FEASIBILITY REPORT

FOR THE MODERNIZATION OF MINING FACILITIES IN THE REPUBLIC OF BOLIVIA

(Vol. 2)

MARCH 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

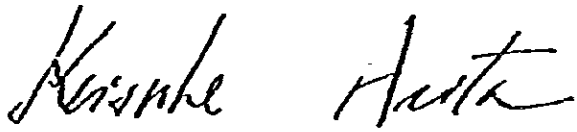
In response to the request of the Government of the Republic of Bolivia, the Government of Japan decided to conduct a feasibility study on the Mining Facilities Modernization Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Bolivia a survey team headed by Mr. Minoru Sunita two times in the period from July, 1981 to February, 1983.

The team held discussions on the Project with the officials concerned of the Government of Bolivia and conducted a field survey on the Catavi Mine. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute 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 Republic of Bolivia for their close cooperation extended to the team.

Tokyo, March, 1983



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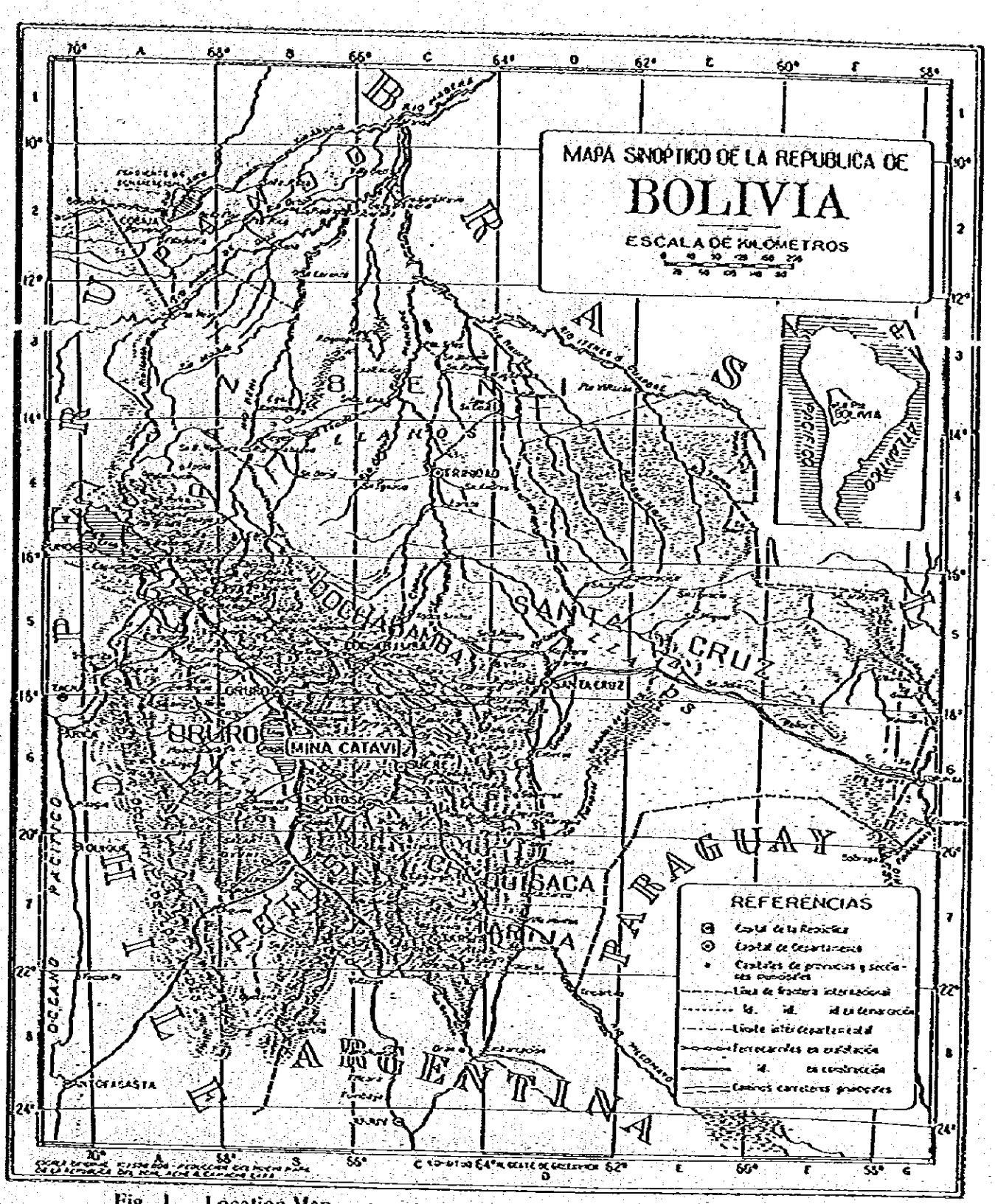

