THE STUDY ON MODERNIZATION PLAN OF BENEFICIATION PLANTS OF CFM IN THE UNITED MEXICAN STATES

FINAL REPORT

March, 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the United Mexican States, the Japanese Government decided to conduct a study on the modernization plan of the beneficiation plants of CFM and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Mexico a study team headed by Mr. Hironori Hashiguchi, the DOWA Mining Co., Ltd., from July, 1989 to February 1990.

The team exchanged views with the officials concerned of the Government of the United Mexican States and conducted a field survey. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the development of the Project and to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the United Mexican States for their close cooperation extended to the team.

March, 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

CONTENTS

Page

SUMMARY

1. Summary of Mining Potential

(1) Parral Beneficiation Plant Area

Ore deposits surrounding Parral beneficiation plant have a long history, but there are a few spots subjected to a large scale mining in the past. Oxidized ore zones have not been exhausted and almost all sulfide ore zones remain intact, resulting in an estimation that there will be a sufficient amount of ore reserve. Ore grades are high and stable. The operation of mines is steady with an expectation of a stable supply of ores for the long term.

(2) Guanacevi Beneficiation Plant Area

This area has been exposed to large scale mining operations for a long time, with oxidized and sulfide ore zones that have been almost completely mined out. Therefore, the main ore supply from this area consists of the remaining minerals and some old waste that can now be mined. The ore reserve is decreasing toward depletion in the near future. Although the mines are well equipped with facilities, the ore reserve is insufficient. The exploitation of the ore supply from the Santa Cruz Mine will expectedly fulfill the beneficiation capacity of this plant for the coming two years, but unless new ore deposits are discovered, the supply source of ore to the plant will be exhausted.

(3) Barones Beneficiation Plant Area

This area has a long history and is crowded with veins of abundant ore reserves. Because the past mining operations focused mainly on oxidized ore zones, discovery of sulfide ore zone can be expected. Unlike the other two areas, ore grades in this area are generally lower, because of the lower maquila beneficiation fee. Mines are full of spirit, and construction of private beneficiation plants and leaching plants are proposed. Ore production may be maintained for a long term, but the production quantity and ore grade may fluctuate because of the influence from private ore treatment.

2. Summary of Beneficiation Tests

As a result of chemical and physical analysis of ores from 18 surveyed mines, some 70% to 80% of the silver is from sulfide mineral and the rest is native silver.

As to beneficiation tests, the result of investigation on reasons why silver recovery is low from Casale ore at Parral plant has revealed that some silver is difficult to recover because it is contained in quartz. Beneficiation tests have indicated that the silver recovery from Rosario ore at Guanacevi can be improved by mixed flotation of oxide and sulfide ores, and that from Calicanto ore at Barones plant by the combination of mixed flotation of oxidized and sulfide ores in conjuction.

3. Summary of Diagnosis on Status Quo of Beneficiation Plants

Diagnostic results and proposals for improvements are available at the three beneficiation plants. Among these proposals, improvements in the beneficiation recovery, in the operation rates of facilities and in the plant maintenance, and operating cost reduction are mutually related. The basic items for them are instrumentation and automation for the beneficiation plant, establishment of the maintenance and repair systems, and conversion of the Maquila System into the All Ore-Purchasing System.

First of all, the instrumentation and automation is aimed to improve experience with the process, eliminate too many manhour, wastage, waste of energy, and their influences on the cost, recovery and operation rate, resulting in a steady operation. To realize this target, many factors such as ore feed, grinding particle size, water supply, quantities of reagents, pulp density and pH value must be controlled, and data must be compiled from the daily operation to comprehend the optimum conditions for these factors. Instrumentation provides objective data on a continuing basis. In addition to these hardware elements, it is also important that operators and staff acquire ability for operation and management.

Secondly, the disruptive state in which a machine breakdown is repaired temporarily interfers with the normal process, makes for inadequate operational load factors, and falling down in the overall operation rate, while increasing maintenance cost, and causing an inventory lack of parts and spares, with a resultant decrease in the operation rate of the facilities. Therefore, here we proposed to establish a preventive maintenance-repair system as an overall means to cope with these problems. To be specific, routine inspection for maintenance purposes should begin immediately - some operators should examine doubly the facilities by using check-sheets. Then annual plans for maintenance and periodical suspension of operation for maintenance should be incorporated, and inspection results should be recorded in the maintenance log for each piece of equipment such as data for planned maintenance and proper inventory of spare parts of developed for the future. In addition to these measures, failure detector devices should be introduced to reduce the load of workers and to avoid erroneous oversights.

The mixed beneficiation system of Maquila and Ore Purchasing has many faults, such as time loss due to the intermittent operation, the beginning of operation, during the suspension of operation and the production waiting time; waste due to overuse materials; changes in the operational conditions by ores; the complexity of the process; and resultant decrease in the productivity rate. The only way to solve the problem is by switching the system to the All Ore-Purchasing system. This conversion will not only improve on these faults, but also will enable the establishment of monthly and annual maintenance and budget plans and the introduction of a controlled beneficiation system. To realize this conversion, the conditions for purchase recovery should be more equitably defined by test results of beneficiation recoveries in the past and recoveries obtained from beneficiation tests. The conditions for purchase recovery will be revised step by step by accumulating monthly data. The lower limit of ore grade should be determined for purchasing arrangements. Specific purchasing conditions should be decided for ores that are difficult to treat. The ore purchase system should be finalized by adding these conditions to the beneficiation conditions, treating cost, refining cost, penalties and the sales cost. It seems that there are many varieties of ore types that come from respective mines, but they stem from a group of

ore deposits when viewed from a geological standpoint, and therefore it may be sufficient to classify these ores into five types - oxidized ore, sulfide ore, high grade ore, low grade ore and complexed ore.

An planned management system is proposed to improve the administration division. The system is run by tallying the actual practices within the plant to the budget prepared on the basis of sufficient consideration to identify any abnormal values, and to investigate its causes and remedies, and to plan for the future and to establish measures which correspond with that prospect. This data is compiled and fedback to operations, and then is parlayed into the profit analysis and the optimal personnel plan. With such a system, an integrated income/outgo budget can be prepared based on projected costs for raw material management, ore treatment planning, ore acceptance, analyses and administration on the premise of annual or semi-annual budgets. Also needed is a personnel plan and a finance plan. These budgets and plans are compared to the monthly reports. To simplify the work, save labor and to provide an appropriate personnel disposition for the work, personal computers should be introduced to record data on various books and to analyze results, providing a basis for sound operation and management.

4. Summary of Current Economic Analyses

CFM has raised the Maquila fee charged since January, 1989, and the Maquila fee per ton is now at 30,000 pesos (13 US$ for custom ore). At the Barones beneficiation plant, however, the fee rise is insufficient to resolve the Maquila fee at 16,500 pesos (17,500 pesos for purchased ore) because of the protest of the association of medium and smaller miners. As a result, the first half of fiscal 1989, the records indicate the costs on a per ton of treated ore basis are profiting by 5,228 pesos for the Parral plant while a recurring loss of 3,815 pesos continues at the Guanacevi plant, and a staggering recurring loss of 15,799 pesos for the Barones plant. If the Maquila fee of 30,000 pesos were applied to the Barones plant, the record would be a recurring loss of only 1,990 pesos.

Accordingly, major themes for modernization plans for beneficiation plants are for raising the efficiency of the Parral plant, reducing the loss and raising the efficiency for the Guanacevi plant, and reducing losses as much as possible.

(1) Parral Beneficiation Plant

The plant is held under sound operation without any big problems except that the assets have not been reevaluated. The break-even point indicates that the plant would not go into the deficit even if the sales were to go down to around 2/3 of the current value - the operation is extremely sound and stable even as it is.

It is concerned, however, that these facilities have become obsolete and worn down because there have been no investments for the long term to maintain and renew the equipment. It is important that a revaluation of the assets show proper depreciation values so that investment for maintenance and renewal of facilities is possible.

(2) Guanacevi Beneficiation Plant

The plant has shown a large deficit for almost every year. It is difficult to expect a big increase in the sales because of a downward trend of the ore treatment quantity in future due to the low mining potential of this area.

To improve the income and outgo, there is no way other than to cut down, considerably, the prime cost through better organization of the operation. For instance, the income and outgo can only be balanced when 14% of costs (sales cost and administrative expense are reduced. These cost reductions must be realized through strict operational control.

(3) Barones Beneficiation Plant

The plant is compelled to show a very big deficit each year, with the largest problem among any of the three plants surveyed. The cause for the loss is that the maquila beneficiation fee and the purchased ore beneficiation fee have been suppressed at a price much less than actual beneficiation cost.

To dissolve the red, the cost of operation must be substantially cut, and at the same time the beneficiation fee must be increased to an equitable price. The revision of the beneficiation fee has already become a political issue, so that it may be difficult to request a raise in the beneficiation fee to an appropriate level similar to that of the other two beneficiation plants. Accordingly, the improvement of the present conditions can only be achieved if a new beneficiation plant equipped with modern facilities would additionally be built by using funds to raise the current low recovery rates of ore, and the operational costs reduced by resolutely executing modernization controls, while at the same time raising the beneficiation fee even by the minimum.

5. Summary of Modernization Plans for Beneficiation Plants

(1) Modernization of Existing Facilities in Parral Plant

The modernization plan aims at measures against obsolescence, maintenance, and efficiency improvement of facilities; stabilization of operation; improvement of labor conditions; and achievement of labor-saving. Current conditions are: ore treating quantity = 6,400 t/month, Au = 0.74 g/t, Ag = 325 g/t, Pb = 0.2% and Zn = 0.2%. A modernization can raise those beneficiation recovery rates for each metal by 2% - 3%, so that new rates of recoveries are Au = 67.20%, Ag = 68.25%, Pb = 52.5% and Zn = 47.25%.

The details of the modernization work are:

(a) Replacement of worn out ball mills
(b) Reinforcement of dust collectors as a measure against the dust in the crushing system that causes troubles in machines and electric filter systems, and pneumoconiosis in laborers
(c) Instrumentation to stabilize the operation
(d) Organization of the administration division to save labor and to manage the business faster and more correctly.

The capital spending would be 1,493 million pesos (563,000 US$), and the production cost will be reduced by 3,556 pesos per ton of treated ore. This value plus the current recurring profit of 5,288 pesos will contribute to the promotion of mining in this area.

For reference, the Internal Rate of Return (IRR) is 19.9% - 18.0% when the market price of silver falls by about 10% and 21.7% when the price rises by some 10%, and the Accounting Rate of Return (ARR) is 18.3% and the Payback Period (PB) is 5.5 years.

Conditions concerning the investment are:

(a) The market price of each metal used as the base for the income calculation is the average of international market prices of the metal during the period from January to June, 1989.
(b) The smelting purchasing conditions for ore concentrate are those of IMMSA (a major smelting company in Mexico).
(c) The interest is assumed to be 5% because of a promise of loans from international financial institutions like the Inter American Development Bank (IDB).
(d) The term for depreciation is 10 years for machine and equipment, 15 years for buildings and structures, with a scrap value of 5% and the fixed installment amortization.
(e) The exchange rate between the peso and the US dollar is 1 dollar = 2,650 pesos, which was the rate at the time of this survey.
(f) The total amount of improvement is the sum of the increase in income corresponding to the investment (the increase of returns in beneficiation recovery rates) and the reduction in the cost corresponding to the investment (the decrease in beneficiation

cost and general administrative cost), and the IRR is calculated on the basis of the total amount of improvement through the Discount of Cash Flow (DCF) method.

(g) The investment efficiency, the ARR (%), equals to [total amount of improvement - (depreciation expense + interest)] / investment amount.

(h) The recovery term, the PB, is the number of years to recover the investment, and is shown as 1/ARR.

(i) Many factors such as the beneficiation recovery and the ore grade can be used for the sensitivity analysis, but the market price fluctuation of silver is adopted in this case. The fluctuation range is around 10% in the upper and lower sides of the average shown in (a).

These conditions have also been applied to the other two beneficiation plants.

(2) Modernization of Existing Facilities in Guanacevi Plant

Purposes of the modernization are for maintenance of facilities, energy-saving, stabilization of the operation, reduction in commodity expenses, and labor-saving and organization of the administration division. Prior conditions are: ore treating quantity = 7,751 t/month (the present amount). Au = 1.45 g/t and Ag = 253 g/t. The modernization can raise the beneficiation recovery for Au and Ag by some 2.3%, so that the expected recovery is about 80% for Au and Ag.

The details of the modernization work are:

(a) Installation of filter presses for energy-saving

(b) Improvement of the grinding system for energy-saving and stabilization of the operation

(c) Reinforcement of reagent facilities necessary to cut down on reagent cost and to stabilize the operation

(d) Reorganization of the floatation system for energy-saving

(e) Rationalization of the administrative division for labor-saving.

The capital spending for the modernization is 810 million pesos (306,000 US$), and the production cost will be decreased by 5,155 pesos per ton of treated ore. This reduction brings about a recurring profit of 1,340 pesos/t rather than continuing the current deficit, without causing any additional burden to the mines.

For reference, the IRR is 49.5% - 47.5% when the market price of silver falls by about 10% and 51.5% when it rises by some 10%, and the ARR is 59.2% and the PB is 1.7 years.

(3) Barones Plant

The working rate of the plant is so low that the mines restrict their ore production or stock their ores at their own mining sites. Ores of high grade and mass-production are treated in the CFM's El Bote Mine near the Barones Plant at a high Maquila fees. Furthermore, medium sized mines provided with large ore reserves are planning to build their own beneficiation or leaching plants, and private trust or purchased beneficiation plants are being built to deal with ores from medium and smaller mines. These conditions and the cheap beneficiation fee of the plant has caused a trend that ores of only low grades, where treatment is difficult and small lots are supplied to the Barones plant, while ores of good quality, high grade and large lots flow out to other beneficiation plants. This has resulted in repetition of a vicious cycle of reductions in recovery and production rates, and resulted in the red operations. Improving the status quo of the plant will be extremely difficult, and the only way is by the combination of improvement of existing facilities with the installation of a new beneficiation factory aiming at raising the recovery rates and the added value of sulfide ores.

(A) Modernization of Existing Facilities

Prior conditions are: ore treating quantity = 9,056 t/month (the present amount), Au = 0.47 g/t and Ag = 175 g/t. The proposals are:

(a) The result of beneficiation tests has revealed that a mixed treatment of oxidized and sulfide ore could improve the recovery rate. Therefore improvement of the flotation and the cyanidation systems to realize a mixed treatment.

(b) Instrumentation and automation to stabilize the operation, to cut down the cost of purchased goods and to improve the labor conditions (especially mechanization of the monitoring system)

(c) Improvement for labor-saving and organization of the administration division

Capital spending is expected at 612 million pesos (211,000 US$), and the operation cost will be reduced by 4,262 pesos per ton of treated ore. Expected rise in recovery rates should be 2% for Au and 4% for Ag, and 21 workers can be eliminated.

For reference, the IRR is 52.1% - 51.0% when the market price of silver falls by about 10% and 54.4% when it rises by around 10%, and the ARR is 63.7% and the PB is 1.6 years.

(B) Construction of New Modern Beneficiation Plant

Adjacent to the existing plant, a new beneficiation plant (crushing - grinding - floatation - dewatering) will be built for a differential floatation method of Pb-Cu-Zn recovery. The planned ore treatment quantity was investigated for two cases - 150 t/day and 200 t/day, because the proper quantity was assumed to lie between the two amounts when the ore stocks and production restrictions of mines were taken into consideration. The expected ore grade is: Au = 0.8 g/t, Ag = 160 g/t, Pb = 0.8%, Cu = 0.4% and Zn = 1.6%, and the expected beneficiation recovery rate is: Au = 33%, Ag = 76%, Pb = 73%, Cu = 86% and Zn = 68%. The labor force contains 21 workers.

The equipment includes:

(a) Machines and electric facilities

(b) Civil engineering and construction work.

The total investment amount is 16,025 million pesos (6,047,000 US$) for the 150 t/day capacity, or 17,628 million pesos (6,651,000 US$) for the 200 t/day capacity. The resultant reduction in production cost will be 2,762 pesos (@150 t/day) or 11,006 pesos per ton (@200 t/day) of treated ore, and therefore the total modernization effect including the advantage derived from the modernization of existing facilities will become 8,451 pesos or 12,487 pesos. As a result, the current deficit of 15,799 pesos will be reduced to 7,348 pesos or 3,312 pesos but is still in the red. This remaining red can only be imposed by medium and smaller mines as part of a revised beneficiation fee.

The conclusion is to implement the modernization plan and to raise the beneficiation fee from current 16,500 pesos/t to 25,000 pesos/t.

For reference, the IRR related to the new beneficiation plant is 6.5% for 150 t/day or 9.2% for 200 t/day, which, when added to that for the modernization of existing facilities, becomes 8.5% for the former or 10.7% for the latter. The construction terms of the new plant is two years.

1. INTRODUCTION

According to the policies for economic reconstruction of the Mexican government, Comision de Fomento Minero (CFM) of Republic of Mexico Ministry of Energy and Mining (SEMIP) is now executing measures to rationalize and to raise the productivity of the national enterprise.

This report describes results of the survey on the policies of the modernization plans for the three beneficiation plants which the CFM is managing. The survey, as a part of the above-mentioned measures, was conducted on the basis of the Scope of Work, on which the CFM and the Japan International Cooperation Agency have agreed and signed in September, 1988.

Medium and smaller private mines distributed in the United Mexican States are so frail in economic foundation and technical capability that they cannot afford to have their own beneficiation plants. Therefore the CFM has built and is managing a beneficiation plant in each mining area, and medium and smaller mines over one thousand are enjoying the benefits from these beneficiation plants. Many of the CFM's beneficiation plants, however, are forced to operate with deficit because of low beneficiation recoveries and facility production rates, which has resulted in application of the above-mentioned measures for reorganization and productivity improvement.

The following beneficiation plants were selected as the subjects of the survey.

(1) Parral beneficiation plant in Chihuahua State
(2) Guanacevi beneficiation plant in Durango State
(3) Barones beneficiation plant in Zacatecas State

In addition, six mines related to each of the three beneficiation plants were investigated.

Purposes of the survey of the three beneficiation plants are as follows.

(1) Reduction of the operational cost
(2) Improvement of the facility production rate
(3) Improvement of the beneficiation recovery rate
(4) Investigation and evaluation on expansion, diversification and integration of production processes
(5) Improvement of the facility production rate by establishment of a preventive maintenance system.

Prior to the field survey, a preliminary study was carried out in Japan, based on which survey plans were made and the inception report was prepared. The inception report was submitted and explained to, and discussed with the CFM, and then the field survey began. In the field survey, the following items were carried out.

