed from the mine is at a ratio of one ton of ore for every ten tons of low grade material. It is obvious therefore that as a possible means of developing ore, the cost of this stoping operation was out of line with the standard buscon system. Should there be an operating mill on the property, then this system would be highly desirable.

As stated earlier in the paper, the mantos tested by this means which are the first, third, and fourth, indicated that the ratios of shipping ore to milling ore
would be as follows for each manto: 1 to 65, 1 to 106, and 1 to 250. The last figure for the fourth manto is not considered significant as it based on the mining of only about 300 tons of material. Cost of the stoping per ton of ore was 7.430 pesos per ton or $ 1.39 per short ton placed dump.

Only a start has been made on something that can be of great importance and is one way of determining the reserves of the mine. However this test work can only be carried out when there is a surplus of labor as the production of shipping ore per man shift is only .028 as compared with the mine average of .060 for all classes of work. Plate VI shows a sketch of a typical stope installation, using a double drum slusher for scraping the broken ore and a mounted machine for breaking the ore. Although the manto which is illustrated is only about one half meter wide, it is necessary to break three quarters meters additional of limestone to be able to work the flat stope. This is typical of the first manto in many locations. The usual cycle was half an hour for setting up slusher, drilling tail holes when necessary, followed by one hour of slushing. Three quarters of an hour was taken up in setting up the machine and four hours of drilling time. Tearing down, loading and blasting took three quarters of an hour more. Average blast was only fifteen to twenty tons in this stope. Blasts were larger in the third manto, where the width was nearly three meters. The cycle given above was with two men. The use of a third man to start drilling while the others were slushing would have improved the results but no men were available, as we used one driller for two stopes, and one slusher man for the two stopes. While drilling out in one stope, they would be slushing in the other, drilling rounds in both stopes daily.

LONG HOLE DRILLING

One of the three and a half inch mounted drifters using one and one-quarter lug shanked steel was equipped with sectional drill rods for drilling test holes up to 50 feet in depth. The cost per foot for labor is 1.50 pesos, and for materials is 2.25 pesos. Total cost per foot is 3.75 pesos or $ 0.43 dollars per foot. This work has been very successful in replacing diamond drilling and has located
several small bodies of ore for us in close proximity to other ore bodies. Proper application of this work under the direction of the resident geologist should be of inmeasureable value in assuring ourselves that no ore is being overlooked.

CLEANING OLD STOPES

A minor, but sometimes very successful way of finding ore is to clean out abandoned buscon workings. This work is under the direction of the buscon chief who consults each case with the mine superintendent. The work is undertaken when either he or some old miner remembers that a thin seam of ore was allowed to become buried under waste. To remain successful it must be used sparingly and only when he is positive that the ore exists. No records exist showing the location of such ore and we are entirely dependent on the memories of the men involved. The cost of this work does not exceed a few hundred pesos per month.

RECAPITULATION OF FACTORS INVOLVED

Ore extraction is first of all dependent on making available to the buscon sufficiently attractive working faces where he will work and produce ore. He must not be allowed to steal the ore. To obtain these working faces it is necessary to carry on concurrently with other work development headings driven by hand or machine. The cheapest headings are driven by hand but they are much slower and require more many shifts per meter of advance. Therefore when labor is short, machine work should be favored if the cost can be met. Diamond drilling should be restricted to obtaining structural information. Test stoping should not be started unless, there is a mill in active operation with a need for the ore, or second, it is deemed necessary that information be obtained on milling ore reserves. Long hole drilling using a standard three and a half inch drifter should be used in connection with buscon workings before a working is abandoned to be sure no ore was overlooked. Occasionally it will be found desirable to clean out an abandoned buscon working to reach ore left in a former operation.

TRANSPORTATION

Transportation from where the ore is received to Wadley is accomplished
by means of three modes. The first is a standard 20-cubic foot mine car which takes the ore from the metalera to the upper tolva (upper bin) at the upper end of the aerial tramway. The aerial tramway lowers the ore by means of two counterbalanced buckets to the lower tolva (lower bin) from which it is loaded into the trucks belonging to the company. As the ore is lowered on the tramway, materials are brought up in the empty bucket. All materials for the mine are handled in this manner. As the trucks come up empty from Wadley they bring up the supplies. The labor and materials employed in the trucking are contracted as is also the cost of the lower tolva attendents who send the materials up on the empty buckets.

The reader's attention is called to Plate X, A and B, showing views of the upper and lower tolvases.

C O S T S

Antimony mining at the San Jose mines is a cost proposition as production is the primary object with profit being the secondary consideration. Therefore, under present all-out requirements for antimony we should produce all the ore possible at a cost not exceeding the value placed at Wadley. As was brought out earlier in the paper, page 6, the value of 40% antimony ore at Wadley during the month of April was 8.5 cents per pound of metal. A perfect operation would be the maximum production at a cost not exceeding 8.5 cents per pound.