Fig. 1 Location Map

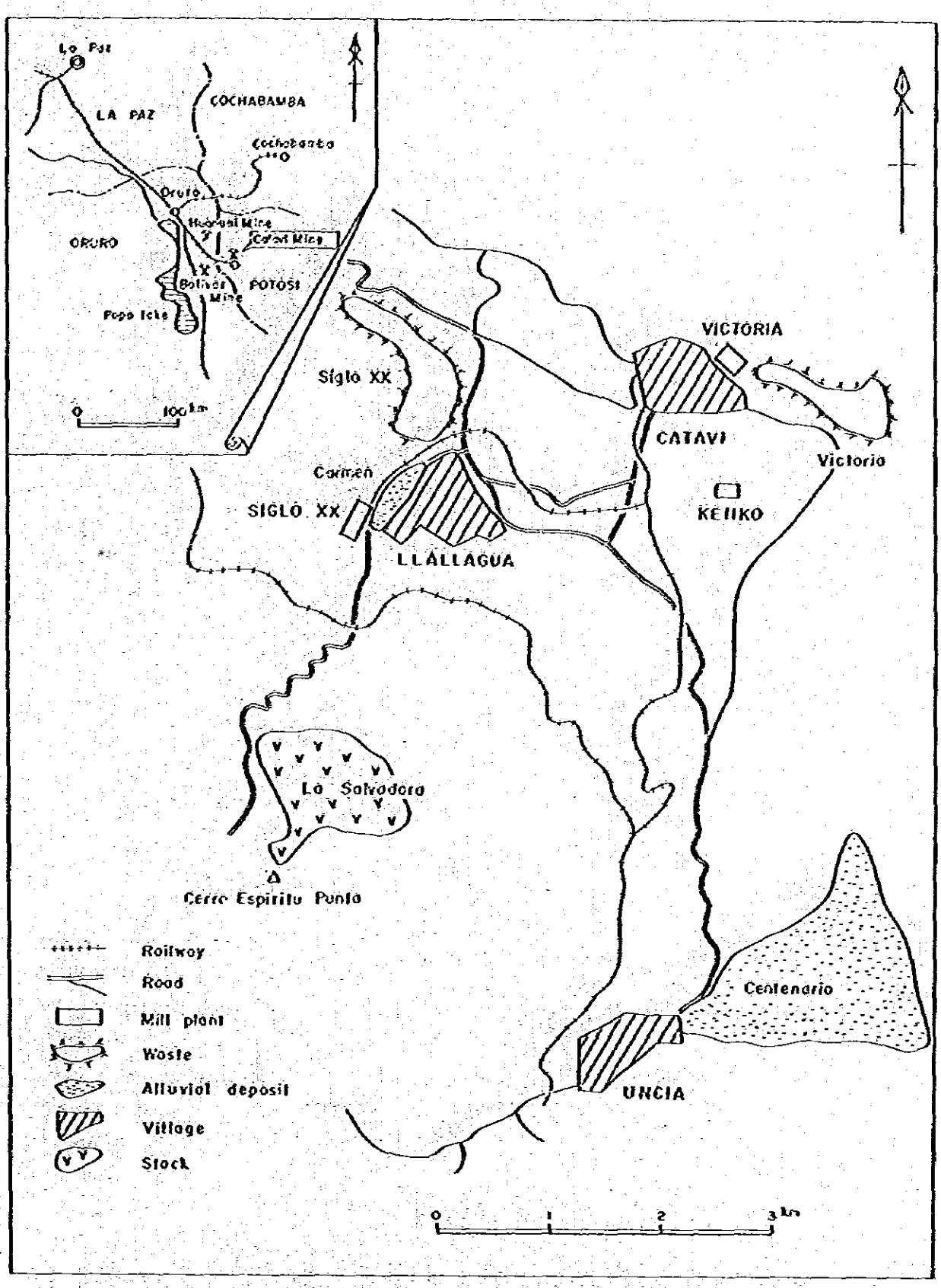

Fig. 2 Location Map of the Catavi Mine

SUMMARY

SUMMARY

1. Purpose

Under the title of "Feasibility Report for the Modernization of Mining Facilities in the Republic of Bolivia", a series of various studies were carried out from July 1981 through March 1982 as a first term and from July 1982 through March 1983 as the second term at Catavi Mine. These studies included status quo investigations, examinations on probing, exploration and concentration, analyses and discussions on policies for modernization, and proposals arising from these studies.