(1) Gathering and compiling data and materials
(2) Examining mining potentials
(3) Investigating the status quo of beneficiation plants
(4) Beneficiation tests
(5) Collecting financial and economic data
(6) Diagnosing the current conditions of beneficiation plants.

Immediately after the field survey, a summary of the field survey was reported and discussed at the site, and these results were arranged into a Progress report, which was then submitted and explained to, and discussed with the CFM.

Results obtained and materials gathered through the field survey were analyzed and tested in Japan with the following items.

(1) Analyzing and compiling results of the field survey
(2) Executing beneficiation tests and analyzing their results in Japan
(3) Evaluating mining potentials
(4) Making conclusions from the diagnosis on beneficiation plants and preparing proposals
(5) Preparing modernization plans for beneficiation plants
(6) Evaluating the economic efficiency

The draft for the final report was drawn up by putting together the above items. The draft was submitted and explained to, and discussed with the CFM, and thus this final report has been completed.

The field survey was conducted by six members of the survey group from Japan and their counterparts from the CFM, with on-the-spot cooperation of the chief and persons-in-charge at each beneficiation plant; the head and persons-in-charge of geology, mining, machinery and electric equipment at the CFM's branch office; the owner and persons-in-charge at each of medium and smaller mines; and an observer from the CFM.

The field survey was conducted on the mining - geological and the economic-financial divisions from July 17 to September 14 in 1989 (60 days), and on the divisions of beneficiation, related facilities and tests, and chemical analysis from July 17 to October 11 in 1989 (87 days). The draft for the final report was discussed for nine days from February 8 to 16 in 1990.

The final report consist of nine chapters.

The first chapter, introduction, explains the purposes of the report and the items carried out through the survey.

The second chapter, background of the project, describes outlines of the status quo and policies of the mining industry in the United Mexican States.

The third chapter, summary and analyses of results from the field survey, reports, based on evaluation of mining potentials, the geology and ore deposits in each beneficiation plant area, and the ore reserve, production activity and mining cost of each mine. After that, the outline, beneficiation method, metal balance and beneficiation records are reported for each beneficiation plant, followed by discussions on the maintenance, production rate of beneficiation facility and chemical analysis division. Examination of the conditions for maquila and ore-purchasing system and the financial-economic analyses are reported in the last part of this chapter.

The fourth chapter explains the results of beneficiation tests carried out in Mexico and Japan.

The fifth chapter, evaluation of mining potentials, appraises the mining potentials on the basis of the ore reserve and production capability of each mine, to judge the operational continuation in the future of each beneficiation plant.

The sixth chapter describes the conclusions of diagnosis of the status quo of each beneficiation plant, explains the plans to improve the beneficiation recovery, beneficiation facility and its maintenance and beneficiation system on toll basis and to reduce beneficiation cost, and also reports the rationalization plan for the administration division of each beneficiation plant.

The seventh chapter describes the economic evaluation of the present state.

The eighth chapter mentions the modernization plan, and the amount of capital necessity and its economic effects on existing facilities for each beneficiation plant. The chapter also provides a special section for the construction plan of a new factory for the Barones beneficiation plant, which has the most difficult problems. In the last part of this chapter, an economic evaluation on these investment plans is given.

The ninth chapter, conclusion of the survey, compiles the modernization plans for the existing facilities at the three beneficiation plants and the construction plan of a new factory at Barones beneficiation plant, and shows the suggestions based on these plans to finalize the report.

The tables and figures are collectively given at the end of the volume.

2. BACKGROUND OF THE PROJECT

(1) Current Situation and Policy of the Mining Industry in Mexico

Mexico is among the most affluent countries in mineral resources in the world.

About two-thirds of its land mass has geological potential for mineral resources. Mexico has abundant deposits of both metallic minerals such as silver, copper, lead, zinc and other non-metallic minerals such as celestite, fluorite, barite and sulfur.

Many of the non ferrous metallic mineral deposits are distributed in northern states. Copper is produced in Sonora State, while silver, lead and sulfur are produced in Chihuahua, Coahuila, Durango, Zacatecas and San Luis Potosi States. Phosphorus, sulfur, and iron which are considered to be strategic minerals for Mexico are produced mainly in Baja California Sur, Veracruz and Colima States, respectively.

The mining industry in Mexico has steadily played an important role in promoting regional development, supplying materials for industry, earning foreign currency, and securing employment for her people.

Mining activities are present in about 250 municipalities all over the country and contribute to the direct employment of 221,000 people.

The production of the mining sector reached about 3.8 trillion pesos in 1987 and accounted for 1.3% of the gross national product. (See Table 2.1.1) Among the minerals produced, silver has the greatest share with 29%, followed by copper (29%), sulfur (13%), and zinc (11%). Mexico's output of as many as 14 minerals are listed among the top five of the world of mineral production rankings (excluding communist bloc countries), namely, silver (1st), bismuth, celestite, fluorite, graphite (2nd), antimony, barite (3rd), molybdenum, zinc, arsenic, cadmium, sulfur (4th) and mercury, lead (5th). (see Table 2.1.2) The above 14 minerals are responsible for about 70% of the mineral production in Mexico, excluding petroleum.

Also notable is the export of the mining sector which amounted to about 1.38 trillion pesos in 1987 and accounted for 5.2% of Mexico's total export revenues. (see Table 2.1.3)

Production shares by type of enterprise in the mineral industry are 54% for national corporations, 30% for large-scale private companies and 16% for middle-to-smaller mines. However, as the ongoing privatization of the national corporations make progress, the above shares will change accordingly and the national corporations are expected to deal only with major strategic minerals.

Among the major corporations engaged in mining are such private companies as Grupo Industries Penoles, IMMSA Group, San Luis Industry Group, Empresas Frisco, S.A. de C.V., Real de Angeles Mine and other national corporations including Pan American Sulfur Corporation, Exportadora Istmo S.A. (Azufre) Export Corporation (Sulfur), Consorcio Minero Benito Juarez Pena Colorada, S.A., Mexico Phosphorus Ore Corporation, Salt Export Corporation, Cananea Mine, Mexicana de Cobre, Minera Carbonifera Rio Escondido, S.A., Cia Minera Real del Monte y Pachua, Las Cuevas Mine (fluorite).

With the view of promoting middle-to-smaller-scale mines (about 3,000 all over the country) regarded as one of the three main forces in mineral production in Mexico, the Mexican government has provided technical and financial support for all aspects of mining activities through such governmental agencies as the Comision de Fomento Minero (CFM), Consejo de Recursos Mineros and the Mexico Non-metallic Mineral Fund.

The beneficiation plants on which this study has been conducted was established by CFM around the country as part of the government support program to help minor, middle-to-smaller mines, unable to finance their own beneficiation plants. Therefore, they are indispensable institutions for promoting middle-tosmaller mines.

The following is an outline of main mineral products in Mexico.

1) Silver

The average annual output of silver in Mexico, between 1983 and 1987, is 2.15 thousand tons. In 1987, Mexico produced 2,415 tons (up 4.9% from the previous year), or 18% of the total world output, and also had that distinction the previous year. In 1987, as in the previous year, Minero Real de Angeles (domestic production share - 12%) and other large-scale mines operated successfully and stable market conditions affected production of middle-to-smaller mines favorably.

During the same period, 1,583 tons, or about 70% of total output was exported in the form of bullion to the U.S., Japan, Great Britain, and Sweden. The U.S. (share - 73%) and Japan (19%) alone accounted for more than 90% of Mexico's total silver export. The U.S. imported 26% of its total imported silver from Mexico during that same period.

Although Mexico's silver production decreased 2.3% from the previous year to 2,359 tons in 1988, it still maintains first place in the world. The production decrease was mainly due to the sluggish international price. But, the decline in the quality and the partial disruption of mining caused by operational problems at Real de Angeles Mine were also responsible for the decrease.

2) Bismuth

The average annual output of bismuth in Mexico between 1983 and 1987 was 733 tons. In 1987, Mexico produced 1,012 tons, or more than 23% of the total world output, and ranked second in the world.

Bismuth is produced as a byproduct of lead in Mexico. Since Mexico has been ranked fifth in lead production, it has always stayed within the top five of the world in bismuth production for the last several years.

Mexico exported an average of 307 tons of bismuth, or 42% of the average annual output, each year between 1983 and 1987. 57% was exported to the U.S. (31% of U.S. import), 39% to Belgium and Luxemburg, and 4% to other countries.

Although the output figure for 1988 is not known, Mexico is believed to have maintained second place in the world.

3) Celestite

The average annual output of celestite in Mexico between 1983 and 1987 was 34,720 tons. In 1987, Mexico produced 47,739 tons, or 24% of total world output, and ranked second in the world following Turkey.

It is an advantage to Mexico that the main celestite deposits concentrate in Coahuila state which has proximity to the U.S., its largest consumer.

Although Mexico has recently yielded first place to Turkey, which had sharply stepped up its production, Mexico has stayed within the top five of world rankings and remains as a principal producer of celestite.

Total export amount of celestite between 1983 and 1987 was 194,429 tons, most of which was exported to the U.S. (94%) with the remaining 6% to other countries.

Although the output figure for 1988 is not known, Mexico seems to have come back to first place in the world.

4) Fluorite

The average annual output of fluorite in Mexico between 1983 and 1987 was 672 thousand tons. In 1987, Mexico produced 724 thousand tons, or 15% of world total output, and ranked second in the world. Abundant fluorite deposits and proximity to the U.S., the

world biggest market, are advantageous to Mexico, as in the case of barite and celestite.

During the same period, 83% of its total output was exported. 45% of the exported fluorite was in meta-radical grade and 55% in acid grade. 44% of about 1,200 thousand tons of the meta-radical grade fluorite exported was bound for the U.S., 12% for Japan, 8% for Canada and remaining 36% for more than 20 other countries. 65% of about 1,500 thousand ton of the acid-grade fluorite was bound for the U.S., 8% for Canada and 27% for more than 10 other countries.

Out of 2,400 thousand tons of total import of fluorite by the U.S. for the same period, 51% was from Mexico.

5) Graphite

The average annual output of graphite in Mexico between 1983 and 1987 was 39,510 tons. In 1987, Mexico produced 38,461 tons, or slightly over 6% of world total output, and ranked second in the world following South Korea. Mexico's production increased 17% in 1988 and moved up to first place in the world, outpacing South Korea.

It is an advantage to Mexico that the main producing center, Sonora state, has proximity to the U.S. where most of the product is exported.

The average annual export between 1983 and 1987 was 39,510 tons, of which a staggering 97% was exported to the U.S. 45% of the U.S. import was from Mexico.

6) Antimony

The average annual output of antimony in Mexico between 1983 and 1987 was 3,205 tons. In 1987, Mexico produced 2,839 tons, or 5% of the world total output, and ranked third in the world, following Bolivia and South Africa.

In Mexico, antimony production in the form of ore is conducted mostly by small mines and accounted for about 38% of the total output. Commercially exploitable, large-scale antimony deposits have not yet been found. 62% of the total antimony output is produced as a byproduct of the lead refining process. It is generally accepted that Mexico is ranked among the major antimony producing countries in the world.

Most of the output (75%) was exported in the same period. Almost all the antimony ore was exported to the U.S. while 51% of the bullion was exported to the U.S., 25% to Brazil, and 24% to other countries.

7) Barite

The average annual output of barite in Mexico between 1983 and 1987 was 395 thousand tons. In 1987, Mexico produced 401 thousand tons, or 9.2% of the world's total output, and ranked third in the world. Mexico was abundant barite deposits and vigorously produces and exports, while it consumes barite mainly for its petroleum industry.

About 17%, or 328 thousand tons of the total output in the same period was exported and most of it - 96% - was bound for the U.S.

8) Molybdenite

The average annual production output of molybdenite in Mexico between 1983 and 1987 was 4,286 tons. In 1987, Mexico produced 4,400 tons, or slightly over 5% of the world's total output, and ranked fourth in the world. Although the leading three countries, namely the U.S. (first), Chile (second) and Canada (third) combined to share a commanding 72% of the world total output, Mexico has remained within the top five for the past five years.

Mexicana de Cobre and Minera Cumobabi which belongs to the Empresas Frisco, S.A. de C.V. Grupo combine to control almost 100% of molybdenite production in Mexico. Especially, Mexicana de Cobre alone which has a commanding 70% share.

Refined molybdenite of 33,473 tons was exported in the same period, of which 35% was bound for West Germany, 30% for China, 16% for Great Britain and 19% for other countries.

9) Zinc

The average annual output of zinc in Mexico between 1983 and 1987 was 273 thousand tons. In 1987, Mexico produced 271 thousand tons, or about 4% of the world's total output, and ranked fourth in the world following Peru.

It is because the production of the major mines under the IMMSA Group and Grupo Industrias Penoles has successfully progressed for the last several years, that zinc production in Mexico is in relatively good shape.

A good part of the output (66%) was exported in the same period, of which 29% was in the form of zinc bullion and 37% in the form of ore.

Half of the exported ore (48%) was bound for Belgium and Luxemburg, 33% for the U.S. and 19% for more than 10 other countries including Japan.

On the other hand, as much as 63% of the exported zinc bullion was bound for the U.S. followed by Nicaragua (9%), China (8%), Costa Rica (4%) and the remaining 16% was for more than 40 other countries including Japan.

10) Arsenic

The average annual output of arsenic in Mexico between 1983 and 1987 was 4,603 tons. In 1987, Mexico produced 5,304 tons, or

about 10% of the world's total output, and ranked fourth in the world (third in 1988) Mexico has steadily ranked in fifth place from 1983 to 1986. (1st: Sweden, France, 2nd: USSR, 3rd: Chile 4th)

In Mexico, since arsenic is mainly produced as a by-product recovered from the process of copper refining, copper output trends have great influence on arsenic production.

Between 1983 and 1987, Mexico exported 15,779 tons of arsenic (in the form of arsenic tri-oxide), or 69% of its total output. 97% was bound for the U.S. and the remaining 3% went to Brazil.

11) Cadmium

The average annual output of cadmium in Mexico between 1983 and 1987 was 1,210 tons. In 1987, Mexico produced 1,249 tons, or about 10% of the world's total output, and ranked fourth in the world following Japan (share: 13%), the U.S. and Canada (8% each) and Belgium (7%).

Since in Mexico, cadmium is produced as a byproduct of zinc production, cadmium output depends largely on the output of zinc, or the primary product. In this regard, cadmium production is similar to those of arsenic (a byproduct of copper) and antimony (a byproduct of lead).

Between 1983 and 1987, Mexico exported an average of 511 tons of cadmium each year (42% of the output). Over half of 2,533 tons (57%) of total exported refined cadmium was bound for the U.S., 8% for Brazil and the remaining 35% for other countries.

12) Sulfur

The average annual output of sulfur in Mexico between 1983 and 1987 was 1,960 thousand tons. In 1987, Mexico produced 2,304 thousand tons, or slightly over 4% of the world's total output, and ranked fourth in the world. (third in 1988)

Highly profitable, large-scale sulfur deposits distributed in several locations in the Southeastern region of the country, contribute to making Mexico rank fourth place or higher in the world. Mexico defines sulfur as one of its strategic commodities and the mining of sulfur is mostly undertaken by national corporations, which account for more than 80% of the total output.

The annual average of 1,516 thousand tons of sulfur, or 77% of the output, was exported to the U.S. (36% of U.S. import), 8% to Great Britain, 0.5% to Guatemala and 17.5% to other countries.

13) Mercury

The average annual output of mercury in Mexico between 1983 and 1987 was 262 tons. In 1987, Mexico produced 124 tons, or 2% of the world's total output, and ranked fifth in the world. Mercury output in Mexico is low compared to its amount of deposits and the output fluctuates every year. (e.g. fourth in the world in 1987)

One of the main reasons for the fluctuations is that most of the production is dependent on small mines which lack scheduled prospecting and mining. Another reason is that the fluctuation in mercury price has a serious impact on the production of small mines.

During the above five-year perid, the output peaked at 394 tons in 1985 and then, it sharply dropped to less than one-third the peak output of 1987.

Mexico exported a total of 813 tons, or 62% of the output, between 1983 and 1987. About half (53%) was exported to Brazil, 32% to Argentina, 4% to the U.S. and 11% to more than 15 other countries.

14) Lead

The average annual output of lead in Mexico between 1983 and 1987 was 183 thousand tons. In 1987, Mexico produced 177 thousand

tons, or slightly over 5% of the world's total output, and ranked fifth in the world following Peru. (fourth in 1988 followed by Peru)

Most (90%) of Mexico's output of lead is produced by large-scale mines under the IMMSA Group or Grupo Industrias Penoles Systematic and large-scale mining and beneficiation of compound minerals (silver, lead, zinc) have been made possible by the progress of a series of equipment modernizations at those mines.

About half (51%) of the total output between 1983 and 1987 was exported in the form of refined lead, or crude ore. About 36% of exported refined lead was bound for the U.S., 25% for Belgium and Luxemburg, 15% for Italy, 4% for Brazil and the remaining 20% for more than 35 other countries.

On the other hand, lead ore was mainly exported to such countries as Belgium, Luxemburg and the U.S., while crude ore was mainly exported to Japan and the U.S.

(2) Mexico's policy for its mining industry

1) History

In the colonial era, mining in Mexico was a source of wealth for Spain (the mother country), and in the first century after its independence, Mexico still earned half its foreign currency reserve exporting silver.

In the era of President Porfirio Diaz (1872 - 1911), mining of other minerals than gold and silver and modernization of the mining sector began, prompted by a policy of encouraging investment by foreign capital under the favorable circumstances in which abundant resources and cheap labor were available. At the same time, the laws governing the rights of resource development, which dated back to the colonial era, were revised. State control of natural resources was abandoned and mining rights were made transferable to foreigners. Supplying materials for foreign markets

had been regarded as the sole purpose of the development of the mining sector as a result of lack of domestic capital and demand for mineral products.

It was in this situation that mining enterprises in Mexico were completely under the control of foreign capitalists and a source of material supply for industrial development of foreign countries.

As the revolutionary government solidified its foundation after the Mexico Revolution, the state control over the mining sector strengthened step by step, resulting in Section 27 of the Constitution which was aimed at reconstruction of state control. Establishment of Comision de Fomento Minero (CFM) and Consejo de Recursos Minerals No. Renovables (predecessor to CRM) were efforts to promote the mining industry. Mexicanization of the mining industry was further accelerated in 1961 when the Mining Industry Act was enacted. The law limited the sponsorship of mine development to the Mexican government, individuals of Mexican nationality, or corporations dominated by Mexican shareholders. It is generally understood that the Mexicaniza-tion policy achieved its initial goal when Cananea Mine S.A. was Mexicanized in 1971.