In view of the general attitude of the buscon it is expedient that enough faces be in progress where he can find new working places so as to attract him into the mine. Therefore it is desireable to build up development so that it will build up production. To build up development so as to interest more buscones the hand labor program should be increased and additional short projects be planned.

The program can be balanced theoretically in the following manner. Cost of ore is 3.5 cents per pound, fixed charges for overhead and depreciation are 2.5 cents per pound and transportation to railhead is .235 cents per pound.
Total costs, not including development, are 6.235 cents per pound, which means that up to 2.265 cents per pound can be spent for development work. In practice it cannot be established so positively in view of the fact that the fixed charges will vary on a per pound basis if production drops or rises above a certain level. Cost of ore also rises or drops. In the succeeding sections, under the general heading of Balancing a Development program, more detailed conclusions will be drawn considering all the factors involved.

BALANCING A DEVELOPMENT PROGRAM

In every mine, the operator is faced with the problem of maintaining a balanced development program so that production can be sustained without reducing ore reserves. To do this an adequate method of measuring ore reserves must be developed.

MEASURING RESERVES

Antimony occurs in pockets which may contain from one kilo of ore to several hundred thousand kilos. It is impossible to sample and determine the antimony metal contained as shipping ore in any block. Milling ore can be measured. A system, empirical in every sense, has been developed whereby the buscon chief, mine superintendent, and general superintendent analyze the production possibilities block by block, formation by formation. These analyzes are predicated on the experience each man has obtained with antimony production from other areas similar to whichever block may be under consideration. This method is the first to be used in arriving at a reserve figure for the mine. It affords a method of measuring reserves monthly and determining if the development work is keeping sufficient ore in sight.

Prior to the development of the system mentioned above, no effort was made to determine development work necessary to maintain the proper reserves. When antimony was in demand and the price went up, additional development work was done. When the price went down, the antimony in sight was mined out and development work was reduced or stopped entirely. This affected a delay in putting
the mine back into production when the price once more went up as development work had to be done first to find the ore. Under the present system as a record is kept of the reserves in each block, production can be picked up within a minimum time if sufficient labor is available.

The actual method used in measuring the reserves is as follows. Sheets have been printed providing for annotation of level, block and formation and in succession three blank columns. In the first column, the buscon chief places his estimate of the production possibilities say of the first manto, San Jose level, Block J-32. He knows that this block has been partially mined out but that ore was left showing in small stringers in such and such a place. He also knows that approximately so much ore was taken out of such and such a grade from the portion mined. From this he calculates what he believes is left in the block. The mine superintendent will check the figures and will if necessary go to the block in question to see for himself what ore has been mined and whether conditions are favorable for finding more ore. The general superintendent has the final say checking the calculations of the other two.

This data is totaled and carried by sub-areas within the mine itself. The sub-areas are kept as geologic units wherever possible. For example, the San Jeronimo workings are kept as a unit. The Santa Emilia are another unit. The San Pablo and portions of San Jose and Nueva Esperanza are another unit. In all there are eleven sub-areas within the mine. These totals are watched carefully and under the development program no area is permitted to drop.

The ore receiver records on each buscon ticket on which he reports the ore received the origin of the ore and a record is kept of the ore produced in each working place. This affords a check on the estimates of ore reserves made by the three men concerned.

THE LABOR PROBLEM

A factor which enters into this discussion at this point, is the limited labor available near the mines. There have been as many as 800 men working in the mine either as buscones or company account men. At the present time there are
approximately 350 men. As a matter of course, every effort should be made to produce as much ore as possible and benefit by the higher price. At the same time, reserves should not be permitted to drop below a six months limit. It has been suggested that during boom times an effort be made to overdevelop the mine to permit operation at lower prices and costs when the market goes down. This could be done if sufficient labor were available. The reverse is the case at the present time, and it would be preferable were sufficient ore developed to place every stress on mining it, reserving a fixed sum of money for development during periods of small demand. This would serve a useful purpose, in that it would keep on hand a larger supply of labor than is ordinarily available when the work in the mine is reduced. In the Wadley district there is no other work available and as soon as the mine reduces its work, the workers must leave for other areas. This is what happened during 1949 and most of 1950 as we gradually reduced our operation more and more.

In concluding this section it should be noted that increase in price paid to the buscon will not increase the quantity of ore he will deliver. On the contrary it may mean he will deliver less as he can make the same money he always has with fewer hours work. Proper thought must be given to the competition given sometimes when there is a sale for ixtle fiber. Some men working ixtle fiber away from this district can make ten to twelve pesos per day, and the average a buscon makes is about 10 days pay of five pesos per day. Circumstances may force a raise in price for ore to the buscones.