The results of the studies can be summarized as follows. The ore reserves of grades higher than the break-even point have sharply decreased over the past several years, comprising a quantity for only two years of mining operations by the end of 1982. Almost all of the facilities, operating conditions and organization, however, remain as they were during the period when only high-grade ores were being mined and treated, resulting in an extremely low productivity level. On the other hand, various costs such as personnel expenses and material prices have gone up year by year. These factors have made the Mine management situation more and more problematic, so that after-tax income registered a red-ink figure of 15 million US dollars in 1980 and 25 million US dollars in 1981. It is therefore clear that, if operations are continued in the future on the same basis, the annual deficit will rise every year and will constitute a substantial loss when the high-grade ores have been exhausted. Because of national and social constraints, however, the Mine cannot be closed absuptly.

Based on the above conclusion, the following fundamental concepts have been established to propose measures for modernization.

(1) Operations must be maintained for at least ten years into the future along with an improvement in economic efficiency.

(2) To realize this target, measures must be put into effect to create a new profitability by increasing the treatment capacity of crude ores to a level of 10,000 t/day and by greatly enhancing the production of metallic tin.

(3) As a means for this, conceptual designs of model plans should be made for the Mining, Concentration and Administration Departments, from which an improvement of productivity and the appropriate allocation of personnel should be studied.

(4) This plan should be analyzed from an economic viewpoint, and several case studies should be carried out using a variety of grades and treatment quantities of crude ores, to determine the conditions under which the maximum yield can be obtained in ten years on the basis of a

reasonable scale of operation.

(5) Along with the modernization of Catavi Mine, a scheme should be designed to explore new ore deposits in the vicinity, in order to develop COMIBOL and the surrounding community.

Based on the above conceptions, the following proposals are brought forward.

2. Outlines of Proposals

(1) Mining

For building up the mining plan, the major premises are cost reduction and productivity improvement in the Mining Department as a whole, by (A) the development of a new underground stoping method which is well suited to the ore deposit situation, giving consideration to the balance of quantities between underground stoped ores and surface ores with regard to 10,000 t/day treatment, which is the basic concept for the modernization program; and (B) surface stoping and transportation in large quantities at low cost from Siglo XX Desmonte. The resulting proposals are as follows.

1) For underground mining, stoping methods were examined under the following conditions pertaining to the Block Central region.

(a) Possible methods for selective stoping to a certain extent (with the aim of improving the ore grade).

(b) Suitable methods applicable to a solid geology with few cracks (reducing the treatment of bulky ores).

(c) Methods of making mass production possible at low cost.

(d) Methods requiring no large changes in the existing facilities and operating system.

As a result, sub-level stoping has been shown to be the best applicable method, with the following detailed proposals.

(a) In the Block Central region, four stoping blocks which are advantageous for sub-level stoping have been selected from the standpoint of ore-grade distribution. The total quantity of mineral accessible in these four blocks is 7,378,070 tons, with an average tin content of 0.41%.

(b) As many developing levels as possible should be excavated within the ore deposits, to prevent the greater prolongation of gangways, and to supplement the ore output. An efficient and maneuverable machine is recommended to shorten the work term. (See Table II–1-17).

(c) For transportation, ventilation and drainage, the existing facilities should be

Fig. 3 Location Map of Equipment

optimally used without any major changes.

(d) The estimated stoping efficiency under the conditions described above has been put at 22.2 tons per man-hour, and this figure is better than that of the Yanahara Mine, a typical lump sulfide ore deposit in Japan where the same stoping method is being employed at an efficiency level of 15 tons per man-hour.

2) Positive Use of Surface Ores (Desmonte)

The quantity of Desmonte amounts to 22 millions tons with 0.27% tin content, and they are gathered in a relatively defined area with a comparatively uniform grain size. This permits easy loading and transportation and makes immediate stoping on a large scale possible. As shown by the results of concentration tests, these waste rocks are easier to upgrade than tailings from the Victoria region, and consequently the overall stoping cost be greatly reduced.

(a) Stoping

Because of the dump situation, stoping should be carried out from the upper layer progressively downward.

(b) Stoping and transportation machines (See Table II-1-23)

Large and universal types of stoping machines should be used. As to transportation, an economic comparison between the dump truck system and the load-and-carry system has indicated that the former is better in this case. With dump truck transportation, the overall efficiency of Desmonte (tailing of heavy liquid concentration) stoping will reach about 130 tons per man-hour, which in turn, will remarkably reduce the mining cost for both underground and surface mining, and also will enhance productivity.

3) Long-Term Mining Program

The mining cost and productivity have been summarized for the coming ten years in the plans for production, personnel allocation, construction and mining operations (See Tables II-1-32 and II-1-33). As a result, the mining cost will decrease to an average of US$ 1,172 per ton of ores throughout these ten years, and productivity will make a great jump to about 850 tons of ores per man per month.