The new Mining Industry Act enacted in 1975 was a result of a re-examination of the strategies and policies with regard to the uti-lization of natural resources, which became necessary as the national economy grew. The new law strongly required transferees of mining rights to commence development plans without delay and prescribed the direct participation of the government in mineral production activities.

In short, the Mexicanization of the mining industry once con-trolled by foreign capaitalists, and the reconstruction of a declining mining industry have been pursued by each government subsequent throughout Mexico's history. The efforts have resulted in a dramatic increase of output. With large-scale investment projects brought to completion in the 1980's, Mexico is recovering

from a slump since the mid-century to a once again prominent mining country.

However, the existing Foreign Capital Introduction Law enacted in 1973, as implied in its formal name "The Law in Order to Promote Mexican Investment and Regulate Foreign Capital in Mexico" , basically limits foreign capital to less than 49% of corporate shares in Mexico.

As a result, foreign capitalists have not necessarily been interested in investing in Mexico and development plans did not make progress as they had been expected without sufficient domestic capital.

Although the Miguel de la Madrid administration executed the Foreign Capital Law rather flexibly, enabling foreign capitalists to participate 100% in some Mexican enterprises, in order to facilitate the inflow of foreign capital, but the mining sector was still excluded from application of such measures.

2) Policy of the present administration for the mining industry

The current Salinas administration has not only advanced the policies of the previous De la Madrid administration, but also moved one step further. It set about a detailed execution rule for the introduction of foreign capital law in May 1989 in which 100% participation of foreign capital was endorsed and the procedures of investment in Mexico were greatly simplified. As a result, though the maximum share of participation by foreign capital set forth in the new Mining Industry Act (49%, but up to 34% in state-owned areas) remained unchanged, if combined with the use of a trust provided by Mexican banks, foreign capitalists would be able to hold the majority of participation share in substance.

President Salinas announced the ", National Development Plan 1989 - 94", in May, 1989, which addressed the mining industry roughly as follows:

"The mining industry has always been linked to the development of this country and is a great potential source for the development of rural localities as well. Additionally, it contributes to our acquisition of foreign currency through export. It is so strategically important that certain minerals are mentioned even in the Constitution. Therefore it is necessary to conduct an investigation actively and extensively, and to accumulate expertise with underground resources for the promotion of the mining industry. Furthermore, various types of financial schemes should be considered to promote middle-to-smaller mines. The Mining Industry Act also needs to be revised into a modernized version. Appropriate technologies, even though they are foreign, are necessary to be adapted willingly, if they fit the conditions and production capacity of our mining industry in Mexico".

Although concrete measures for the mining industry by the Salinas administration are yet to be proposed based on the National Development Plan 1989 - 94, prospective contents are expected to succeed those stated in the "Policy Outline 1988 - 94 (mining industry)", or the proceedings of the Mining Industry Conference held during his campaign for presidential election, in which candidate Salinas made the following nine policy proposals.

(1) Reexamination of regulations and standards for the mining industry
(2) Empowering and stream-lining of the agencies for promoting our mining industry
(3) Preservation of state-owned mine plots and priority in conducting investigation
(4) Strengthening the role of research institutes
(5) Attention to safety and environmental problems
(6) Promotion of research for the use of minerals for industrial use.
(7) Enhancement of support for middle-to-smaller mines
(8) Financial measures to promote the mining industry
(9) De-centralization of agencies for promoting mining industry

Four of the articles, or (2), (7), (8), and (9), of the 9 articles are aimed at supporting and promoting middle-to-smaller mines and suggest that the present administration expects middle-to-smaller mines to play an important role.

It was also mentioned that the role of the central government should be limited to a supplementary position mainly to facilitate a smooth adjustment of interests between holders of mineral rights and landowners, or between middle-to-smaller-scale mines and large-scale mines.

3. SUMMARY AND ANALYSIS OF FIELD SURVEY RESULTS

3.1 Outline of Geology and Ore Deposits

3.1.1 Parral Area

(1) Outline of Stratigraphy, Rock and Structure

The basement of the district is the Parral Formation of presumed lower Cretaceous of Mesozoic (formation is more than 1,000 m thick). The formation is green to gray coloured and meta-sedimentary rocks, consisting of alternation of limestone and lutite. The basement is overlain unconformably by Tertiary Escobedo Formation, divided into upper, middle, and lower members. The bottom of the lower member is a conglomerate bed containing fragments of metamorphosed lutite, andesite and quartzite, and is overlain by sandy tuff. The middle member is composed of andesite, and the upper member consists of basaltic and dacitic tuffs. Intrusive rocks are quartz monzonite, andesite, basalt and dacite. The quartz monzonite forms some stock shape, and the others intrude as dikes mainly in the NNW-SSE direction.

In the southwestern part of Parral City, there is a large fault. The basement rock of the southern part is in fault contact with Tertiary volcanic rocks of northern part. In addition, in the northern part of Parral City, there are two parallel faults in the NNW-SSE direction, and the eastern one forms the boundary between mountains and a plain.

(2) Mineralization, Alteration and Related Igneous Rock to Ore Deposition

The ore deposits in the area are of vein type and are hosted mainly in the top of the Parral Formation to the lower part of the Escobedo Formation. These rocks are called "Pizarra" and have been subjected to the alteration of propylitization, silicification and argillization related to the mineralization. But, at the San Francisco del Oro mine, a replacement type ore deposit hosted in calcareous sedimentary rocks is found.

The relationship among the ore formation, faulting and intrusion of igneous rocks are complicated. After the intrusion of quartz monzonite, faults in the NWW-SSE direction took place and then were filled with dacite and vein materials. Another later faults and dikes

dislocated the veins. The igneous rock related to the ore deposition is regarded as Tertiary rhyolite.

(3) Distribution of Ore Deposit

The veins in the area can be divided into two main groups. One of them is 18 kilometers southwest of Parral City, distributed in a 12 km x 8 km range from San Fransciso del Oro to Santa Barbara that is one of the largest lead, zinc, copper and silver deposits in Mexico. Another one is a 12 km x 7 km range north of the Parral City, including the Zinc de Mexico mine. In addition, subgroups of veins are distributed 19 kilometers south, 30 kilometers southeast, and 40 kilometers north-northeast of Parral City. The directions of the latter two subgroups are mainly from N-S to NNW-SSE, and concordant with some of the dikes.

The vein group predominate in the area from San Francisco del Oro to Santa Barbara are held in operation by leading enterprises, and others by minor ones. The distribution density of veins north of Parral City is three veins per square kilometer. The sulfide ore zone of each vein is oxidized to the depth of 50 m or 100 m below the ground surface.

3.1.2 Guanacevi Area

(1) Outline of Stratigraphy, Rock and Structure

Basement in this area is Paleozoic black schist, Jurrasic metamorphosed slate and sandstone, and Cretaceous lutite, sandstone and volcanic rocks.

Tertiary rock unconformably overlies the basement in wide area and Lower Tertiary is the Guanacevi conglomerate of Paleogene, characterized by red and sandy matrix and is overlain by the thick sandstone, lutite, andesitic tuff, fine tuff, tuff breccia and lava of Eocene. Upper Tertiary consists of rhyolitic welded tuff, tuff breccia and tuff of Oligocene to Miocene.

As intrusive igneous rocks, there are sheets of dacite and dikes of diorite, and the latter intrudes in the NW-SE direction.

Main fault in the area is observed near the Santa Cruz, in the NW-tSE direction, and the upper most Tertiary rhyolitic pyroclastic rocks of the southwest part of the area is in fault contact with the lower Tertiary Guanacavi conglomerate and andesitic pyroclastic rocks of the northeast. Another is the San Juan fault 3 kilometers north of the above fault, parallel with it.

(2) Mineralization, Alteration and Related Igneous Rock to Ore Deposition

The ore deposits in the area are of vein type, with the exception of one manto type. These ore deposits are found in Tertiary tuff breccia and andesite. The alteration related to the ore deposition includes the silicification and chloritization. The veins were deposited presumably after the formation of intrusive rocks and the faults. Igenous rock related to the ore deposition is regarded as dacite.

(3) Distribution of Ore Deposit

The veins in the area are distributed in a 10 km x 10 km range. The main direction of vein system is NNW-SSE, but NNE-SSW is predominant in the western part. Large Santa Cruz Vein, which is in the southwest part of the area is now being prospected by Penoles Co., Ltd.

The distribution density of veins is three or four veins per square kilometer. The depth of the oxidized ore zone varies spot by spot, but is less than 50 m.

3.1.3 Barones Area

(1) Outline of Stratigraphy, Rock and Structure

The oldest rocks in this area are metamorphosed Triassic sedimentary rocks. Jurasic conglomerate derived from volcanic rocks is distributed in some parts of this area. The Zacatecas greenrock which consist of andesite, porphylitic andesite and diorite is Cretaceous in age.

The Tertiary rock unconformably overlies the above basement, and are divided into three units. The lower Tertiary is Zacatecas red conglomerate of Oligocene and has a sequence of bedded fluvial deposits, characterized by reddish matrix. The conglomerate is overlain by rhyolitic tuff and lava of Miocene, and then the basalt sheet or lava flow was erupted in the Pliocene. The intrusive phases includes silisic lava domes and dikes. Those intrusives are represented by several northwestern direction plugs which are exposed in the central part of this area.

The older fractures in the NWW-SEE direction after the metamorphism in this area were filled with vein material, and then cut by faults in the NNW-SSE direction.

(2) Mineralization, Alteration and Related Igneous Rock to Ore Deposition

The ore deposits in this area are of vein type and were deposited in the metamorphic rocks and Cretaceous greenrock. It is difficult to distinguish the related alteration to ore mineralization from the regional propylitization. Igneous rock related to ore deposition is regarded as Tertiary rhyolite.

(3) Distribution of Ore Deposit

There are five major vein groups distributed in a 50 km x 15 km and they are Cantera, Mala Noche, Veta Grande, Tajos de Panuco and Plomosa from south to north. The veins strike N45° W to N85° W and dip 50° SW-70° SW or 75° NE, and are parallel to Tertiary dikes.

The depth of the oxidized ore zone is less than some 50 meters below the ground surface.

The distribution density of the veins is high and five to six veins per square kilometer.

3.2 Calculation of Ore Reserve

The calculation of ore reserve is estimated on the basis of natural ore reserve, minable ore reserves, certainty of ore reserves, sampling method for evaluating grade, and definition and criteria of ore species and specific gravity. These calculation methods are generally described in a book for mining geology and mine evaluation, but in Japan the calculation is carried out according to the criteria for the calculation of ore reserve, specified in the Japanese Industrial Standards (JIS). The ore reserves of the medium and small mines surveyed in this study are discussed in comparison with calculation results based on JIS. Because most mines surveyed are vein type ore deposits, only vein-related parts are extracted from the JIS specification for comparison.

3.2.1 Outline of JIS's Criteria for Calculation of Ore Reserve

(1) The ore reserve is expressed in terms of the natural ore reserve and the min-able crude ore reserve.

(i) The natural ore reserve means the mass of an ore deposit lying in the earth crust.

(ii) The minable crude ore reserve is the estimated mining output that is the sum of the minable quantity in the natural ore reserve and the quantity of mingling waste:

$$\text{Minable crude ore reserve} = \frac{(\text{natural ore reserve} \times \text{Mining recovery})}{(1-\text{Percentage of dilution})}$$

where,

$$\text{Mining recovery} = \frac{\text{Recovered ore quantity}}{\text{Natural ore reserve}}, \text{ and}$$

$$\text{Percentage of dilution} = \frac{\text{Waste quantity}}{\text{Minable crude ore reserve}}$$

(2) Each of the natural ore reserve and the minable crude ore reserve is classified into three values: the proven, probable, and possible ores.

(i) The proven ore is a block surrounded with three or more sides. Generally it is a section of an ore deposit that appears in the upper and the lower drifts and in a shaft connecting the two drifts, or a section of an ore deposit surrounded with a drift and two raises (or sinks) from the drift. As a rule, the vertical interval between galleries is within 30 m, and that between shafts or raises (or sinks) within 60 m.

(ii) The probable ore is a block surrounded with two or more sides. In fact, however, even if a block is faced to only one side, the block can be regarded as an probable ore when the reserve and grade of the block can be sufficiently estimated from the characteristics of the ore deposit, and mining conditions and borings from the past.

(iii) The possible ore is a block in an area, the presence of which can be geologically predicted but cannot be reckoned as a proven or an probable ore. When borings suggest the presence of an area, and mining conditions from the past and the characteristics of the ore deposit allow sufficient prediction on the volume and grade of the area, a block in such an area can be regarded as an possible ore.

(3) Indication of Ore Reserve

Although the minable crude ore reserve is necessary for an enterprise, the pay limit of a minable ore reserve varies case by case, so that the ore reserve is indicated by grades. That is, all grades of the lowest limit and better are classified into certain standard groups, and then the ore reserve for each group is calculated.

The metal of interest should be the target metal of the enterprise, but when there are two or more metals, the major metal is regarded as the standard and the quantities of other metal converted by calculated coefficients, are added to the quantity of the major metal.
The equation is:

Converted grade = $a_1 + (b_1b_2b_a + c_1c_2c_3 + \cdots\cdots) - (b_4 + c_4 + \cdots\cdots) / a_2a_3$

where,

$a_1b_1c_1$: grade of each metal

$a_2b_2c_2$: integrated recovery including beneficiation, smelting, etc.

$a_3b_3c_3$: product price

$a_4b_4c_4$: costs for transit, beneficiation, smelting, etc. per ton

(4) Sampling

(i) In principle, the sampling interval should be 1 (one) m or less for gold/silver ore deposits, and 2 - 5 m for other ore deposits.

(ii) The sample should be taken by digging a small groove of 3 - 10 cm wide and 1 - 5 cm deep on a line representing the full picture of the ore deposit at a fresh spot with an exposed surface. The whole amount of the sample should be analyzed.

(iii) Specific Gravity

The specific gravity should be decided from measurements on as many samples as possible.

3.2.2 Outline of Ore Reserve Calculations on Medium and Smaller Mines in United Mexican States

(1) The ore reserve in Mexico is indicated in a mixed form of the natural ore reserve and the minable crude ore reserve specified by JIS.

In calculation on the proven, probable and possible ore, estimated length and height are used as the basis for the volume of a block, but if the vein width is smaller than the mining width, the latter is used as the vein width. Therefore, the calculated ore reserve is the natural ore reserve when the vein width is larger than the mining width, and is the minable crude ore reserve when the vein width is smaller than the mining width, wherein the dilution of grade due to mingling waste is not taken into consideration.

(2) The ore reservation is classified into the proven, probable, and possible ores.

(i) The proven ore is a block confirmed with three or more sides. Generally it is a section of an ore deposit that appears in the upper and lower drifts and in a shaft connecting the two drifts, or a section of an ore deposit surrounded with a drift and two raises (or sinks) from the drift.

(ii) The probable ore is a half of a block confirmed with two or more sides.

(iii) The possible ore is a quarter of a block confirmed with one side. In addition, when borings allow readily the presence of a block, and mining conditions in the past and the characteristics of the ore deposit sufficiently implicate the volume and grade of the ore deposit, then a quarter of a block in such an area is regard as an possible ore.

(3) Indication of Ore Reserve

There is no grade classification of the ore reserve---only the target metal of the enterprise is indicated. There are no converted grade indications based on a standard metal.

(4) Sampling

(i) As a rule, the sampling interval should be every one meter for gold/silver ore deposits.

(ii) The sample should be taken by digging a small groove on a line representing the full picture of the ore deposit representing the full picture of the ore deposit at a fresh spot with an exposed surface. The whole amount of the sample should be analyzed.

(5) Specific Gravity

The Specific gravity should be decided from measurements on as many samples as possible.

3.2.3 Ore Reserve Calculations of Mexican Medium and Smaller Mines Viewed from JIS's Ore Reserve Calculation

Ore reserve calculations of Mexican medium and smaller mines are those promised by actual conditions of enterprises and financing from CFM. Although the differences between Mexican ore reserve calculations and those of JIS hopefully have been clearly understood from the above descriptions, these differences are again enumerated in the following.

(1) Ore Reserve

The case where the vein width is larger than the mining width corresponds to JIS's natural ore reserve, but the mining recovery and the percentage of dilution for real mining are not taken into consideration. At real mining sites, in fact, only the veins are being mined, with very little mingling of waste.

As far the mining recovery, parts other than the toe are almost completely mined, but the toe is frequently mined, resulting in a very high mining recovery.

A vein width smaller than the mining width causes waste mingling and thus dilution of the grade. At mining sites, however, narrow veins other than veins of high grades are left without mining, bringing about the trend of a lesser mined ore quantity rather than a lowered grade.

(2) Certainty of Ore Reserve

The proven ore is similar to that of JIS. The probable ore is a half of that of JIS, and the possible ore is a quarter of that of JIS. Because these reserve calculations are made a part of the basic cri-

teria for the financial studies from CFM, the higher the risk, a larger allowance is considered in the calculation.

(3) Indication of Ore Reserve

This is similar to JIS's system of indicating only the ore metal of the enterprises' target. There are no grade classifications and no converted grade indications of main metal standard, but the mine owner holds sufficient knowledge on the value of each part of the vein because of the small production scale and estimations from past conditions of the vein enabling the owner to decide the best course of action relative to the economic conditions at the time.

(4) Sampling

Sampling is similar to that of JIS, but the sampling interval is less frequent.

(5) Specific Gravity

The specific gravity is decided in a way similar to that of JIS.

From the above description, the trend of the ore reserve calculation on Mexican medium and smaller mines, when compared with that specified in JIS, can be identified as follows.

(i) While the ore reserve is somewhat similar the minable crude ore reserve of JIS, the proven ore should be slightly reduced for real mining work, and the probable and the possible ores be somewhat increased. As a whole, the Mexican ore reserve can be said to have a secure value with some margin for error, a calculation result much less than that obtained using JIS's base.

(ii) As to the grade, the sampling interval is less frequent than that of JIS, which may result in less accuracy. However, the characteristics of an ore deposit varies from area to area, and therefore, it is desirable that the optimum sampling interval be decided on the basis of careful considerations for the actual conditions based on the costs and required accuracy.

3.3 Outline of the Mines

3.3.1 Parral Area

3.3.1.1 El Triunfo y La Revancha Mine (Fig. 3.3.1.a,b)

Owner: Sr. Miguel Casale Dominguez (Minera Casale, S.A.)

Date of Survey: July 26, 1989

(1) Location

NW of Parral Plant, 20 km by road from the Plant.

(2) Vein and Ore Reserves

1) Scale: There is the sole vein strike and dip of which are N30°W and 80°W. Its width is 1.5 to 2.0 m.

2) Stability and continuity: Both the width and the ore grades are comparatively stable throughout the vein.

3) Ore and gangue minerals: Galena, sphalerite, quartz and calcite.