EFFECT OF MECHANIZATION

As has been noted in the comparison of man shifts involved in the advance in hand driven and machine driven faces, the more mechanized the work becomes the more men can be released for other work. As the basis of the production of antimony is the buscon system, the more men that are available to work on producing ore, the more should be produced. However, as labor is cheap, the more mechanization the higher the costs. This factor must be taken into account as
the program progresses. In one sense, it can be partially balanced by watching ore reserves, increasing the hand work when reserves are high and production can be increased, and reducing the hand work and increasing machine work when reserves are low.

DETERMINING THE DEVELOPMENT PROGRAM

In the section headed Costs, page 28, we developed an allowable amount of money to be spent for development, which was 2.265 cents per pound. Development includes machine driven faces, hand driven faces, diamond drilling, long hole drilling, test stoping, and mine cleanup. Production goal for the mine is 150 tons of metal per month. Present production is about 85 percent of the goal. Of the 2.265 cents per pound allowed for development, 2.0 cents per pound should be spent on hand and machine development combined. The remaining 0.265 cents per pound should be spent in diamond drilling, long hole drilling, and mine cleanup. Nothing should be spent at this time for test stoping. Towards the present goal, 330,000 pounds of antimony metal, $6,600.00 dollars can be spent on hand and machine development. For diamond drilling, long hole drilling, and mine cleanup, $374.50 dollars can be spent. These are equivalent to 57,090.00 pesos and 7,564.42 pesos.

Taking these in reverse order as the last requires but little attention, no more than 400 pesos should be spent on mine cleanup monthly. The geological department is not set up to follow up with long hole drilling at the present time and therefore the balance or 7,164.42 pesos should be spent on diamond drilling for the month.

We know that reserves as of March 31 are adequate, therefore we should increase our work by hand so as to bring into production more areas more quickly. The development program outline for the month of April is shown in Tables 1
and 2, pages 34 and 35. There are twelve faces to be driven by machine and eighteen faces to be driven by hand. Of the twelve machine faces, two on the second sub-level will be driven by the same crew; similarly of the eighteen hand faces four will be driven by two crews. Therefore expected advance by hand will be 32 meters and by machine 66 meters per week. Cost per month at the estimated costs of 60 and 185 pesos per meter will be a total of 60,759.00 pesos per month. This exceeds the budget amount by 3,669.00 pesos. The program set up for April is the maximum that should be carried unless production increases above the goal. Every program must be revised monthly to take into account ore encountered during the month with the headings, and to reduce or increase the proportion of hand work to machine as might be determined by the condition of the reserves.

Attention is called to the location of the development faces as programmed for April. The locations are shown on Plate III. Normally it is the effort of the mine management to concentrate their work in only a few areas so as to obtain better costs. In the case of antimony and the nature of the buscon system the wider the spread of development faces is, the more efficient the work can be carried on. During the course of a day a buscon may blast two or three times and it is more efficient for him to be separated some distance away from his companions so that the blasting and powder smoke do not affect the others. Further, as antimony occurs in pockets the wider the area we are working the greater the chances for developing large quantity production. Such a spread is limited by the quantity of material that might be required such as rail, pipe, etc. The distribution shown on Plate III of development headings has been found to be the best over the period since the latter part of 1947.
TABLE 1.

LIST OF FACES DRIVEN BY HAND DRILLING.

1. SAN PABLO - Raise from first manto to zero marker looking for ore above manto.
2. SAN PABLO - Face north along first manto.
3. SAN PABLO - Raise manto from inclined raise to zero marker.
4. SAN PABLO - Drift north from raise at 1 on first manto to intersect buscon workings.
5. SAN PABLO - Inclined raise on second manto.
6. JAPON - Drift south along Nueva Esperanza fault to look for ore found in the mapping.
7. SAN JOSE - Raise on second manto.
8. SAN PEDRO - Intermediate drift north above level on second manto.
9. SAN PEDRO - Intermediate drift south on third manto.
10. SAN PEDRO - Intermediate drift south on Estrellas fault.
11. SAN PEDRO - Raise on San Elías fault to cut ore in winze from San Juan-level.
12. SAN PEDRO - Croscut west to cut projected extension Barones fault (which is west and parallel to Nueva Esperanza fault.)
13. SAN PEDRO - Inclined raise on second manto.
14. SAN PEDRO - Inclined raise on third manto.
15. GENERAL - Drift northwest on #31 fault.
16. GENERAL - Inclined raise on second manto.
17. EL VIOLIN - Drift north on Los Angeles fault.
18. SAN JERONIMO - Intermediate drift southwest on seventh manto.