As described above, putting the plan into practice will naturally result in a great improvement in the mining operations.

(2) Concentration

The results of our first term investigation have revealed out that the following problems are key points in improving the Concentration Department.

a. The decline shown in the concentration results.

b. The concentration system and its capacity.

c. Instability of operation and the deterioration of concentration equipment.

d. The rise of concentration costs

In addition, the results of our concentration tests, carried out through the first and second investigation terms and focusing on the gravity concentration of mixed ores in the ratio of 35% underground ores to 65% surface ores, can be summarized as follows.

a. Preconcentration by heavy media separation included many negative factors.

b. Tin ores were easily separated when their grain sizes were between 50 and 200 mesh.

c. Recovery by table concentration were 59.8% for 48.9% tin content high concentrates, and 10% for 5% tin content low concentrates.

d. The desulfurization rate was 73.5% to 97%.

e. It was hard to remove 100% of the iron present by means of magnetic separation.

Based on the problems and test results described above, a mill plant with a new system is proposed to be installed as follows.

a. A new mill plant having a 10,000 t/day treatment capacity, 3,500 tons from underground ores and 6,500 tons from surface ores, should be constructed on the eastern slope slope of Cerro-Pichakani.

b. The concentration system, aiming at low-grade ores containing some 3% tin, should mainly comprise a table concentration method combining the comminution, grinding (especially avoiding over-grinding) and classifying processes attending the isolation of Sn, and final desulfurizing and iron-removal treatments to upgrade the concentrates. Preconcentration by heavy media separation should not be adopted because of low recovery, the high price of ferrosilicon and instability of operation.

c. This proposal is a conceptual design, and thus a pilot plant (over 20 t/day treatment capacity) should be installed to enhance the sampling precision and to determine the details of design prior to starting the actual construction work.

The expected concentration records are 50% Sn for high-grade ores, 4% Sn for low-grade ores, and 60% for the integrated recovery. To maintain these levels, all instrumentation and analyses should be performed in a real-time system to reinforce supervision and to assure optimum results.

d. To make the new concentration system effective, a precondition is the adoption of a preventive maintenance system for the entire equipment.

e. Concentration tailings will be finer in grain size and twice as large in quantity than in the existing system, and therefore a besieging embankment should be built up by an accumulation

of coarse particles at Estancia Chojlluma Valley, into which tailings should be dumped.

f. As to water supply, because the fine-grain table series requires a specifically low-pulp density and the overall consumption of water will be as much as 150,000 m^3/day, the condensation rate should be 80% or more (with the exception of loss due to evaporation) to provide a good water balance in the dry season.

(3) Construction Program (for 10,000 t/day treatment)

The following is an outline of the plans and expenses for construction work in each of the Mining, Concentration and Administration Departments.

a. Mining

A four-year term has been estimated for so-called construction work before starting the sub-level stoping : two years for investigation and design at the beginning, followed by the procurement of equipment, and the excavation of the main haulage levels, developing ore passes, drifts and so on ; and two years for the excavation of developing gangways.

Six months has been projected as the preparation term for heavy concentrates and waste-rock mining, which require only the procurement of equipment.

b. Concentration

Somewhat more than three years has been estimated as the term required from the commencement of investigations and design to starting operation.

The construction work is projected to require about three years prior to the first trial run, with parallel progress in investigations and design, the procurement of equipment, civil engineering work, building construction, electrical work and others.

The construction of the tailing dam mainly consists of the building up of the dam site, which is estimated to require about three and a half years.

Additionally, about two years have been estimated for the water supply system, including the procurement of equipment, water intake, pumping facilities and piping work.

c. Others

Company residences, new office buildings and their related facilities should be carried forward along with the above-mentioned construction works.

d. Construction Expenses

The construction and incidental expenses are listed in Table 1.

Table 1 Cost of construction In 1,000 U.S.$

Classification	Amount		
	10,000 t/day	9,000 t/day	8,000 t/day
Mining equipment	6.772	5.612	5.436
Mineral processing equipment	78.257	73.209	67.961
Water supply equipment	3.534	3.318	3.092
Tailing dam	4.732	4.023	4.479
Affices and houses construction	1.633	1.633	1.633
Administration equipment	455	455	455
Other expeces	20.942	19.842	18.688
Total	116.325	108.092	101.744

(4) Personnel Allocation Plan

A reasonable allocation of personnel has been considered in order to make the new operating system effective and to realize the improvement of administration, the bases of which are the integration of new concentration processes and the automation of the various machines which are the key points of the modernization policies. The result is the allocation of some 300 persons for mining, 470 persons for concentration and facilities engineering and 436 persons for the administration, totaling about 1,200 persons.