4) Country rock: Andesite and dacite, which form the Escobedo Formation.

5) Developing status: The vein has been developed for 240 m by 70 m in strike side and dip side respectively. A part of the vein between L4 and L5 (56 m) has not been mined, yet.

6) Ore reserves:

Proven	46,557 t
Probable	28,337
Possible	9,639
Total	84,533

Ore grade: Ag 374 g/t (Receivable from silver minerals alone).

7) Exploration: As a result of the core drilling, aimed to prospect below L5, a lower extension of the vein has been proven, as follows:

Width: 2.4 m

Ore grades: Au: Tr, Ag: 770 g/t, Pb: 1.3%, Zn: 1.4%, Cu: 0.12%

Although there are some blocks to be mined or prospected not only above L4 but between L4 and L5 at present, further exploration must be made below L5 in the future. It will be necessary to prospect an upper part of the vein above L4 earlier to get to high

grade ore reserves because the real ore grades are lower than those of ore reserved by one-half, due to poor recovery at the beneficiation plant.

(3) Production

1) Production: 70 t/day, Ag 374 g/t

Oxidized ore zone and secondary enriched zone near the surface have been extracted.

Beneficiation recovery is so low that the owner of the mine and the Parral plant of CFM call it to question.

2) Working shift and personnel: 2 shifts/day, 6 days/week.

Drilling	2 men/shift x 2 shift =	4 men
Drilling assist.	2 men/shift x 2 shift =	4 men
Mine tub (upper level)	4 men/shift x 2 shift =	8 men
Mine tub (lower level)	4 men/shift x 2 shift =	8 men
Miscellaneous	4 men/shift x 2 shift =	8 men
Foreman	2 men/shift x 2 shift =	4 men
Assist. foreman	2 men/shift x 2 shift =	4 men
Compressor	1 man/shift x 1 shift =	1 man
	Total	40 men

3) Mining method: Underhand open stoping with underground glory hole.

a) A drift (2 m x 2 m approx.) is driven at 45 degrees upward. At blasting, the blasted ore falls into a funnelled chute through the drift automatically.

b) The remaining ore is stoped except for a low grade portion which shall be a pillar. As with drift stoping, the ore falls into a funnelled chute automatically.

c) To produce 70 tons/day of ore, 2 faces are operated at the same time on each shift.

d) Slurry and AN-FO are used.

4) Transportation

a) The ore drawn from the funnel chute is transported by a mine tub (1 ton capacity; actual loading with the ore of the mine is 800 kg) with manual labor to the ore bin on surface, via the upper level, an ore pass and the lower level (adit level).

b) The shaft is equipped with a 1 ton air hoist used for the transportation of materials.

c) On surface, a handful of ore is collected for assay from each mine tub, before dumping to the ore bin. The assay results are referred to the mining plan.

5) Ventilation: Natural ventilation, caused by the difference of the altitude between the portals of the shaft and the lower level, only.

6) Drainage: There is very little mine water. No drainage system, therefore, is needed.

7) Cost:

Mining	$34,500/t (incl. transportation to the plant: $5,000.)
Beneficiation	31,902
Smelting & Refining	8,205
Total	74,607

(Estimated by the Parral branch of CFM)

a) Wage for the drilling man $85,000/week

b) Assay cost (Private laboratories in Parral): $2,000/element

c) Ore transportation (The mine to Parral Plant, express agencies in Parral): $5,000/t

d) 10 ton dump truck: $89 millions
20 ton dump truck: $150 millions

e) Leg drill: $6 millions

f) Drilling rod (insert): $250 - 300 thousands (L = 1.8 m)

g) Machinery and Equipment:

• Leg drill.		
• Air hoist (Rope pull = 1,000 kg)		
• Compressor (75 cu.ft/min., gasoline engine)		1
• Mine tub (1,000 kg)		5
• Dump truck	20 t	1
	10 t	1

(4) Comments

a) This mine produces ore efficiently with a minimum of machinery and equipment. Its technical skill, including management's skill of operation, is at the highest level among all of mines surveyed in Parral.

b) However, the funnelled chute could be a deadly hole for the miner who work on the steep floor.

c) Further, mining cost is more expensive than the average of the smaller mines in Parral which is $25,000 - 30,000/t, due to a smaller scale stope. An adoption of shrinkage or sub-level mining methods and the introduction of a mine car loader would be of considerable help.

3.3.1.2 La Presa Mine (Fig. 3.3.2)

Owner: Sr. Victor Arias

Date of survey: July 27, 1989

(1) Location

NW 10 km from the Parral Plant.

(2) Vein and Ore Reserves

1) Scale: Only one vein is recognized.

Observed on Level 3: Northern half: N5°W, 50°W, 100 m long.
Southern half: N5°W, 60°W, 360 m long.

Width: 0.5 - 2.5 m or more (average 1.5 m).

The northern end of the vein is cut by fault and disappears. The over the fault side is virgin for exploration. At the fault, the strike of the vein suddenly changes to N40°E caused by the fault. There is a fault at the southern part of the vein, but it does not affect the continuity of the vein. The vein extends southward further than the claim limit. Shallow zone up to 10 m depth is oxidized and the deeper zone is sulfide ore.

2) Stability and continuity: Both the vein width and ore grades are stable.

3) Ore and gangue minerals: Galena, sphalerite, quartz, fluorite, and kaolinite.

4) Country rock: Rhyorite.

5) Developing status:

a) The southern 100 m of the claim had been already mined by the former owner of the claim. At NW of La Presa there is a mine which worked a branch of the vein of La Presa.

b) According to old records, there are levels at every 100 ft. intervals up to "L20". However, they seemed to abandon deeper levels because of the flood of mine water at L 16 - 18 and the difficulty of the ore beneficiation due to the presence of copper minerals.

c) There is an abandoned shaft on the south side of La Presa. The air flows through all levels of La Presa towards the shaft naturally. Previous mining works in the area of La Presa were done with the same shaft.

d) Concerning the shaft of La Presa, its repair, including reconstruction of the head frame, had already been done when Mr. Arias obtained the claim.

6) Ore reserves:

Proven	167,670 t
Probable	11,542
Possible	5,974
Total	185,186

Ore grades: Ag 120 g/t, Pb 4.36%, Zn 3.88%

All reserves proposed to be mined are sulfide ore.

7) Exploration: There are enough ore reserves for more than 10 years operation above the L4.5 level. Further, an unmined portion of the vein would seem to extend to the deepest level. It is not necessary to explore further ore reserves for a while.

(3) Production

1) Production: Under reopening work. Proposed: 1,000 - 1,500 t/month production, starting 2 - 3 months later.

a) During the latter half of 1950s to 1960s, U.S.A. capital, Eagle Peach operated mines within the district. Mr. Arias,

the present owner, obtained a part of its claims.

2) Proposed Mining Plan (The deep portion, about 200 m from surface.)
   a) The upper part of the vein above level 4.5 will be mined.
   b) Shrinkage mining method.
   c) The level 4.5 will be a transportation level with 1 cu.yd class LHD.
   d) Ore will be transported in the existing shaft equipped with a 1 ton engine hoist which can be converted from a power train of a used car.
3) Ventilation: There is an abandoned old shaft at the south side of La Presa. Fresh air flows to the present shaft naturally.

(4) Comments
   a) Drainage pumps of today are much better than that of the 1960's. Therefore, the deeper portion below L4.5 could be mined. (The transportation system of the shaft must be updated if or when the deeper portion is mined).
   b) The proposed method, shrinkage mining, would meet natural conditions of the mine (i.e. the dip of the vein and the strength of the country rock.)
   c) Under the condition that a fan be installed, sufficient fresh air would flow in L4.5, where a LHD should be introduced, because La Presa is connected with an abandoned shaft from a neighboring claim.
   d) The northern zone beyond the fault and a deeper zone under L4.5 should be prospected when production from the shallow zone is operated favorably.

3.3.1.3 La Esperanza Mine (Fig. 3.3.3)

Owner: Sr. Daniel Rios Astorga

Date of survey: July 28, 1989

(1) Location

NE 8 km from the Parral Plant

(2) Vein and Ore Reserves

1) Scale: At the surface, N20°W, 55°E, 0.5 m wide. At the level of 80 m deep from the surface, N10°E, 70°E, 0.45 m wide, oxide and sulfide ore mixed. The grades are Ag 150 g/t, Pb 3.0% and Zn 3.0%. A bonanza is deposited between Vertical Shaft and Piedrera Shaft, a little closer to the Vertical Shaft. It is 150 m long in strike and 200 m long in dip side.

2) Stability and continuity: At the level of 160 m deep, the northern part of the vein is extremely varied in ore grades and vein width. A fluorite vein runs in parallel to a sulfide vein at 1.5 m distance, and the former does not contain ore minerals. Ore grades of the sulfide vein are Ag 60 g/t, Pb 2.0% and Zn 2.0%. At the southern part of the vein on the same level, the floor is comparatively high grade ore, e.g. Ag 150 g/t, Pb 3.0% and Zn 5.0%. At the 210 m depth, mineralization with sulfide, fluorite and quartz were observed. At this level, ore grade decreases as it goes further from the shaft northward. Vein is N-S, 55° - 70°E, width 0.2 - 2.0 m. The width of the vein is variable along strike side. In dip side, however, the width and the ore grades are stable.

3) Ore and gangue minerals: Galena, sphalerite, chalcopyrite, silver bearing pyrite, quartz and fluorite.

4) Country rock: Andesite in the upper part. The lower part of the vein, a hanging wall, is conglomerate and a foot wall is rhyolite.

5) Developing status: The vein has been developed for 250 m by 165 m (from the surface) in strike and dip respectively. Three shafts named Tiro Piedrera (167 m), Tiro Vertical (83 m) and Tiro Tripie (20 m) have been excavated. It seems that drifts were driven 30 m below the deepest level now in operation. It is said that the bottom of the Tiro Piedrera shaft is far deeper than the drifts.

6) Ore reserves:

Proven	27,685 t
Probable	4,253
Possible	2,140
Total	34,078

Ore grades: Ag 100 g/t, Pb 4.0%, Zn 5.0%.

7) Exploration: In order to keep the level production, it will be necessary to discover one bonanza after another since each bonanza is so small. Therefore, it is essential to prospect new bonanzas in the strike side. Further, the lower extension of the existing bonanza must be proven first. An operation has to be well planned based on the results of such exploration.

(3) Production

1) Production: Twenty tons/day, Ag 100 g/t, Pb 4.0%, Zn 5.0%.

a) Oxide ore, the grade of which is Ag 150 - 160 g/t, cannot be mined at current silver prices. The owner intends to mine oxide if or when the price goes up. At present, sulfide ore is mined at the deepest level.

2) Working shift and personnel: Two shifts/day, 2 faces/shift

Drilling	2 men/shift x 2 shift =	4 men
Mucking and haulage	2 men/shift x 2 shift =	4 men
Skip	2 men/shift x 2 shift =	4 men
Truck (mine to plant)	2 men/shift x 1 shift =	2 men
	Total	14 men

3) Mining Method: Gophering (Overhand open stoping.)

4) Transportation: Mucking on mono wheel cart with manual labor and a skip lifted by an engine hoist.

5) Cost

Mining

(including transportation cost to the beneficiation plant):

	$30,000 /t
Beneficiation:	31,902
Smelting & refining:	36,000
Total:	97,902

a) The owner is worried about mine water and the inefficiency of the small skip transportation system. It does not compare with a long distance shaft lifting.

3.3.1.4 Tilita Mine (Fig. 3.3.4)

Representative: Sr. Ramon Concha Baca

Date of survey: July 29, 1989

(1) Location

SE 68 km from Parral Plant

(2) Vein and Ore Reserves

1) Scale: At the level 1: N30°E, 45°W, 0.3 m wide. At level 4: N70E, 45-50S, 2.5 m wide. There is a sole bonanza, length of which is 15 m in strike side. Oxide zone extends very deeply.

2) Stability and continuity: The vein is unstable in strike side. Two veins were observed. In dip side, the veins are long and could extend downward.

3) Ore and gangue minerals: Galena, sphalerite, manganese, arsenopyrite, quartz and calcite.

4) Country rock: Metamorphosed sandy lutite and sandstone. These are silicified around the vein.

5) Developing status: Developed for 125 m long in strike side by 85 m long in dip side.

6) Ore reserves:

Proven	10,696 t
Probable	3,699
Possible	2,112
Total	16,507

Ore grades: Au 0.9 g/t, Ag 519 g/t.

7) Exploration: Outcrops run parallel to the operating vein. It is expected one may discover new veins by means of cross-cuts from the existing drifts. Compared with prospecting the lower extension of the existing bonanza, it is risky and difficult but quite effective to get large reserves.

(3) Production

1) Production: Ten tons/day (mainly sulfide ore is produced), Ag 800 g/t, Au 0.5 - 1.0 g/t (max. Ag 1,200 g/t)

2) Working shaft and personnel: Two shifts/day.

Miners (underground)	5 men/shift x 2 shift =	10 men
Skip	1 man/shift x 2 shift =	2 men
Miscellaneous (truck, etc.)	1 man/shift x 1 shift =	1 man
	Total	13 men

3) Mining method: Gophering (overhand open stoping with platform).

4) Transportation: Mono wheel carts to a skip, lifted by an engine hoist on surface. Because the veins extend in a steep dip direction, platforms are set up in order to stope overhead ore deposited between each level.

5) Ventilation: Natural ventilation

6) Drainage: Pumped up with 2 inch pipe for 8 hours/day. Estimated 4 l./min.

7) Cost:

Mining	$28,000 /t
Beneficiation	31,902
Smelting & Refining	4,100
Total	64,002

Average wage of miners: $8,000/day, $50,000/week.

(4) Comments

a) There are a series of NE-SW veins around the mine. Length of each vein is approximately 2 - 3 km. Some of them are operated as several independent mines.

b) Tilita is located on a nearly flat plateau. Although there are parallel outcrops, Tilita's own is unknown. According to the owner, the mine was discovered by geochemical prospecting.

c) In short, there could be virgin veins discovered.

3.3.1.5 La Fourtuna Mine (Fig. 3.3.5)

Owner: Sr. Braulio Lozoya Lozoya

Date of survey: July 31, 1989

(1) Location

S 40 km from Parral Plant

(2) Vein and Ore Reserves

1) Scale: N75°E, 70°N, 0.5 - 2.0 m wide, and Ag 300 g/t.

2) Stability and continuity: A drift was driven for 20 m to west and 80 m to east along the vein. Mineral above the drift seems to have been extracted completely as there are 2 m width cavities. At the east end of the drift, width of the vein decreases to 0.1 m. Generally, the width of the vein seems to have been even, inferred from the mined-out cavities. Three bonanzas mined were observed. These were:

West: 100 m long in strike and 45 m long in dip.

Center: 20 m long in strike and 45 m long in dip.

East: 30 m long in strike and 45 m long in dip.

All of the above have already been mined out completely.

3) Ore and gangue minerals: Galena, sphalerite, pyrite, quartz, calcite and epidote.

4) Country rock: Monzonite.

5) Developing status: Developed for 250 m by 45 m in strike and dip respectively. The deepest level was connected to the surface by a ramp (-3°, facing north)

6) Ore reserves: Nil.

7) Exploration: Prospecting of the lower extension of the bonanzas by means of prospecting drifts after sinking a shaft might be considered. However, capital cost required would be quite large.

(3) Production

1) Production: Idle for 3 months.

a) In 1988, 1,000 t of ore were sent to a beneficiation plant, and 75 t of those were forwarded to the CFM Parral Plant (Ag 600 g/t). It is said that the mine produced 400 t/month with 12 employees.

b) Ore stock on surface and primary concentration at the mine site:

. At the mine, ore was screened with 1 cm square mesh of screen. Because the country rock is harder at this site and less crushed when blasting than quartz vein, it remains

above the screen. It is said that hand picking was also applied.

. Around the portal of the ramp, about 1,000 t of ore is piled on the surface.

2) Personnel: Two men at present.

3) Mining method: N/A.

4) Transportation: It is said that mined ore was transported by LHD via the drift and the ramp.

a) A mine car loader (rocking action type: Eimco 600B) was left behind near the portal of the ramp.

5) Ventilation: Natural ventilation (supposition).

6) Drainage: There is little mine water. However, a 15 HP electric pump is left behind at the bottom of the ramp because the portal of the adit is located below the level of the nearby river.

(4) Comment

a) Comparing the mine's potential with other small mines in the Parral area, we think too much has already been invested. Although the vein could extend under the existing drift, its development would require further investment. There are a lot of alternative sites for investment in the Parral area other than this mine.

3.3.1.6 Unificacion Cordero Mine (Fig. 3.3.6)

Owner: Sr. Agustin Rascon Ramos

Date of survey: August 1, 1989

(1) Location

62 km north from Parral Plant

(2) Vein and Ore Reserves

1) Scale: The mining claims cover a large area of 218 ha. In the claims, there are lots of veins and sites from old mining activities. Only one vein is operated at present. The oxidized zone extends to about a depth of 45 m from the surface.

A) San Pedro, Centenerio and Trinidad Vein:

a) Idle due to a flood from a fault.

b) According to the owner of the mine, width of the vein is 1.35 m (sulfide). Grades are Ag 500 g/t, Pb 6.0%, Zn 9.4% and Fe 6 - 7% (contained in pyrite). Concerning mill recoveries, better results shall be gotten than in the other veins of this mine, because of a lesser iron content. Strike and dip are N60°E and 70°N respectively.

c) Proposed Plan: A reinforcement of the drainage system (10B pipe line, pump, and generator). At present, 100 l/sec of water is pumped from underground.

The shaft of San Pedro should be sunk to 100 m depth from surface (now 45 m). Then, a crosscut will be driven to catch the veins of Centenario and Trinidad. Drift shall be 250 m long along the veins.

B) The Operating Vein (San Pedro)

a) N50°E, 70°W, 1.0 m wide at L45 m (from surface), oxide ore. An oxide ore zone above L45 m is not operated because of low silver price and of poor mill recovery.

b) N30°E, 70°W, 2.0 m wide at L60 m (vein part: 1 m, disseminated part: 1 m), sulfide ore is produced here at present, forty meters of the vein (in strike side) is observed.

2) Stability and continuity: We surveyed the drift driven along the San Pedro Vein. Continuity of the vein width and the stability of the ore grades are very good.

3) Ore and gangue minerals: Galena, sphalerite, marcasite, chalcopyrite, pyrite, quartz, calcite and hematite.

4) Country rocks: Monzonite, lutite, limestone. Sericitization, propyritization, and hematitization were observed.