Numbers refer to location on Plate III.
TABLE 2

LIST OF FACES DRIVEN BY MACHINE DRILLING

19- GENERAL
   - Lateral south parallel to Nueva Esperanza fault

20- GENERAL
   - Drift south on Colorado fault.

21- GENERAL
   - Inclined raise on second manto

22- COLORADA
   - Drift north on San Elias fault

23- COLORADA
   - Drift north on first manto

24- COLORADA
   - Intermediate drift south on first manto

25- SECOND SUB-LEVEL
   - Drift west on fourth manto

26- SECOND SUB-LEVEL
   - Crosscut southeast to look for fourth manto on east side of transverse fault, should cut second and first mantos on west side of transverse fault

27- SECOND SUB-LEVEL
   - Drift along first manto in a westerly direction

28- SAN FELIPE
   - Drift north along Colorado fault to look for intersection with first manto on east side of fault

29- REPUBLICA
   - Lateral southeast parallel to and in hanging wall of Colorado fault

30- SAN JERONIMO
   - Raise on seventh manto to look for intersection of manto with NIOE fracture

Numbers refer to locations of places on Plate III
GENERAL CONCLUSIONS

The following general conclusions can be drawn from the Studies of antimony occurrence in the San Jose mines.

1) The antimony occurrence is limited to certain favorable beds and fractures. The most important are the mantos of which the first, fourth, and seventh offer the greatest possibilities for production of shipping ores. Of the fractures, the most important producers are the NIOE for shipping ores and the N25W for low-grade ores for milling. The NIOE fractures are probably the most important single source for antimony ore of shipping grade.

2) Reserves of shipping ores can be measured empirically.

3) By keeping reserves calculated monthly, a program for development can be set up and balanced monthly.

4) Certain procedures have been worked out for the sampling of the mantos which can be used for actual determination of reserves of shipping ores.

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Thanks are given to Mr. G. M. Wiles, Manager, Mining Department National Lead Company for the permission to prepare this paper and to Mr. O. D. Niedermeyer, Manager, Texas Mining & Smelting Division of National Lead Company for the support and kindly criticism which has always been given the author.

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(2) Baker, Charles Lawrence Trans. A I M E Vol. LXVI 1921, General Geology of Catorce Mining District page 44

(3) White, Donald E. and Gonzalez, Jenaro op. cit. page 137

(4) Baker, Charles Lawrence op. cit. pages 45 and 46

(5) White, Donald E. and Gonzalez, Jenaro op. cit. page 141

(6) Barton, J.C. Oral communication to the author in 1947

(7) Brown, John Stafford Ore Genesis Hopewell, N. J. The Hopewell Press 1948
A.- View west of portal of General level adit showing Blacksmith shop and structure beds of Santa Emilia limestone below the upper series of mantos.

B.- View west from General level showing structure and position of Corona limestone (Jc), San Jose shale (Jsj), Santa Emilia limestone (Jse) upper and lower series of mantos (US) and (LS).

PLATE VII
A. View of mine dumps from truck road looking northeast showing positions, San Pablo, Japon, and San Antonio levels.

B. Hand Jig used by buscones in cleaning ores.

PLATE VIII

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A.- Buscon sorting coarse ore at Metalera, General level; room where car is, is weighing room.

B.- View of buscones sorting ore. Note small piles delivered by each man and fines as well as coarse.

PLATE IX
A. View of lower tolva, at lower end of aerial tram. Truck is company property and is loaded with sacked corn to be sent to mine.

B. View of upper tolva at upper end of aerial tram, taken as loaded bucket leaves tolva.

PLATE X
PLATE II
GENERALIZED GEOLOGIC PLAN
GENERAL LEVEL
SAN JOSE MINES
Wodley, S. L. P.
Scale 1:5000  April 1951

EXPLANATION
- Faults
- Axis of Anticline
- Axis of Syncline
- Axis of Overturned Anticline
- Axis of Overturned Syncline

Legend:
- San Jose Formation
- Santa Emilia Formation
- First Manto
- Second Manto
- Third Manto
- Fourth Manto
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LEGEND

- CORONA LIMESTONE
- SAN JOSE SHALE
- STA EMILIA LIMESTONE
- BASAL LIMESTONE
- FAULTS

NOTE: LETTERS A, B, ETC. REFER TO TEXT SEE PAGE 12

PLATE IV
IDEALIZED CROSS SECTION E-W THROUGH CATORCE MOUNTAIN RANGE LOOKING NORTH.
"SAN JOSE MINES"
WADLEY, S.L.P.
SCALE 1:33,333 APRIL 1951.