Our investigations over the past two years have revealed that the worst factor depressing the balance of payments of situation Catavi Mine is the yearly rise in costs, most of which stems from the decline in productivity.

During repeated discussions with COMIBOL, it has been mutually agreed that the rationalization and simplification of any operation can never be avoided for enforcing "modernization", and that the new programs in the second-term investigation should be case studies based on the new system, as undertaken to COMIBOL. Therefore, in that sense, the above-mentioned personnel allocation represents the minimum allocation of persons necessary for the new system.

To shift to the new system proposed by us, a term for preparation and construction will naturally be required, during which reasonable reassignments can be carried out step by step to gradually realize the modernization process. It may also be a more important policy to start explorations in the vicinity as early as possible, to which some employees will be assigned to develop new ore deposits in the earlier stages.

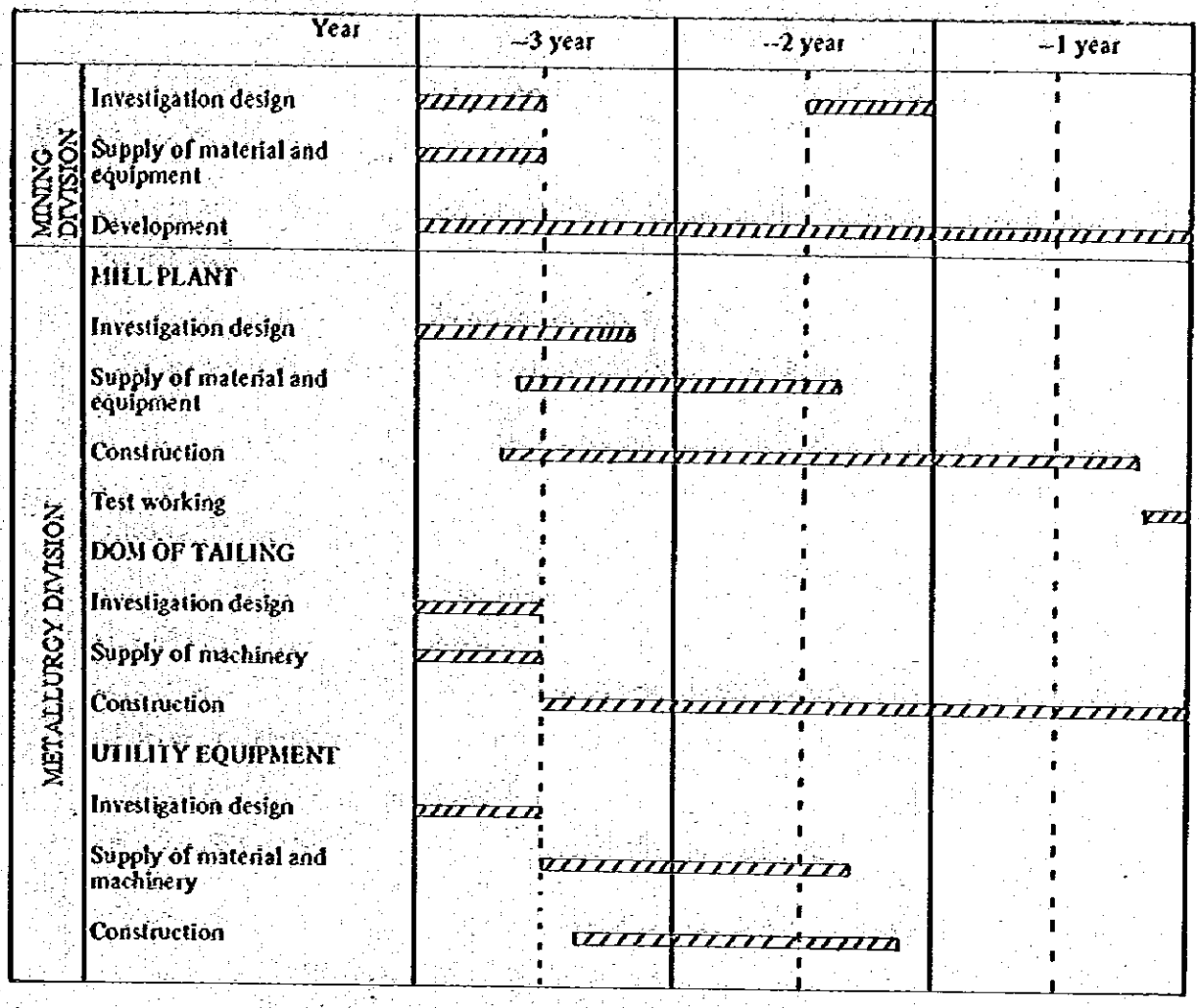

Fig. 4 Progress Schedule of Concentration Equipment

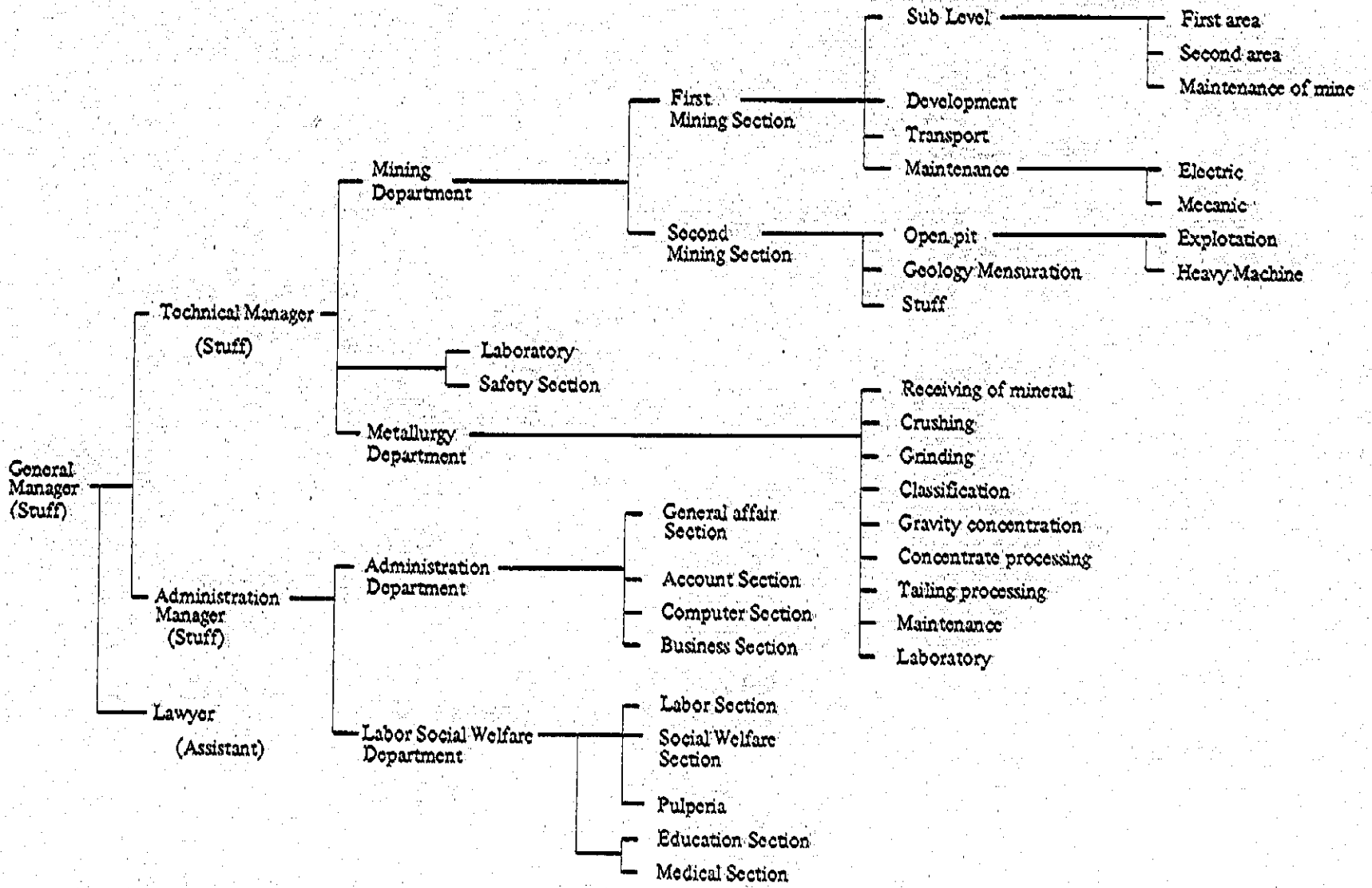

Fig. 5 New Organization of Catavi Mine

(5) Economic Appraisal

The greatest premise of this project is the raising of the profit level largely by the active and optional use of the economic merit that comes from gathering production sites together and enlarging the scale of operations through the modernization of facilities and operating systems.

The economic appraisal of this project has been based on calculations of revenues and expenditures for crude ore treatment levels of 10,000 t/day, 9,000 t/day and 8,000 t/day, with the latter two as case studies, and also made a sensitivity analysis and DCF calculation. The results are listed in Tables II-7-1, through II-7-5, but can be outlined as shown in Table 2.