5) Developing status:

a) The present owner inherited the mining claims from his father. They have operated mines of the claims for 60 years in all. They also run a farm near the claims.

b) There is an idle shaft, from which the owner's father once mined ore. A flood of mine water caused the end of production.

c) The owner operated the south side claim of the operating claims, with 4 shafts. Its production has been also suspended due to a flood of mine water.

6) Ore reserves:

Proven	20,159 t
Probable	5,076
Possible	3,078
Total:	28,313

Ore grades: Ag: 304 g/t, Pb 6.5%, Zn 4.3%

7) Exploration: Among the mines surveyed in the parral area, this mine is the best for reasons of high ore grades, continuity, numbers of veins and huge claim area.

(3) Production

1) Production: 250 t/month, Ag 315 g/t, Pb 12.0%, Zn 7.0%

2) Working shift and personnel: Two shifts/day, 1 face/shift, 10 workers.

a) According to the owner, the problem is a shortage of hands. The mine could produce about 400 t/month (15 t/day 25 days/month) if there were sufficient workers. Due to its isolated location, it is very difficult to take on regular employees, so, the mine owner hires cowboys who work at nearby ranches.

3) Mining method: Overhand bench-cut stoping (Bancos Ascendentes: in Spanish).

To blast W 2 m x H 2 m face, 10 blasting holes are drilled to 1.2 m depth by a leg drill. Twenty t/blast.

4) Transportation: Instead of mine tubs, a skip bucket put on a carriage is used for transportation. Mucking on the skip is done with manual labor. It is lifed by an engine hoist on surface.

5) Ventilation: Natural ventilation.

6) Drainage: 26 l/sec (37 l/sec x 8 hours/day plus 20 l/sec x 16 hours/day) of mine water is pumped up with 60 HP pump powered by a diesel engine. Actual head is 64 meters.

7) Cost:

Mining	$41,050 /t	
Beneficiation	31,902	
Smelting & refining	9,550	
Total	82,500	
Drainage cost		US$10/t
Transportation to the beneficiation plant		$12,000/t

(The owner has 3-10 ton trucks for transportation.)

(4) Comments

a) High grade product (ore) covers expenditures caused by lots of mine water and its isolated location.

b) We would like to suggest construction of a large scale shaft equipped with more modern machinery and a main level which connects to a series of veins, instead of a small shaft at each vein. However, the owner seems to want to keep his mine for a long time as an inheritance from his father, but not to make money transitory.

3.3.2 Guanacevi Area

3.3.2.1 San Jose Chico Mine (Fig. 3.3.7)

Owner: Sr. Vicente Aguirre Chavez

Date of survey: August 8, 1989

(1) Location

Three kilometers west from Guanacevi Plant

(2) Vein and Ore Reserves

1) Scale: There is a high grade vein in the northern part of L 7. Although its width is only 0.2 m, ore grades are extremely high. Ag 70 kg/t and Au 200 g/t. In the southern area, ore above L 6 is oxidized. An oxidized ore zone extends to L 8 in the northern area of the mine.

We observed the working face of L 8 - north. A fluorite vein with quartz stringers is N50°E, 60E and 1.1 m wide. It contains manganese.

There were 3 bonanzas observed. The length in strike side of each bonanza is about 80 m. Concerning the extension in dip side, they are observed as follows:

South: Surface to L6 (-127 m). It disperses under L6.

Center: Surface to L9 (-200 m). It could extend deeper than L9.

North: Surface to L7 (-143 m). Driving a prospecting drift, below the bonanza, they did not discover the lower extension. On the other hand, the other bonanza (Au 5.4 g/t, Ag 346 g/t, 2.1 m wide) was discovered by a prospecting drift on L8, which is 24 m below L7. It could extend downward.

2) Stability and continuity: Both vein width and ore grades vary extremely.

3) Ore and gangue minerals: Galena, sphalerite, fluorite, barite and quartz.

4) Country rock: Andesite in the upper region, and conglomerate in the lower part.

5) Developing status: Developed for 68 m in strike side by 200 m in dip side. The deepest level is L9. The mining blocks around the shaft have already been mined from surface to L9. These mined-out blocks show that there were big bonanzas in the mine. For example, there is a mined-out cavity sized at L50 m x H20 m x W5 m above L6, at the south side of the shaft. High grade ore, grading Au 6 g/t and Ag 500 g/t was produced from the cavity. On L7, 8 and 9 prospecting drifts were driven southward. However, they did not discover any mineral which could be mined at current silver price.

6) Ore reserves:

Proven	19,195 t
Probable	12,375
Possible	64,966
Total	96,536

Ore grades: Au 2.5 g/t, Ag 260 g/t

7) Exploration: Prospecting drifts are being driven northward on L7, 8 and 9.

a) The drift on L9 is to prospect the lower extension of the vein which is currently mined on L8.

b) We surveyed a few cross cut, some of which hit parallel veins to the existing (main) drift.

c) We are of opinion that they should prospect southward for a bonanza, driving a drift from L8. In addition, it should be considered to explore a deeper zone below L9.

(3) Production

1) Production: The northern part of the vein below L8 is the sole minable block in the mine at present. In the mining block 3 stoping faces are being driven. Production is 180 - 240 t/week or 800 t/month grading at Ag 250 g/t, Au 1.5 g/5. Cut off grade: Ag 200 g/t, Au 1 g/t.

a) Shaft sinking is being made for the development of the deeper zones.

b) Waste rock, coming from exploration and development work is back-filled to the mined-out cavities.

2) Working shift and personnel:

Mine manager	1
Shift bosses	3
Drilling	5
Drilling assist.	5
Mucking	2
Mucking assist.	2
Mine tubs	8 - 10
Shaft lifting	2
Compressor	1
Cap Lamps (maintenance)	1
Truck driver	1
Mine office (administration)	4
Total	35 - 37

a) The owner of the mine operates this mine and others as well in the State of Durango. His representative is stationed in the City of Torreon where a smelter is located.

b) On Monday, workers tend to be absent. The rate of absenteeism reaches 30% on Monday.

c) Similar to the other smaller to middle mines in Mexico, workers easily switched jobs. Every 2 years, employees are rotated with each others.

3) Mining Method: Underhand open stoping with platform (Rebajes Abiertos con Tranqueo in Spanish).

a) Excavating a man way, they utilize the other inclined drift as a funnelled chute. Therefore, it is a kind of underground glory hole method.

b) In case of a level excavation, a mine car loader (rocking action type: Eimco 12B) is used for mucking.

c) According to the mine manager, a 2 m x 2 m drift is driven by 1 m a shift.

4) Transportation: A funnelled chute to a mine tub on L8 (or 9), and the skip lifted by an electric hoist to L6 and then transported by mine tubs to a portal.

a) On L6, there are two portals.

5) Ventilation: Natural ventilation

6) Drainage: 8 l/sec of mine water is pumped up.

7) Cost:

Mining (incl. exploration)	$70,000/t
Ore transportation (mine site to beneficiation plant)	4,500
Transfer in the stockyard of the plant	4,000
Beneficiation	30,000
Conc. Transportation (Plant to smelter)	4,000
Smelting and refining	10,000
Miscellaneous	N/A
Total	120,000

a) Mining cost shown above is broken down as follows:

Exploration: 30%
Mining preparation: 20%
Mining 50%
Or, personnel: 40% and materials: 60%

b) It is said that most of workers in other local industry earn the legal minimum wage of $11,600/day or $81,000/week in Guanacevi (The minimum wages vary by a district. The minimum

wage in Parral is 4% higher than that of Guanacevi.) On the other hand, a drilling man of San Jose Chico earns $150,000/ week including a bonus.

(4) Comment

a) This mine is one of the most mechanized mines in Guanacevi. Further, the management invests in exploration work. However, we cannot deny that the peak prosperity of this mine has passed.

3.3.2.2 Barradon Mine (Fig. 3.3.8. a,b)

Owner: Minas de Barradon, S.A. de C.V.

Date of survey: August 8, 1989

(1) Location

Two kilometers west from the Guanacevi Plant

(2) Vein and Ore Reserves

1) Scale: There were 2 veins recognized. One is Barradon Vein which is N-S, 65°E and 0.6 m wide. It does not produce any ore due to the low grades at present, a prospecting drift was driven along the vein. According to the owner, 1 kg/t Ag was recorded little southward of the drift heading. Along this vein another prospecting drift was excavated upward. The ore samples collected at the working face was 70 g/t Ag. In order to stope the remaining ore left at the upper part of the vein, a developing drift was also excavated north. Another vein is La Chiripa, grades of which are Ag 7 oz/t and Au 1 g/t (the owner's evaluation). It is N50°W, 65°NE and 0.5 m wide.

2) Stability and continuity: Judging from the mined-out cavities, vein width and ore grades are very stable. However, the grades of the remaining ore is unstable.

3) Ore minerals and gangue minerals: Galena, sphalerite and quartz.

4) Country rock: Andesite.

5) Developing status: Assuming from the cavities, the bonanza mined was 260 m in strike side x 219 m+ in dip side x 1-1.5 m wide.

Further, it seems that there was a large bonanza cavity at the crossing point of the Barradon and La Chiripa veins where a 150 m in strike x 70 m in dip cavity was observed. There was also a 15 m in strike x 40 m in dip bonanza at the point where a crosscut on L10 ran across the vein.

6) Ore reserves:

Proven	80,198 t
Probable	17,250
Possible	8,000
Total	105,448

Ore grades: Au 1.55 g/t, Ag 182 g/t

7) Exploration: It is proposed that prospecting the remaining ore of La Chiripa is feasible. There would be no room to be explore other than at that point.

(3) Production

1) Production: Eighty t/week, Ag 250 - 300 g/t (cut off Ag 200 g/t, Au 1 g/ton).

a) At present, old waste filled-in cavities during early 19th century to early 20th century is processed.

b) The upper part of the vein and La Chiripa vein below the adit are the next target. However, it is thought that it would not be economical at current silver prices.

3) Transportation: Hand mucking on a skip bucket which is lifted by an engine hoist. Lifted up to the adit level, ore is then transported by mine tubs.

a) Funnelled chutes resulting from old mining activity are utilized to guide ore to mine tubs.

b) Expecting higher silver price, some machinery has been prepared.

4) Ventilation: Natural ventilation

5) Drainage: 16 l/sec x 10 hours/day of mine water is pumped up.

6) Cost

Mining:	$22,693/t
Beneficiation	30,000
Smelting & refining	8,199
Total	60,892

a) Average wage of miners: $80,000 - 90,000/week. It is about 50% higher than those of local jobs.

b) In Guanacevi, due to its isolated location, prices are 20 - 30% higher than those of major cities.

3.3.2.3 Capuzaya Mine (Fig. 3.3.9)

Owner: Sr. Juan Chavez

Date of survey: August 9, 1989

(1) Location

Two kilometers west from Guanacevi Plant

(2) Vein and Ore Reserves

1) Scale: There are 2 veins recognized. One is N20°W, 65°E, 0.1 m wide and Ag 500 - 2,000 g/t. It is composed of a mass of quartz stringers, and a little pyrite is contained (this is the extension of the vein from Barradon Mine). Another vein is N40°W, 80°W, 1.75 m wide and Ag 300 g/t.

2) Stability and continuity: Both vein width and ore grades are stable.

3) Ore and gangue minerals: Sphalerite, galena, chalcopyrite, calcite, fluorite, barite and quartz.

4) Country rock: Andesite, Strongly silicificated.

5) Developing status: Developed for 550 m in strike by 150 m dip. Two stoping faces are driven on the 40 m level below surface. There is a 130 m shaft which connect underground work with the surface. Most cavities are the results of mining activities in the 19th century. Much sampling has been done so far, and assay results are up to 100 g/ton of silver.

6) Ore reserves:

Proven:	59,265 t
Probable:	66,310
Possible:	59,840
Total	185,415

Ore grades: Au 0.48 g/t, Ag 205 g/t.

7) Exploration: There were 2 veins discovered by 5 core drillings 150 m below the transportation level (160 m deep from surface). The repair of the shaft excavated during the 19 century has been suspended at 10 m depth due to a flood of mine water.

(3) Production

1) Production: 50 - 60 t/week, Ag 300 g/t
Extracting ore left after old mining activities.
2) Working shift and personnel: One shift/day, 8 employees.
3) Mining method: Underhand open stoping with platform (Rebajes Abiertos con Tranqueo).
4) Transportation: Hand mucking to mine tubs on the transportation level (adit) to surface.
5) Ventilation: Natural ventilation.
6) Drainage:
7) Cost:

Mining:	$27,249/t(Incl. transportation to the beneficiation plant: $3,500)
Beneficiation:	30,000
Smelting $ Refining	6,395 (Incl. transportation to the smelter: $2,302)
Total	63,644

(4) Comments: It seems that minable ore has already been extracted early in the 20th century.

3.3.2.4 San Rafael Mine (Fig. 3.3.10)

Owner: Sr. Francisco Alanis Quinonez

Date of survey: August 9, 1989

(1) Location

Five kilometers west from Guanacevi Plant.

(2) Vein and Ore Reserves

1) Scale: The vein is N10°W, 65°E and 0.7 m wide. Levels are driven every 25 m intervals. There is a bonanza in the vein. The deeper it goes, the greater it grows. The bonanza is 85 m long on L4 (85 m deep from surface), and 135 m long on L8 (135 m deep from surface).

2) Stability and continuity: Both vein width and ore grades are stable.

3) Ore minerals and gangue minerals: Galena, sphalerite, manganese, quartz, and fluorite.

4) Country rock: Andesite chloritizated.

5) Developing status: Developed for 240 m in strike side by 110 m + (under L4) long in dip side.

6) Ore reserves:

Proven	31,365 t
Probable	46,920
Possible	71,350
Total	149,635

Ore grades: Au: 4.1 g/t, Ag: 396 g/t

Minable zone proven is limited to L130 m x H25 m x W2 m, because of the following:

a) The claim limit lies 10 m north of the shaft equipped with a skip. Further, on L9-north, ore grade drops to Ag 100 g/t from Ag 600 g/t at the limit line.

b) The upper part above L8 has already been extracted.

c) Ore grade declines to only Ag 80 g/t at 130 m south of the shaft. On the other hand, ore grades are extremely high. At the excavation of L9-south, maximum grade, Ag 6 kg/t plus Au 60 g/t were recorded (40 t of the high grades were shipped to a smelter directly). Normal grades are Ag 800 g/t and Au 9 g/t (vein width is 2.1 m). In addition, the vein extends downward.

(3) Production

1) Production: When the survey team visited, preparation to extract ore between the L8 and L9 was being made. Proposed throughput is 1,200 t/month. The shaft sinking is carried out in order to mine the lower part of the vein under L9. It is hard work because of a flood of mine water.

2) Working shift and personnel: Total 30 employees (incl. underground workers: 8 men/shift x 2 shift/day = 16 men).

3) Mining method: Shrinkage.

4) Transportation: Mucking on a mine tub by a mine car loader (rocking action type: Eimco 600B), and then the skip (capacity 650 kg). Facilities for a larger shaft hoist were being built. When we visited, a new hoist house was being erected.

5) Ventilation: Natural ventilation.

6) Drainage: Mine water: 300 m3/day.

7) Cost:

Mining (up to a stock yard on surface):	30,000/t
Transportation (the mine site to the plant)	9,000
Beneficiation	30,000
a) Shaft sinking (size: 2 x 4 m) (excl. renewal of machinery)	2,000,000

b) Average wage of drilling men: $150,000/week (6 days/week).

(4) Comments

a) Among smaller to middle mines in Guanacevi, this mine is one of the most mechanized. Because ore grades are extremely high, it is possible to develop deep underground, overcoming a flood of water. However, we cannot deny that the peak of prosperity of this mine has passed.

b) We would like to suggest ore blending when they hit excellent grade ore. It would extend the mine life.

3.3.2.5 Ample Al Alto Nuevo Porvenir Mine (Fig. 3.3.11)

Owner: Sr. Rafael Martinez Herrera

Date of survey: August 10, 1989

(1) Location

Ten kilometers west from Guanacevi Plant.

(2) Deposit and Ore Reserves

1) Scale: Vertical dip veins (N-S strike) and manto type ore deposits were observed. The width of the vein is extremely varied. When surveyed, W 1~ 1.5 m x L55 m vein and many mantos of which average size of 5 m x 3 m x 4 m were observed. Only the manto type deposits are currently producing.

2) Stability and continuity: The manto type deposits are distributed irregularly.

3) Ore and gangue minerals: Galena, sphalerite, manganese, quartz and calcite.

4) Country rock: The veins are deposited in andesite. The manto types are deposited in tuff breccia.

5) Developing status: Developed for 90 m on plan by 84 m deep from surface.

6) Ore reserves:

Proven	9,267 t
Probable	14,262
Possible	13,578
Total	37,107

Ore grades: Au: 0.63 g/t, Ag: 586 g/t.

7) Exploration: On L5, a prospecting drift is being excavated, from which a block between L3 and L4 shall be mined. It is essential for this mine to control the balance between production and new discoveries of minerals.

(3) Production

1) Production: Fifty t/day (The production varies, depending on the condition of the stopes). 300 t/week, sulfide ore only.

2) Working shift and personnel: 5 shift/day, 2.5 - 3.0 hours/shift, 18 employees:

3) Mining method: Gophering on each level (level interval: 10 m).

4) Transportation: Mucking on mono wheel cart with manual labor to a skip lifted by an engine hoist on surface.

5) Ventilation: Natural ventilation.

6) Drainage: In cooperation with another mine, Nuevo Provenir maintains a well, equipped with a pump. Pumping up 60 l/sec of water, it lowers the underground water table effectively.

7) Cost:

Below are total costs combined with those of the Soto Mine also owned by the owner of Nuevo Provenir.

Labor	$3,500,000/week
Explosives	1,200,000
Fuel	250,000
Travel	300,000
Drainage	800,000
Miscellaneous Materials	300,000
Total mining cost	6,350,000

Estimation of unit mining cost: $6,350,000/week 300 t/week = $21,000/t

a) The owner has never calculated exact expenses. The above is just an estimation based on his figures. An actual cost would probably be higher than the above.

(4) Comment

a) Although each bonanza is comparably large, its pattern is extremely irregular. Very primitive mining methods, therefore, are applied in the mine. To catch up with mechanized mining methods in efficiency, a multi-shift system (5 shifts/day) and a comparably larger stoping faces need to be applied. The potential of this mine (i.e. high ore grades and large bonanzas) makes it possible. Unfilled cavities after stoping seem dangerous and could affect future mining.

3.3.2.6 Noche Buena Mine (Fig. 3.3.12)

Owner: Minera Noroeste De Durango, S.A.
Date of survey: August 10, 1989

(1) Location

Seven kilometers west from Guanacevi Plant.

(2) Vein and Ore reserves

1) Scale: Because the mine is undergoing repair work, none of the stoping face and the vein was observed by our survey team. According to the owner of the mine, width of the veins are 0.4 m to 2.5 m and ore grade is Ag 200 - 300 g/t. Strike and dip are N80°E and 70°N respectively. Oxidized zone extends to 15 m deep.

a) The upper part of the vein above L1 (52 m deep from surface) has already been mined.

b) Concerning extension of vein system, another vein has been discovered 80 m south of the end of L1.

c) Possibilities to the north are limited by the claim limit.

2) Stability and continuity: Both vein width and ore grades are unstable.

3) Ore and gangue minerals: Galena, sphalerite, quartz.

4) Country rocks: Monzonite and sedimentary rocks.

5) Developing status: Developed for 80 m in strike side by 115 m in dip side.

6) Ore reserves:

Proven	15,500 t
Probable	18,000
Possible	32,000
Total	65,500

Ore grades: Au: 0.29 g/t, Ag: 270 g/t.

7) Exploration: A bonanza of 60 m x 80 m+, strike and dip side respectively can be expected to extend downward.

(3) Production

1) Production: No production since an explosive accident in 1988. It was proposed to reopen the mine a half month later at 100 - 140 t/day. A zone between L1 and L2 (L2 is 103 m deep from surface) is to be mined.

2) Working shift and personnel: One shift/day. The repair work is being conducted by 14 workers.

3) Mining method: Shrinkage.

4) Transportation: Funnelled chutes to mine tubs, and then a skip.

5) Ventilation: Natural ventilation.

6) Drainage:

7) Cost:

Mining	$25,000/t
(Incl. Transportation to the beneficiation plant: $8,000)	
Beneficiation	30,000
Smelting & refining	8,199
(Incl. transportation to the smelters: $2.950)	

a) Result of the previous operation before the accident in 1988.

b) Average wage of the miners: $12,000/day. In case of drilling, men's wages are higher: $120,000/week.

(4) Comment

a) It should be rather hard to operate this mine at current silver prices.

3.3.3 Barones Area

3.3.3.1 San Roberto Mine (Fig. 3.3.13.a,b)

Owner: Sr. Jesus Guzman

Date of survey: August 23, 1989

(1) Location

Four kilometers northwest from Barones Plant.

(2) Vein and Ore reserves

1) Scale: There are 2 veins named Bajo and Alto. The former is the principal vein. Alto Vein is N60°W, 60°N and 3 m wide. Bajo is N65°W, 72°N and 15 m wide. As far as it is known, Bajo extends to 450 m in strike by 450 m in dip side within the claim area of 56 ha. Alto Vein is idle now because of low grades.

2) Stability and Continuity: Although the ore grades are not very high, each vein is wide and continuous in its width and grades. Some veins are over 15 m wide by 70 m long in strike side.

3) Ore and gangue minerals: Galena, sphalerite, chalcopyrite, quartz.

4) Country rock: Andesite.

5) Developing status: Developed for 500 m in strike by 150 m in dip.

6) Ore reserves

	Tons	Au g/t	Ag g/t	Pb %	Cu %	Zn %
Proven	2,276,304	0.5	109	1.60	1.80	3.00
Probable	1,494,287	0.5	106	0.87	1.75	2.90
Possible	1,877,167	0.5	110	0.16	2.08	2.65
Total	5,647,758	0.5	109	0.93	1.88	2.86

The ore reserves mentioned above are the mine's original calculation rather than the conservative one based on the CFM method.

7) Exploration: In 1981, a company which had intended to take over the mine made 5 core drillings which reached a total of 1,500 m to prospect an extension of the present outcrop. As a result, 3 new veins were discovered, and ore reserves of the mine grew extremely large. Although present mining is limited to the 160 m depth,

development of the new discoveries existing up to 359 m depth are now in progress.

(3) Production

1) Production: 1,500 t/month, grading Au 0.5 g/t, Ag 90 g/ton, Pb 1.2%, Cu 1.2%, Zn 3.6%. All sulfide ore.
Construction of a beneficiation plant is proposed. See the report of the San Bernabe for details.

2) Working shift and personnel: Six days/week, 1 shift/day, 18 employees.
   a) San Roberto is operated as a subordinate mine of San Bernabe owned by the same person. Technical, mechanical, and administrative staff who are stationed at the San Bernabe Mine are excluded in the above numbers.
   b) According to the owner, rate of absenteeism of the workers is quite low. Further, most workers have served for a long continuous period.

3) Mining method:
   a) (On L8 at present): Shrinkage.
   b) (Proposed method applied to the deeper zone): Mechanized cut & fill applied with hydraulic transportation of concentrate tailings.
   c) For stoping preparation and or exploration, 3 drifts are being driven at present. The 4.5 m x 5 m drift is one of those being excavated by a trackless mining method with 10 ton trucks and a 3 cu.yd tire loader. Further, it is extremely important that the drift applied with the trackless system is cut into the foot wall but not in the vein.
   d) At a conventional (non-trackless) working face, a pneumatic loader is introduced.
   e) A drift heading is advanced 1.5 m per round.

4) Transportation:
   a) Trackless stope: At a draw point, mucking by a tire loader to a 10 ton truck to the surface.
   b) Non-trackless stope: From a funnelled chute to mine tubs with manual labor, then a skip lifted in the shaft (equipped with

the skip). Ore from trackless stopes shall be lifted in the shaft, too.

5) Ventilation: Natural ventilation only at present. It was pointed out by the engineer of the mine that mechanical ventilation is needed for the trackless system.

6) Drainage: Two hundred fifty m^3/day of mine water is pumped out.

7) Cost

See the report of San Bernabe. San Bernabe is managed together with this mine.

(4) Comment

See the report of San Bernabe.

3.3.3.2 San Bernabe y Pupa Mine (Fig. 3.3.14.a,b)

Owner: Sr. Jesus Guzman

Date of survey: August 24, 1989.

(1) Location

Two point five kilometers northeast from Barones Plant.

(2) Vein and Ore reserves

1) Scale: San Bernabe and Pupa veins were recognized. San Bernabe is N70°W, 50° - 60°N and 0.2 - 2.5 m wide. There are 4 bonanzas in the vein, and drifts are driven along them as follows: (strike x dip, respectively)

West: 115 m x 115 m, Center: 50 m x 50 m,

East: 20 m x 10 m, East-center: 60 m x 60 m,

Pupa is N70°W, 70°N and 1.7 - 3.3 m wide. There are 2 bonanzas in the vein, as follows:

West: 20 m x 10 m, East: 10 m x 10 m.

Oxidized zone extends to 40 m depth from surface.

2) Stability and continuity: Both vein width and ore grades are very stable.

3) Ore and gangue minerals: Galena, sphalerite, chalcopyrite and quartz.

4) Country rock: Andesite.

5) Developing status: Throughout the mine, there are lots of cavities, from which oxidized minerals were extracted previously. San Bernabe Vein has been developed for 410 m in strike by 156 m in dip. Pupa Vein has been developed for 300 m in strike by 130 m in dip. Currently, Pupa is being developed and extracted, driving on a ramp with trackless method. The ramp runs parallel to a foot wall of the vein, and cross-cuts are excavated at 20 m intervals for access to the vein.

6) Ore reserves

Pupa Vein	t	Au g/t	Ag g/t	Pb %	Zn %
Proven	260,517	0.54	155	0.52	0.41
Probable	277,316	0.57	160	1.24	1.36
Possible	426,808	0.77	192	1.65	1.97
Total	967,641	0.65	173	1.23	1.38
San Bernabe Vein					
Proven	111,094	0.60	164	1.15	1.53
Probable	165,000	0.00	167	1.00	1.70
Possible	64,549	0.55	137	0.80	1.15
Total	340,643	0.30	160	1.01	1.54

a) The ore reserves mentioned above are the mine's original calculation rather than the conservative one based on the CFM method.

b) This calculation of ore reserves seems rather optimistic. On the other hand, the estimation of ore grades seems conservative.

c) *Sulfide ore deposited deeper than 40 m from surface have been* left right there.

d) Exploration: We can safely say that there are lots of reserves proven and a potential for an exploration in the claim area of a total 222 ha (San Roberto: 56 ha, San Bernabe: 29 ha and the other: 137 ha)

(3) Production

1) Production:

a) Open pit: 1,000 t/month, Au 1 g/t, Ag 250 g/t (oxide).

b) Underground: 2,000 t/month, Au 0.8 g/t, Ag 200 g/t, Pb 0.4%, Zn 0.3%.

c) Construction of an in-house beneficiation plant is proposed. The cost including working capital for 3 months, 3.5 billion pesos would be financed by CFM. The plant capacity of 200 t a month should be completed at the end of this year if CFM accepts financing the plan.

d) According to the plan, the results of beneficiation will be more favorable. A subsidiary of Penoles was appointed for conduction of and supervision of the plant construction.

2) Working shift and personnel: One shift/day, 62 employees.

a) The number of the employees includes technical, mechanical, and administration staff and truck drivers who serve both San Bernabe and San Roberto.

b) A mining engineer was hired 6 months before our survey. It seems that his 15 year's experience at a major mining company, IMMSA contributed to the modernization of the San Roberto and San Bernabe.

3) Mining method: Shrinkage.

It differs from the other mines surveyed in that a man-way raise is excavated separately from the stope. With the independent man-way, it is possible to stope ore safely and efficiently.

4) Transportation: Trackless system is the same as that of San Roberto applied to a portion of the mining blocks.

5) Ventilation: Natural ventilation

Forced ventilation by a fan shall be needed when the stopes with the trackless system become deeper.

6) Drainage:

7) Cost:

Mining	$18,500/t
Beneficiation	16,500

This mining cost is broken down as follows:

a) Personnel: 22%, Materials: 22 - 23%, The other cost including depreciation of the equipment: 55 - 60%.

b) A 4.5 m x 4 m drift excavation: $1.1 million/m (excluded in the mining cost).

c) Slurry explosive: $26,000/25 kg carton.

d) Seven foot long insert rod: $33,000/rod.

e) The weekly wages of the workers: $220,000 - 500,000/man excluding benefits.

(4) Comments

a) The mines of San Roberto and San Bernabe are the most modern and mechanized mines among the mines surveyed.

b) Generally speaking, too much mechanization tends to push up mining cost. In this particular, case of San Roberto and San Bernabe, the rate of mechanization seems to be well balanced with the manual labor costs of Mexico.

3.3.3.3 Las Cumbres Mine (Fig. 3.3.15)

Owner: Sr. Jesus Marrillo martinez

Date of survey: August 25, 1989.

(1) Location

Six kilometers north from Barones Plant.

(2) Vein and Ore reserves

1) Scale: There are the veins of Alto and Bajo, and they run parallel to one another, with NW-SE strike and 60° - 70°N dip. Both of them are eastern extensions of the San Bernabe vein system. Bajo Vein is being worked and is 1.5 - 2.5 m wide. The assay results at L150 m (now stoping) are Au 0.45 g/t, Ag 185 g/t, Pb 1.0% and Zn 1.84%. Its width is 1.2 m. A shallow zone above the 45 m depth is oxidized.

2) Stability and continuity: Both vein width and ore grades are stable.

a) Concerning extension in strike side, Bajo is 250 m, and Alto is 300 m. These have been proven by drifts along the vein.

b) There is "ready to stope" ore between L125 m and L150 m. In addition, it also extends to dip side downward below L150 m.

3) Ore and gangue minerals: Sphalerite, galena and quartz.

4) Country rock: Andesite.

5) Developing status: Developed for 170 m in strike by 65 m in dip. Each vein forms a bonanza.

6) Ore reserves:

Proven	7,567 t
Probable	5,730
Possible	6,720
Total	20,017

Ore grades: Au: 0.45 g/t, Ag 185 g/t, Pb 1.00%, Zn 1.84%

a) The above ore reserves were calculated in 1988 by the CFM method. This proven reserve is a result of a discount that is multiplied by 2/3.

b) Sulfide zone above L125 m (from surface) has been mined-out.

c) There is some minable oxide ore, but not included in the above ore reserves.

d) Both veins extend further than the claim limit westward.

e) Concerning the extension eastward, the San Bernabe vein is cut by a fault at the 150 m point to the limit line of the claims, where the drift ends. There is a possibility one could find the vein's extension, by driving a few meters of cross-cut.

f) Leaving 100 m to the limit, an excavation of a prospecting drift has been suspended because of a decrease of vein width, down to 0.6 m. An estimated extension is to be prospected.

(3) Production:

1) Production: Twenty five t/day, Au 1.5 g/t, Ag 200 g/t, Pb 1.5%, Zn 2.5%

2) Working shift and personnel: 6 days/week, 2 shifts/day, 15 - 16 employees.

3) Mining method: Shrinkage.

a) Transportation levels are driven along the vein similarly to the other mines (except San Roberto and San Bernabe).

b) Funnelled chutes are installed at the transportation levels every 8 m intervals.

c) The levels and the shaft were not excavated by the present owner, but are results from ancient mining activities. Accordingly, the owner has lots of "ready to stope" ores just by pumping up mine water alone.

4) Transportation:

a) From a funnelled chute to skip buckets (500 kg capacity) on carriages, and then lifted by an engine hoist on surface.

b) No ladder is installed in the shaft. Miners go in and out underground via the skip.

5) Drainage: With 2B pipe line, mine water is pumped up for 2 to 3 hours every 4th day. It seems that the deep part of the shaft under the present working level functions as a buffer tank.

6) Ventilation: Natural ventilation.

a) Because there are some ancient shafts, sufficient fresh air flows underground.

7) Cost:

a)	Mining	$35,191/t (including ore transportation).
b)	Beneficiation	16,500
c)	Net smelter return	77,591
d)	Profit (c-a-b):	25,900

A. The above is an estimation by the Zacatecas branch of CFM, which is studying if an application for a loan requested by the mine owner should be accepted.

B. The salary and wages to employees (per person)

Mine manager:	$1,500,000/month
Drilling man:	$ 14,000/day
Drilling assistant:	$ 11,000/day
Shaft winding operator:	$ 14,000/day
Mucking man:	11,000/day

(4) Comments

a) Contrary to this limited claim area, there is a lot of ore reserves and potential for new discoveries for the minor mine. We are

of opinion that the owner should venture into further exploration since he can further profit with nominal development cost.

3.3.3.4 Calicanto Mine (Fig. 3.3.16.a,b)

Owner: Sr. Hector Mayorga Sanchez

Date of survey: August 28, 1989

(1) Location

One half kilometer east from the Barones Plant.

(2) Vein and Ore reserves

1) Scale: Four principal veins were recognized. Calicanto consists of two parallel veins -- Alto and Bajo. These 2 veins were the same vein originally, but separated into 2 veins by a fault. Both veins have the same strike, N70°W, but were dipped to the reverse side of each other, 60°N and S. Only the Bajo Vein is being processed. Its vein width is 0.4 - 2.0 m. The following 2 bonanzas were recognized:

West: 60 m in strike by 130 m in dip.

East: 40 m in strike by 30 m in dip.

Alto Vein is 1.0 m wide.

The other two are Nevada (N70°W, 45°S) and Vicochea (N50°E, 50°NE) Veins. The area of claims totals 94.6 ha. Oxidized zone extends to 80 m depth from the surface.

2) Stability and continuity: Both vein width and ore grades vary point to point. Although vein width and ore grades reach 7 m wide, Au 60 g/t and Ag 27 kg/t are a part of a bonanza, normal ones are 1.5 - 2 m and Ag 200 - 300 g/t.

3) Ore and gangue minerals: Galena, sphalerite, pyrite, quartz and calcite.

4) Country rock: Andesite.

5) Developing status: Calicanto Veins are developed for 270 m in strike by 130 m in dip.

6) Ore reserves:

Sulfide ore

Vein	Proven	Probable	Possible	Total
Calicanto	14,626	36,873	37,350	88,851
Vicochea	8,750	9,420	13,650	31,820
Nevada	4,530	9,825	19,875	34,230
Total	27,906	56,126	70,875	154,901

	Ore grade	Beneficiation Recovery
Au	1.31 g/t	41%
Ag	148 g/t	57.8%
Pb	0.86%	49.1%

Oxide Ore Proven reserves: 750 thousand ton.

	Ore grade	Beneficiation Recovery
Au	1.06 g/t	52.16%
Ag	181 g/t	56.49%

a) The above ore reserves were calculated by CFM in February, 1988.

b) At current metal prices, minable reserves are much less than above. The production in 1988 is, namely, Au 1.4 g/t, Ag 200 g/t and Pb and Zn 1% each.

c) There are lots of cavities resulting from old mining activities throughout the mine. Some cavities were filled with the waste rock of those days. Those tailings could be ore with present metallurgical technology.

7) Exploration: The mine has lots of reserves. We feel confident about ore reserves.

(3) Production

1) Production

a) Sulfide ore mined at L130 m (from surface): 500 - 700 t/month, Au 1 - 2 g/t, Ag 240 - 250 g/t.

b) Back filled (as waste rock) sulfide ore from old times around L60 m (proposed): 200 - 300 t/month, Ag 200 g/t.

c) Oxide ore extracted from Bajo open pit: 400 t/month, Au 1.2 g/t, Ag 280 g/t.

- All of the above are produced in the Calicanto Vein, the ore grades of which are higher than others.
- Monthly output varies month by month because of the limitation of the plant's capacity.

2) Working shift and personnel: Two shifts/day, 6 days/week, Forty five employees, including 24 underground miners.

3) Mining method:

a) Underground: Shrinkage stoping is applied, according to the owner. However, it seems that the stoping method is not always kept.

b) Surface Mining: A kind of gophering. Trenching the full width of a vein.

4) Transportation:

a) Underground: Hand mucking to a mono-wheel cart, and skip (500 kg) lifted by an electric hoist.

b) Surface Mining: A 10 ton truck and 3 cu.yd tire loader. Mine tubs and a pneumatic loader will be introduced in the underground, soon.

5) Drainage: Pumped up through 2B pipe line. Mine water of this mine is utilized for beneficiation at the Barones plant.

6) Ventilation: Natural ventilation. Because old cavities and tunnels excavated in past times function as air ways, sufficient fresh air flows thorough the underground workings.

7) Cost:

Mining:	$35,974/t
Beneficiation:	20,375
Conc. transportation	3,564
Cost total	59,913
Net smelter return:	71,650/ton
Total cost	59,913
Profit:	11,737

a) Estimated by Zacatecas branch of CFM.

(4) Comments

a) Ore reserves in this mine would greatly increase if the results of the beneficiation were improved. It is most important to prospect for a big bonanza all the time.

b) It seems to be rather difficult to apply shrinkage stoping to this mine, due to the discontinuity of the veins.

3.3.3.5 California Mine (Fig. 3.3.17. a,b)

Owner: Veta Linda Cia. Minera, S.A.