Table 2 Profit and Interval Rate of Return

in 1,000 US$

	10,000 t/d	9,000 t/d	8,000 t/d
Profit per year before tax (Metal price 6 US$/lb)	6,400	7,600	5,600
(Internal Rate of Return Metal price 6 US$/lb Interest 6% Tax 35%)	10.50%	10.79%	9.95%

The highest pretax revenue is obtainable with 9,000 t/day treatment. The deficits of Catavi Mine in 1981 and 1982 exceeded US$ 15 million, so the above figure indicates a great improvement in the balance of payments, of over US$ 21 million.

DCF calculations have given a result of around 10% for each case, where the tax rate, differing from that in the annual balance calculation, was estimated at 30%.

These calculation results can be judged to show that this project has sufficient economic profitability.

(6) Exploration Program

Our proposals are based in the following investigation results.

a. Situation where Ore Deposits are Located

Our studies have made it clear that the tin ore deposits in this area converge on anticline axes or in wings surrounding the anticline within a great anticlinal structure running north-south, and are deeply related in position and origin with the existence of the stock of quartz porphyry.

b. There is a wide region newly covered with a layer of rhyolite lava, especially in the eastern half of the investigated area. In this region, the San Florencio ore deposit is the same

kind of deposit as the Llallagua deposit, i.e., a "window" exposed from a parent rock of paleozonic stratum; and this fact suggests the existence of blind ore deposits below the lava.

c. Physical Test Results

(a) The difference in density is very clear between the altered quartz porphyry and the paleozoic formation.

(b) The IP values of the mineralized zone and the altered sedimentary rock are much higher than those of the other kinds of rocks.

Based on these data, the following exploration plans are proposed.

a. Because of the relationship of ore deposits with geological strictures and volcanic activitiy, the choice should be aimed at the vicinity of the San Florencio ore deposit.

b. Gravity Prospecting

Area : 10 km x 15 km = 150 km²

Instrument : Lacoste gravimeter

Term : Two months for field work and two months for laboratory work; four month in total.

Cast : US$ 65,000

c. IP Electric Prospecting

IP prospecting should be applied to the region containing a altered zone extending toward the northwest from the San Florencio deposit, to directly detect ore deposits or altered quartz porphyry.

Area : 3 km x 6 km = 18 km²

Instrument : IP Mod. IPR 8 or IP C 2.5 kw and IP transmitter - receiver made by Yokohama Denshi Ltd.

Method : Frequency-Domain method, Gradient array

Term : About six months for field work, and about 2.7 months for laboratory work

Cast : US$ 87,000

Because of the technological level at the site, the gravity and IP prospecting must be carried out under expert advice.

3. Conclusion

The realization of our proposals on the modernization plans for Catavi Mine requires US$ 116 million for the construction cost for a 10,000 t/day capacity of crude ore treatment, and an additional some US$ 150,000 for the exploration costs. It can be easily understood that COMIBOL is now under a severe situation with regard to bearing the entire amount of expenditures.

It is most desirable, therefore, that the Government will provide powerful assistance measures for realizing this project, because the modernization of Catavi Mine is not only a requirement for the mining industry of Bolivia but is also one of the national projects. The successful realization of this new program in such a way must result in a tremendous financial contribution to the local community as well as to the Government.

Moreover, a significant fruit of the modernization of Catavi Mine will be the certain promotion of the settlement of similar problems in other mines, which we believe, will necessarily accelerate the reconstruction of the whole of COMIBOL.

PART I INTRODUCTION

CHAPTER 1. OUTLINE OF CATAVI MINE

(1) Location and Transportation

Catavi Mine, the target of this investigation, is located in Bustillo Prefecture, Potosi State, Bolivia, about 100 km in the south-west direction from Oruro City which is a center in the eastern Andean mining zone. It takes about four and a half hours by car to reach the mine from La Paz, the capital, via Oruro. There is a railway operated by COMIBOL (the Corporación Minera de Bolivia), running between Machacamarca, located about 3 km south of Oruro, and Uncia, located to the south of Catavi, but it carries mainly freight and passengers are conveyed by bus. Although Catavi Mine is in Potosi State, the location is near the boundary with Oruro State, so that the Mine is deeply related with Oruro City in its economic aspect and simply maintains the administrative relationship with Potosi City.

(2) Topography and Climate

Catavi Mine is topographically a part of the eastern Andean mountain system, and the facilities of the Mine are installed in a basin-like zone. The highest peak in the region is Mt. Juán del Valle (4,600 m above sea level), and some fan-shaped formations are to be found in its vicinity, with Uncia Town in the southern foot, Llallagua district in the northern foot where mining facilities and shopping streets exist, and Catavi district in the north-eastern foot where mining facilities and company residences lie. The lowest part of the basin is dotted with small lakes and marshes such as Lake Kenko.