Date of survey: August 29, 1989

(1) Location

Seven kilometers southeast from Barones Plant.

(2) Vein and Ore reserves

1) Scale: Two principle veins, La Fe and Cantera were recognized. La Fe was deposited into a fault which dislocated Cantera. Each vein is 12 - 13 m wide on surface and extended to both strike and dip sides. However, those two veins are currently idle. At present, debris of the La Fe is being extracted. Distribution of the debris which is irregular in size and not sorted is about L1,000 m x W150 m x D60 m.

2) Stability and continuity: The veins extend in strike and dip sides, keeping a continuous width. Concerning the extension to the dip side, it is proven by a cavity resulting from old mining activities, up to 100 m depth. It is inferred that the debris originated from erosional processes in geological age, and that its ore grades do not vary widely.

3) Ore and gangue minerals: Galena, sphalerite, pyrite, and quartz.

4) Country rock: Monzonite and sedimentary rocks.

5) Developing status: Developed for 100 m each in strike and dip sides.

6) Ore reserves: The debris is estimated to reach about 1 million tons graded Au 0.58 g/t and Ag 300 g/t.

7) Exploration: Because the mine has sufficient reserves to be mined by surface mining method, it is not necessary to prospect additional reserves.

(3) Production

1) Production: Three thousand t/month extracted in a open pit.

a) The open operation was started 3 years ago.

b) Construction of an in-house heap leaching plant is proposed. The site for the proposed plant would be located near the village of Minillas (25 km by road from California Mine), where about 350,000 t of "Terrero" (ore dumped as waste rock in old times) are piled up. According to plan, the plant will process 100 t/day each of California's ore and the Terrero (Ag 120 - 130 g/t).

2) Working shift and personnel: Two shift/day, 40 employees.

3) Mining method:

a) Open pit mining: Including spares, 10 ten ton trucks, 3 tire loaders and 1 dozer shovel are used.

- When the survey team visited, a pit had been extended to L100 m x W50 m D20 m approximately. The pit had been excavated without any bench. In fact, there are some cracks on the vertical to over-hanging pit wall.
- Surface mining will be continued to 40 m depth, and then the deeper portion is to be stoped by underground mining with an inclined drift. Nothing available on the pit design until then.

b) To both sides of the strike, drift are being excavated into the vein on the level of the bottom of the pit.

c) As mentioned before, there are old cavities, the portal of which is at the cross of the 2 veins. Some minerals were extracted by gophering.

4) Transportation: Trucks loading in the open pit leave for the beneficiation plant directly.

5) Drainage: Nil.

6) Cost:

The following is a result of an estimation to evaluate the heap leach plant proposed.

Mining:	$16,029/t	
Beneficiation	16,500	(Incl. transportation cost: $8,000)

(4) Comment

a) There are large ore reserves which could be mined with a minimum of cost.

3.3.3.6 Amplicacion San Miguel (Fig. 3.3.3.18)

Owner: Ceferino Parga Castillo

Date of survey: August 30, 1989

(1) Location

Nine kilometers north of Barones Plant.

(2) Vein and Ore reserves

1) Scale: There are 2 nameless veins recognized in the mining claims of 1.99 ha. They are parallel to each other and have strike of N60°W and 65°N dip. However, one of them is not minable because it is distributed in the claims for only a few meters. The others are covered by the claims for about 140 m. A part of the foot wall is disseminated of silver, containing about Ag 400 g/t. At L40 m (from the surface), the working face was distinguished between high grade vein of 0.8 m wide and a disseminated zone of 1.2 m. They say the former is Ag 400 g/t and the latter is Ag 150 g/t.

2) Stability and continuity: Judging from cavities of extracted minerals, the vein was 0.6 - 2.5 m wide. Although the vein width varied, ore grades are high.

3) Ore and gangue minerals: Galena, sphalerite, chalcopyrite, quartz,

4) Country rock: Sedimentary (slate).

5) Developing status: Most parts of the vein have already been mined since old times. Northwest end of L55 m has been filled with waste rocks resulting from old mining activities.

6) Ore reserves:

Proven	1,381 t
Probable	2,600
Possible	3,543
Total	7,524

Ore grade: Ag 303 g/t, Au 0.7 g/t.

a) The above reserves were calculated by CFM.

7) Exploration: The vein is very constant in width and could extend to dip side. However, we are afraid that it would have already been extracted in old times.

(3) Production

1) Three hundred t/month, 1 shift/day.

a) On surface, high grade ore is picked up by hand to be sent to a smelter directly. It is said that its grade is several kg of silver.

b) Further, pyrite rich ore is rejected in hand-picking. The ore may affect cyanization.

2) Working shift and personnel: One shift/day, 10 employees.

3) Mining method: Underground open stoping, contrary to the owner's "Shrinkage" pleading.

4) Transportation: Hand mucking to mono wheel carts. Ore is thrown into ore passes, transported on L55 m by mono wheel carts and then lifted by a skip (200 kg) powered by an engine hoist.

5) Drainage: Pumped up for 10 hours every 8th day.

6) Ventilation: Natural ventilation.

7) Cost:

Mining (incl. transportation to the plant)	$35,099/t
Beneficiation	16,500

a) Salaries and wages (per week):

Mine manager:	$100,000
Miner:	90,000
Assist. minor:	80,000

Shaft winding operator:	80,000
Mucking worker:	75,000
Truck driver:	100,000

3.4 Calculation of Mining Costs

(1) Method of Calculating Mining Costs

Mining costs constitute basic data for present conditions for each mine from the viewpoint of profitability and for determining its future production capacity. In the preceding section, we described the outline of each mine surveyed and presented data which were obtained by listening to the staff of each CFM branch and the mine owners. However, there are several mines for which data could not be obtained in the field survey and whose own data is doubtful. In addition, an examination will be required on how mining costs will change if the present production capacity is increased or decreased.

In this report, we supplement or analyze and verify the data obtained in the field survey, for the above-mentioned purposes, by using the following implified formula, which is utilized in the feasibility study for mining development:

$$C = \alpha T^{\beta} W^{\gamma} \qquad (1)$$

(where, C: Costs, T: Tonnage, W: Stoping width and α, β and γ: Constants)

When determining constants α, β and γ in formula (1), we have established the following formulae by adding the exchange rate and price fluctuation at the time of the survey and the actual conditions of the mine in the relevant district, to figures shown in the Mining and Mineral Processing Equipment Costs and Preliminary Capital Cost Estimation published by The Canadian Institute of Mining and Metallurgy (CIM).

$$N_1 = 2.66T^{0.7}W^{-0.5} \qquad (2)$$

$$C_1 = 36.950T^{-0.1}W^{-0.2} \qquad (3)$$

$$N_2 = 0.602T^{0.5} + 0.037T^{0.7} \qquad (4)$$

$$C_2 = 42.964T^{-0.5} + 4.055T^{-0.3} + 2.971T^{-0.2} \qquad (5)$$

(where, N: Number of necessary persons, C: Supply expenses (peso/t), T: Daily tonnage (t), Wo: Stoping width (m); Attached numbers 1 and 2 mean underground stoping and surface mining respectively.)

(2) Calculation and Analysis of Mining Costs

Results of the calculation are shown in Table 3.4.1.

1) La Revancha

In addition to the calculation of present costs, trial calculation has been carried out concerning the effects to be produced by the introduction of the shrinkage stoping and the expansion of average) stoping width and increase in tonnage.

2) La Presa

The planned tonnage is 1,000 to 1,500 t/month. Therefore, costs have been roughly calculated by way of trial, based on a daily tonnage of 50 tons under the assumed operation of 25 days/month and on the working-face stoping width of 1.5 m, full-width of the vein.

3) La Esperanza

In terms of the number of employees assigned here, it is estimated that the nominal tonnage will be narrowly attained with the stoping width of 2 m. At the place of narrow vein width, it would be impossible for the present number of employees to attain a tonnage of 20 t/day.

4) Tilita

The great number of employees assigned here compared with the tonnage is considered to be because of the necessity of prospecting digs due to an unstable vein.

Securing ore shoot becomes a necessity, and if a delay occurs in prospecting, the employees are left with only the tonnage and that subsequently increases cost considerably.

5) Unification Cordero

Although the standard drainage cost is included in the calculation formula, another special cost has been added to the drainage of the trial calculation. This mine has a great quantity of discharged water compared with its level of tonnage. Even at a production level of 15 t/day, this mine requires more than a dozen

workers, and is difficult to operate without sufficient funds because the mine incurs such a high fixed cost for drainage.

6) San Jose Chico

Since this mine has been comparatively mechanized with mine car-loaders and other machines, the number of mining employees used in the calculation would possibly be somewhat larger than its actual number. The total cost is considered to be a reasonable figure almost equivalent to that in the hearing survey.

7) Barradon

Since the vein width is as small as one meter, the operation is not feasible unless good earnings (high grade of ore) become available. Assuming that man days and costs required for blasting account for 25% of the total, we have calculated back to the mining costs from the present number of employees assigned and tonnage, concerning the case where the ore was stored underground (much in the past) is taken out of tunnels. Nevertheless, the costs still keep the level high at about 36,000 peso/t.

8) Capuzaya

The costs run as high as 50,000 peso/t calculated on a trial basis so that only high grade of ore can pay for its operation.

9) San Rafael

The result of trial calculations show the costs at about 45,000 peso/t. The actual costs are probably far higher than the 39,000 pesos/t obtained by the hearing survey because deeper-underground development is now in progress.

10) Ample Al Alto Porvenier

Conditions for trial calculations are difficult to establish because of the changes in conditions at working faces and irregular working shifts. However, the costs are considered to be at least higher than 36,000 pesos/t.

11) Noche Buena

Calculated costs are almost 37,000 pesos/t even on the assumption that the stoping width is two meters. In addition to this, it

will not be easy to secure as many as 54 workers deemed necessary for operation.

12) San Roberto and San Bernabe

The wage level is excessively high and there is a considerable discrepancy between the mining costs obtained by the hearing survey and those we calculated. On the other hand, the cost for drift digging with the 4.5 m x 4 m cross section of heading was shown at about 1.1 million pesos/m in the hearing survey. In regard to the costs for drift digging, we have carried out a trial calculation using the same simplified method as that which was used in the current trial calculation of mining costs. According to the methods shown in literature published by the U.S. Bureau of Mines, for the drift with a 4.5 m x 4 m cross section of heading, the labor cost amounts to 86,000 pesos/m (1.72 man days/m @300,000 pesos/week 6 days/week), supply expenses to 793,000 pesos/m (317 dollars @2,500 pesos/dollar), equipment maintenance expense to 90,000 pesos/m (36 dollars @2,500 pesos/dollar), and the total to 969,000 pesos/m. That is, this figure is different from the above-mentioned cost obtained in the hearing survey by only 12% of the cost. There seems to be a big mistake in many of the wage, mining costs and the costs for drift digging. In this report, however, the figure of 38,100 pesos/t obtained in the trial calculation is to be used in later analysis.

13) Las Cumbres and Calicanto

For both mines, each discrepancy between costs obtained in the trial calculation and hearing survey (calculation by the relevant CMF's branch, in this case) is within 15%. In regard to the number of persons required for surface mining, it seems to be unreasonable to apply the simplified calculation method to not only Calicanto, but also other medium and small mines.

14) Amplicacion San Miguel

It is considered that the discrepancy between the results of the trial calculation and hearing survey (calculation by the relevant CFM's branch) depends on whether the preparation for stoping is required or not.

15) California

It is considered that factors such as the digging of prospect tunnels and the manual secondary breaking work for large masses of ore cause the discrepancy between results of the trial calculation and that of the hearing survey.

3.5 Outlines of Beneficiation Plants

(1) Parral Beneficiation Plant

1) Location and Access

Parral Beneficiation Plant is located in Parral City in the southernmost part of Chihuahua State. The state capital, Chihuahua City and Parral City are connected by the national highway No. 45, for a distance of 295 km (three hours by car).

Between Mexico City and Chihuahua City, the domestic regular non-stop flight is in service and takes one hour and forty minutes. Concentrates produced at Parral Beneficiation Plant are transported to Chihuahua Smelter (IMMSA) by truck. Major supplies and materials are also carried in the smelter via Chihuahua City in many cases.

2) History

1967: The operation commenced under the management by a cooperative association, the capacity being 150 ton/day.

1976: Construction was carried out to expand the capacity up to 400 tons/day.

Since 1983: As the CFM-owned beneficiation plant, it has commenced the beneficiation of purchased ore of up a capacity at present of 400 tons/day in the floatation process and 240 ton/day in the cyaniding process.

3) Buildings

Each stage of crushing, grinding, flotation and dewatering in the flotation process, and the stage of agitation, dissolution and pregnant solution processing in the cyaniding process are carried out in buildings at the plant. Another part of cyaniding dissolution and washing are performed outdoors though covered with a roof. Such plant buildings for all stages have become considerably superannuated with much dust and ore leakage produced.

The layout of each piece of equipment, cascade-mill type, which makes use of the inclined ground, has been adopted.

4) Nominal Capacity

Flotation process: 12,000 ton/month (400 ton/day, 30-day operation/month)

Cyaniding process: 7,200 ton/month (240 ton/day, 30-day operation/month)

(2) Guanacevi Beneficiation Plant

1) Location and Access

Guanacevi Beneficiation Plant is located in Guanacevi, a mining town in the northwesternmost part of Durango State. The State Capital, Durango City and Guanacevi Town are connected by the national highway No. 26, by a distance of about 300 km.

Approximately 75% of the highway has been paved and the remaining part is unpaved, the total distance taking about six hours by car.

It is also possible to get to Guanacevi from Parral City, Chihuahua State, which is bordered by the northern part of Durango State, by means of a chartered Cessna, taking 30 minutes.

Concentrates produced at this plant are transported to Torreon Smelter (Penoles) by truck.

2) History

1969: The operation was commenced with a capacity of 100 tons/day.

1974: Construction was carried out to expand the capacity of up to 220 tons/day.

1982: The production system was changed over to the 24-hour continuous operation to raise the capacity up to 350 tons/day.

1985: Construction was again carried out to increase the capacity up to 500 tons/day.

At present, the plant has the capacity of 600 tons/day.

3) Buildings

Crushing, grinding, flotation, and concentrate drying in the flotation process are carried out in buildings, but the dewatering of concentrates is partially performed outdoors. The cyaniding equipment is left outdoors as it has only been about 70% completed.

4) Nominal Capacity

Flotation process: 18,000 tons/month (600 tons/day, 30-day operation/month)

Cyaniding process: Not in operation

(3) Barones Beneficiation Plant

1) Location and Access

Barones Beneficiation Plant is located in the suburbs about 2 km distant northwestward from Zacatecas City, the capital of Zacatecas State. Mexico City and Zacatecas City are connected by a domestic regular flight service, which takes almost one hour. Concentrates produced at this plant are transported to a smelter in the bordering San Luis Potosi State.

2) History

1951: The operation was commenced under private management

1961: The Mexican Ministry of Finance participated in the management

1963: It became the Ministry's beneficiation plant, whose operation and management came to be conducted by CFM's employees. In addition, the cyaniding facilities were constructed with a capacity of 120 tons/day.

1983: The plant formally became the CFM's place of business.

1987: Construction was carried out to reinforce the floatation process.

At present, the plant has the capacity of 300 tons/day in the floatation process and 120 tons/day in the cyaniding process.

3) Buildings

The flotation equipment from grizzlies for crude ore receiving to dewatering equipment for flotation concentrates has been installed indoors, but thickeners for tailing have been provided outdoors.

Agitating tanks and countercurrent reaction tanks in the cyaniding process have been installed outdoors, and the equipment for stages from clarification filtering to pregnant solution processing has been provided indoors.

4) Nominal Capacity

Flotation process: 9,000 tons/month (300 tons/day, 30-day operation/month)

Cyaniding process: 3,600 tons/month (120 tons/day, 30-day operation/month)

3.6 Methods and Conditions of Beneficiation

(1) Parral Beneficiation Plant

1) Crude Ore Receiving

The plant has received all of sulfide and oxide ore purchased from more than 30 medium and small mines around it. The stockyard has an area of 3.91 ha, where a considerable volume of both sulfide and oxide ore are in storage at present. The crude ore is carried from the stockyard to storage bins using dump cars, which are weighed one by one.

Three storage bins (two of a 220 ton capacity and one of a 150 ton capacity) have been installed, and ore is stored through a 6" grizzly for each bin.

The receiving of crude ore is carried out during the time from 08:00 to 23:00 by four workers (2x2 shifts) assigned.

2) Crushing

The feed from the storage bins enters jaw crusher (20"x36"). These primary crushing products are forwarded to a vibrating screen (4'x10') using a belt conveyor. The sieve opening is changed depending on the moisture of ore; ½" for the dry and 1½" to 2" for the wet. The coarse screen rejects are treated by the closed circuit in which a cone crusher for secondary crushing. In addition, the magnet is installed above feed conveyor for eliminating mixed iron chips. The fine passed through the vibrating screen are sent to two 150 ton mill bins by belt conveyors.

The crushing process is operated for about 14 hours a day on the average by four workers (2x2 shifts) assigned.

3) Grinding

The feed from the mill bins through manual chutes enters two ball mills (7.5'x7.5' and 7'x7'). The density of slurry in the mills is 70 to 75%.

The discharge from the ball mills is classified by a 15" or 10" cyclone separately. The underflow is returned to the ball mills and the overflow is sent to the conditioner as feed for flotation. Its density of slurry is 25% and the particle size is -200 mesh 60 to 70%.

The grinding process is operated in a 24-hour continuous operation by three workers (1x3 shifts) assigned.

4) Flotation

The flotation process applies two processes, bulk flotation and Pb-Zn separation flotation. The process is varied depending on assay of treating ore.

In the case of the bulk flotation, the collector AF#31(30g/t), AP# 404 (15g/t) and KAX (15g/t), and the frother (10g/t) are added into the conditioner for bulk rougher floation. Bulk concentrates are obtained by bulk cleaner flotation. The tailing of rougher flotation is treated by scavenger flotation after adding AP#404 (10g/t), KAX (10g/t) and frother (5g/t). The froth of scavenger flotation is returned to bulk rougher flotation feed and the tailing is forwarded to the cyaniding process for its treatment. Even if the grade is low in terms of Zn, a similar treatment is given to Pb.

In the case of the Pb-Zn flotation, the collector AF#31 (25g/t), AP#404 (30g/t)and KAX (40g/t), and the frother are put in the conditioner of Pb rougher flotation. In this case, Zinc sulfate ($ZnSO_4$) and sodium cyanide (NaCN) are added, as a depressant against Zn, in the flotation cell. KAX, frother and copper sulfate are added to the tailing of Pb flotation as Zn rougher flotation. In each of the Pb and Zn flotation process, concentrates are obtained after cleaning. The tailings of Zn rougher flotation is sent to a dam.

5) Cyaniding Process

Feed for the cyniding process, the tailing of flotation, is classified by a 10" cyclone first of all. The underflow is sent

to the first of 11 agitating tanks of 16'x16'. The overflow is sent to the one of two 30' thickeners and its overflow is forwarded to the next one. The spigot of the two thickeners is sent to the above-mentioned first agitating tank with density adjusted. The overflow from the second thickener is used circulatedly. In the first agitating tank, the density of slurry is about 45% and the particle size is -200 mesh, 60 to 70%. Sodium cyanide (0.3kg/t) and calcium hydroxide (7 to 9 kg/t) are put into this tank, and agitation and leaching are carried out at pH12 . The underflow from the cyclone stays in the 11 agitating tanks for about 60 hours. The leached pulp is washed for almost 26 hours by the countercurrent method using six washing tanks of 30'x10' to obtain a pregnant solution. Then slime and oxygen in the pregnant solution are removed in three clarifiers of 10'x3', from which the clarified solution is sent to an agitating tank. In the tank, gold and silver are deposited by substitution with zinc dust. For the deposited products, dewatering is performed using four units of a 24-filter manual press. The dewatered cake contains about 30% water, gold by 0.2%, and silver by 70%. Filtrate from the filter press is sent back to the washing tank and deposited products are pumped to the dam as sludge.

6) Concentrate Treatment

Concentrates obtained in the flotation process are thickened to the density of slurry of 60 to 65% in a thickener, then are filtrated by disc filter. After filtration it is dried to around 8% by sum as the moisture of the filtrated concentration is somewhat high. Finally the concentrates are shipped to the smelter using trucks.

The concentrate treatment is carried out by six workers (2x3 shifts) assigned.

7) Treatment of Tailings Disposal and Waste Water

The volume of tailings disposal discharged from the beneficiation plant is approximately 6,000 ton/month and the tailings disposal has been accumulated at the dam. No waste water treatment is carried out.

8) Water and Power Supply

The total consumption of water amounts to 2.0 m3/t (crude ore), of which about 55% is covered by recycled water in the plant system.

The power consumption per ton of crude ore is 65.0 kwh (87.4 to 88.3 on the average).

(2) Guanacevi Beneficiation Plant

1) Crude Ore Receiving

The plant has received crude ore from 35 medium and small neighboring mines entirely in a beneficiation consignment system. It has a stockyard of 8 to 10 ha, whose maximum storage capacity is approximately 40,000 tons. In accordance with the annual storage plan, the received ore is treated when its volume has reached 600 to 1,000 tons the crude ore, is carried from the stockyard to storage bins using dump cars, each car is weighed before being thrown into the bins.

There are four bins (two of a 180 ton capacity and two of a 90 ton capacity), each of which is equipped with a 6" grizzly.

The received crude ore is carried out from 08:00 to 18:00 by two assigned workers.

2) Crushing

The feed from the storage bins enters a jaw crusher (20"x36") for the primary crushing.

Next, the crushed ore carried by a belt conveyor is sieved by a vibrating screen (5'x10') whose sieve opening is of 3/4". The coarse products are treated in the closed circuit with cone crusher. Fine products (under 3/4") are carried by belt conveyors to four 150 ton mill bins to be stored.

The crushing process is operated for about 18 hours a day on average by nine workers (3x3 shifts) assigned.

3) Grinding

The crushed products which have been stored in the mill bins are fed to ball mills using a belt feeder. In the primary grinding, 7'x7.5' ball mills are used. The ball mill discharge is classified using a cyclone (10"). The underflow at the cyclone is fed to a secondary ball mill (7'x5') and the overflow is sent to a conditioner as the feed for flotation.

The discharge from the secondary ball mill is classified using another cyclone (10") for the secondary grinding. The under flow is returned to the ball mill and the overflow is sent to a conditioner. Two circuits of this kind have been provided. In addition to such circuits, another grinding circuit with a combination of 7'x5' ball mill and a 10" cyclone exists, but this circuit has been used less than the former two circuits. The following are typical operational data; the density of slurry in each ball mill: about 70%, of the density of slurry of overflow at a cyclone 25%, and its particle size: -200 mesh 60 to 70%.

The grinding process is operated by nine workers (3x3 shifts) assigned.

4) Flotation

The flotation process consists of the bulk rougher, bulk cleaner and scavenger flotation, and only bulk concentrates are obtained at this plant. To the conditioner of rougher flotation, the collector AF#31 (10g/t), AP#404 (30g/t) and KAX (40g/t), and the frother (10g/t) are added. The froth of bulk rougher is cleaned to obtain bulk concentrates. The tailings of the cleaner flotation are sent back to the rougher flotation.

The tailings of rougher is put into the conditioner for scavenger flotation, and AP#3477 (20g/t), AF#24Z (10g/t) and KAX (10g/t) are added. The froth of this flotation is sent back to the rougher flotation. The tailings are sent to the dam.

The flotation process is operated by six workers (2x3 shifts) assigned.

5) Concentrate Treatment

Obtained concentrates are thickened to the density of slurry of 50 to 70% in a thickener and then are dewatered through disc filters. After that, they are dried up to a moisture of 10 to 15% using a rotary dryer.

The treatment is performed by six workers (2x3 shifts) assigned.

6) Treatment of Tailings Disposal and Waste Water

The volume of tailings disposal discharged from the beneficiation plant is about 6,000 ton/month and the tailings disposal has been accumulating at the dam. No waste water treatment is particularly carried out.

7) Water and Power Supply

The consumption of water is 4.3 m3/t(crude ore), about 50% is covered by recirculation.

The power consumption per ton of crude ore is 45.0 Kwh, which is a low value for small beneficiation plants.

(3) Barones Beneficiation Plant

1) Crude Ore Receiving

The plant has received, from neighboring mines, sulfide ore in a consignment system and oxide ore in a purchasing system, and treated the former by the floatation process and the latter in the cyaniding process. It has a stockyard of about 60Ha (2 km x 0.3 km), whose nominal maximum storage capacity is 300,000 tons but the largest volume stored in the past was 90,000 tons.

The crude ore is carried in storage bins equipped with 8" grizzlies using dump cars. The sulfide ore is provided with three bins (300 ton each) and oxide ore with five bins (150 ton each) for separate storage.

The receiving is carried out from 07:00 to 17:00 by two assigned workers.

2) Crushing

The sulfide and oxide ore enter to mill bins. The feed from the mill bins enters to a jaw crusher (14"x36"). Crushed product is then fed to a vibrating screen with the sieve opening of 3/4" using a belt conveyor. In this stage, iron chips are also eliminated. The fine crushed product which has passed through the screen is stored in each mill bin for sulfide and oxide ore as final products in the crushing process. The coarse products on the sieve are treated in a closed circuit with a cone crusher, and sieved repeatedly.

The crushing process is operated for about 18 to 20 hours a day on average by six workers (2x3 shifts) assigned.

3) Grinding

From the grinding process, the surfide and oxide ore are treated separately. Two Denver-type ball mills (7'x7.5 and 7'x5') have been installed for the sulfide ore and one unit (7'x7'), for the oxide ore.

In the sulfide ore circuit, cyclones (15" and 10" diameters) carry out classification and the underflow is sent back to the ball mills. The overflow is sent to a conditioner (8') as feed of flotation.

In the oxide ore circuit, after being classified with a cyclone (15"), the underflow is sent back to the ball mill as was done in the sulfide ore system. The overflow is forwarded to a cyaniding thickener (30').

The density of slurry in each ball mill is almost 70% and that of its overflow is nearly 25%. Particle sizes are -200 mesh, 70 to 75% for the sulfide ore and -200 mesh, about 68% for the oxide ore.

The grinding process is operated under a 24-hour continuous by six workers (2x3 shifts) assigned.

4) Floatation

At the plant, three flotation circuits - bulk flotation, Pb-Zn flotation and Pb-Cu-Zn flotation - are used depending on the composition of ore.

These three circuits cover the following ore:

Bulk flotation: low-grade sulfide ore which contains almost no copper.

Pb-Zn flotation: Sulfide ore which contains higher grade lead and zinc than those in the above ore, average grades being about 1% for lead and 1.5% for zinc.

Pb-Cu-Zn flotation: The ore which contains copper at the rate of 0.5% (average) in addition to the above.

(i) Bulk Floatation

Collectors AF#208 (25 g/t), AP#404 (20 g/t), AF#31 (30 g/t) and KAX, and frother are added to the conditioner of rougher flotation. Sodium silicate (Na_2SiO_3) is added to the froth of the flotation and bulk concentrates are obtained by cleaner flotation. To the tailings of the rougher flotation, collectors AP#3477 (15 g/t), AF#208 (10 g/t) and KAX (10 g/t), and frother are added to carry out scavenger flotation. The tailings of such cleaner and scavenger are sent back to the rougher. The tailing of scavenger flotation is sent to the dam as the final tailings.

(ii) Pb-Zn Flotation

Collectors AF#208 (25 g/t), AP#404 (20 g/t) and KEX (20 g/t), frother, and NaCN and Na_2SiO_3 as a Zn-Py depressant are added to carry out Pb flotation. After NaCN, $ZnSO_4$ and Na_2SiO_3 have been added to the froth in the flotation, Pb cleaner is performed to obtain concentrates.

After the pH of the tailings of Pb rougher has been adjusted with calcium hydroxide, the collector KEX (25 g/t), frother, and $CuSO_4$ are added to carry out Zn rougher flotation. Cleaner flotation is performed by adding NaCN and Na_2SiO_3 to the froth of rougher flotation to obtain Zn concentrates. The tailings of the cleaner is sent back to the Zn rougher feed and the tailing of this flotation is sent to the dam as the final tailings.

(iii) Pb-Cu-Zn Flotation

Collectors KEX (20 g/t) and AF#238 (25 g/t), frother, and depressant NaCN and $ZnSO_4$ are added to the conditioner of Pb-Cu rougher flotation. To the froth, NaCN, $ZnSO_4$ and Na_2SiO_3 are added and Pb•Cu concentrates are obtained by cleaning. Next, NaCN is added to carry out Pb-Cu flotation and to obtain concentrates of Pb and Cu.

For Zn flotation, rougher is performed covering the tailings of the Pb•Cu rougher in such an orthodox method that pH of the tailings is adjusted with calcium hydroxide and then collector KEX (20 g/t), frother and $CuSO_4$ are added. Cleaning is carried out by adding NaCN and Na_2SiO_3 to the froth in the roughing and Zn concentrates are obtained.

The tailings in each cleaning is sent back to the rougher feed, and that in the Zn rougher is sent to the sludge dam as the final tailings. This flotation process is operated by three workers (1x3 shifts) assigned.

5) Cyaniding Process

The oxide ore which has been treated in the grinding process is sent to the first thickener (30"), and its overflow is forwarded to the second thickener. The overflow at the latter is further strained through four sand filters before being sent to a reservoir. Spigots of the two thickeners are sent to an agitating tank

for cyanidation after the concentration has been adjusted to 40 to 45%. In nine agitating tanks, leaching is performed at around pH12 with NaCN and calcium hydroxide (8 to 14 kg/t) added. The spigots stay open in the tanks for about 45 hours. Leached pulp is washed for around 72 hours by the countercurrent method using five washing thickeners (48' x 12') to obtain a pregnant solution. Next, slime is removed from the solution and deoxidation is carried out for a clarified solution using 30 clarifiers. The solution is then sent to another agitating tank, and gold and silver are deposited by substitution with zinc dust. Deposited products are dewatered using two units of 33-filter manual press. The dewatered cake contains water by about 30%, gold by 0.15%, and silver by 50 to 80%. This cake is dried by butane gas before being sold to the smelter. The filtrate from the filter press is sent back to the washing thickener.

In the cyaniding process, three workers (1x3 shifts), are assigned to agitation and dissolution, three (1x3 shifts) to pregnant solution treatment, or six in all.

6) Concentrate Treatment

Concentrates are thickened to the density of slurry of about 50% in the thickener. Then they are filtrated by disc filter. Furthermore, the concentrates are dried up to a moisture of 12%.

For this operation, two workers (1x2 shifts) are assigned.

7) Treatment of Tailings Disposal and Waste Water

The volume of tailings disposal discharged from the plant is 6,750 tons/month and the tailings disposal is accumulated at the dam. No waste water treatment is carried out.

8) Water and Power Supply

The consumption of water is about 6 m^3/t (crude ore), of which nearly 40% is covered by recycled water in the plant.

The power consumption is 50.0 Kwh/t (crude ore).

(4) Consumption of Principal Materials

In regard to the consumption of balls for ball mills and reagents for beneficiation, we have prepared a table of basic units of major supplies.

Each beneficiation plant is characterized by its use of three to four kinds of collectors in tandem with one another. However, this method has weak points in that the quantitative adjustment of materials to be added during the operation and inventory control, complicate the job. Many reagents are produced on the basis of license in Mexico, but some problems still exist in terms of quality control. Calcium oxide for pH adjustment has weak effects and its consumption has increased.

The consumption of balls in the grinding process has become slightly more than usual because crushed ore is not at the prescribed particle size at the first to second ball-mill stages.

Consumption of Principal Materials

	Parral	Guanacevi	Barones
Balls 3"	1,400	1,200	1,300 (Sulf) 1,000 (Oxid)
AF#208			30
AP#404	31	20 - 50	20
X-350	42	30 - 60	25
X-343			20
$ZuSO_4$	Used quantity		250
$CuSO_4$			300
NaCN	Used quantity		40
AF#31	27	10 - 50	10 - 50
AF#242		10 - 20	20 - 50
AP#3477		20 - 60	20
Na_2SiO_3			100 - 250
Frother	42	40 - 45	40
Cyanidation NaCN	700		1,000-1,500
$Ca(OH)_2$	7,000-9,000		8,000-14,000
Zn dust	50		200 - 250
NH_4NO_2			100 - 500

3.7 Metallurgical Balance and Beneficiation Results

3.7.1 Metallurgical Balance

We have investigated the metallurgical balance of each beneficiation plant, and report results of the survey by floatation method because there are considerable variation in the balance and system depending on the type of ore.

(1) Parral Beneficiation Plant

1)	Pb-Zn flotation	Fig. 3.7.1
2)	Bulk flotation - cyaniding treatment	Fig. 3.7.2
3)	Pb flotation - cyaniding treatment	Fig. 3.7.3

The recovery of gold (Au) and silver (Ag) in each flotation system is about 50 to 65%. In the case of Pb-Zn flotation, the recovery of Ag has been improved though the assay of feed ore is low.

(2) Guanacevi Beneficiation Plant

Since only the bulk flotation has been operated of this plant, we summarize below the metallurgical balance for some mines.

1)	Buena Fortuna	Fig. 3.7.4
2)	San Narcos	Fig. 3.7.5
3)	San Jose Chico	Fig. 3.7.6
4)	Capuzaya	Fig. 3.7.7
5)	El Soto	Fig. 3.7.8

Both the quantity and the grade of ore vary among the mines, but the recoveries of Au and Ag show almost the same tendency as the level of feed ore.

(3) Barones Beneficiation Plant

1) Bulk flotation	Fig. 3.7.9
2) Pb-Zn flotation	Fig. 3.7.10
3) Pb-Cu-Zn flotation	Fig. 3.7.11
4) Cyaniding process	Fig. 3.7.12

In any process, the recovery of Au is very low.

3.7.2 Beneficiation Results

The overall beneficiation result of each plant is attached (see Table 3.7.14 etc.).

In comparison of Au and Ag, which the three plants intend to recover, the crude ore shows the higher level of grade in order of Guanacevi, Parral (including cyaniding system) and Barones (not including the cyaniding process), and the recovery also shows the same tendency.

In the case of the Guanacevi Beneficiation plant, as described before about the metallurgical balance, the total recoveries of both Au and Ag show satisfactory levels of 77 to 78% though they vary depending on feed ore.

At Barones Beneficiation Plant, sulfide ore is treated in the flotation process, but the effect of mixed oxide ore is deletable when we compared with other plants and on-site conditions. Therefore, the plant should be required to establish the process for mixing sulfide and oxide.

3.8 Maintenance Conditions

We have studied actual conditions of the maintenance operation at the three beneficiation plants. At present, no preventive or planned maintenance is, at all, carried out at any of the plants.

(1) Parral Beneficiation Plant

Maintenance personnel

Mechanical Dept.	Foreman: 1, workers: 7
Electrical Dept.	Foreman: 1, workers: 2
Budget	Nil
Spare parts inventory	Although the quantity of consumables is secured, the stock should be controlled to an optimum quantity.
Working plan	Nil (only the replacement of ball mills is planned.)
Tools and devices	Shortage

(2) Guanacevi Beneficiation Plant

Maintenance personnel

Mechanical Dept.	Foreman: 1, workers: 11
Electrical Dept.	Foreman: 1, workers: 3
Budget	Nil
Spare parts inventory	The stock is secured, but should be controlled to optimum quantity.
Working plan	Nil
Tools and devices	Sufficient

(3 Barones Beneficiation Plant

Maintenance personnel

Mechanical Dept.	Foreman: 1, workers: 16
Electrical Dept.	Foreman: 1, workers: 5
Budget	Nil
Spare parts inventory	The stock is secured, but should be controlled to optimum quantity.
Working plan	Nil
Tools and devices	Sufficient

(4) Examination

Each plant has many defects concerning the maintenance of equipment. Actual conditions are that the equipment is repaired only at the time it breaks down. In particular, there are many problems regarding the maintenance of machines.

Although the number of workers for mechanical maintenance is larger than that for the electrical department, they are actually only pressed with repairing unexpected breakdowns. No expenditure for maintenance has been included in the budget. Accordingly, the stock control over spare parts and the purchased goods procurement are only considered as a temporary expedient.

At both Guanacevi and Barones beneficiation plants, tools and devices for repair are adequately prepared in general and simple parts can be manufactured or processed by themselves. However, routine and periodical inspection and control of equipment is not favorably performed. Therefore, both plants fall into a vicious circle in which unexpected breakdowns generated in succession, prevent even an inspection plan established with much effort from being put into practice. In consideration of these points, "persons in charge of repair" for mechanical and electrical repairs may have been assigned to each beneficiation plant and may perform their duties adequately, but there exists no person in charge of the control and maintenance of equipment actually. This conditions a cause that obscures the improvement in operation rates of plants. At the same time, no periodical maintenance plan (planned downtime of operation) is a main cause of so much lost time for temporary shutdown maintenance and sudden breakdown repair.

In order to find a way out of the current condition in which the trouble due to the breakdown of equipment considerably reduces the stability and efficiency of the beneficiation process itself, the preparation and the establishment of a preventive maintenance should be required at the earliest possible time.