The climate consists of the rainy reason from December through April and the dry season from May through November, with the highest atmospheric temperature reaching 20°C and the lowest some −5°C in the dry season (winter). The annual rainfall is 500 to 700 mm, most of which is concentrated in the rainy season. The difference between the day and night temperatures is so great as to exceed 15°C. The general climate is cold, with a small rainfall and low humidity. Therefore, many spots are dry and barren with little vegetation, and the cultivation of agricultural products is limited and productivity is low. Hence the climate is the greatest restriction against the development of the area.

(3) Operations at the Present Time

Catavi mine is proud of having the greatest scale worldwide at present for a mine exploiting virgin tin ore deposits. Since the Mine was developed by Simon I. Patiñ in 1903, many bonanzas have occurred one after another, which made the Patiño family one of the world's plutocratic families. Patiño established a company named Compañia Mines & Enterprises Cons. in 1984, to run not only Catavi Mine but also other superior mines, during which time

Catavi Mine was the mainstay. In 1952, the largest revolution, including a social revolution, since the establishment of Bolivia resulted in the nationalization of all mines under the control of Patiño, and thus they have changed into the mainstays of COMIBOL. The main haulage level was excavated at −650 ML in 1924 to start regular underground stoping, which brought about a highly modernized operation in terms of the world at that time. The cumulated amount of production of metallic tin is said to exceed 500,000 tons, while the grade of crude ores has fallen from 12 – 15% Sn at the beginning down to 9% Sn in the 1920s, 0.8% Sn in the 1960s and 0.3% Sn at present. The ore reserves in 1981 are shown in Table I–1.

Table I–1 Reserves of the Catavi Mine (Jun. 30 1981)

Type of Reserves	Reserve		
	Tons Min.	Sn%	Tons Fino
Vetas	443,472	1.52	6,757.71
Vetas en blocks	115,399	2.08	2,398.34
Puentes	44,338	2.88	1,275.16
Block caving	3,255,329	0.39	12,797.36
Blocks chicos	89,698	0.40	363.14
Existencias	103,478	0.92	948.03
Total (mine)	4,051,714	0.61	24,539.75
Desmontes	21,961,820	0.27	59,845.16
Veneros	297,249,015	0.01	30,558.49
Relaves	32,262,227	0.37	118,686.20
Total (surface)	351,473,062	0.06	209,089.85
Sum Total	355,524,776	0.07	233,629.60

As can be seen from the Table, an important theme for Catavi Mine is how to cope with the deterioration of ore grade.

The production records over the most recent four years are listed in Table I–2, while the present scale of operation is 5,000 tons of daily crude ore output with 0.3% Sn grade, with a workforce of 5,000 employees. Mining methods used are shrinkage stoping for veins and block caving for the mined and filled part and concentrated part of branchveins and their production ratio is 2 : 8, which indicates that shrinkage working faces are decreasing, while block caving is suffering from the draw point.

Table I-2 Production During Recent Years

Year		1978	1979	1980	1981
Production Under Direct Control	Crude ore	1,432,068t	1,266,625t	1,283,515t	1,324,014t
	Assey Sn	0.38%	0.34%	0.32%	0.31%
	Sn-Conc.	7,386t	6,636t	6,181t	5,767t
	Assey Sn	40.07%	38.05%	37.02%	35.41%
Sn-Metal		2,959t	2,525t	2,288t	2,042t
Sn-Metal in saled ore		1,430t	1,408t	1,661t	1,386t
Total Sn-Metal		4,389t	3,933t	3,949t	3,428t

Regarding concentration, the mined and extracted ores are first separated with a heavy media liquid in the Siglo XX pre-concentration plant, and the precipitated ores are then transferred to the Victoria mill plant where they are subjected to gravity concentration (mainly table concentration and partly jigg separation) and finally to the desulfuring floatation process to finish up as tin concentrate. Slime from the mill plant was dumped into Lake Kenko followed by floatation in Kenko concentration plant, which is not in operation now because of troubles with the dredger. The crude ore supply to Siglo XX pre-concentration plant is about 5,000 t/day with some 0.3% Sn content, with the grade of the preconcentrated products being 0.45% Sn and the recovery of tin around 75%. Victoria mill plant treats about 2,000 t/day of crude ores, upgrading these ores to concentrate of some 40% Sn content, which is then concentrated to a level of 60% Sn recovery.

All of the facilities of each mill plant, although they are now operating on low-grade ores with a low recovery, are the same as they were for the high-grade ores with a high recovery, and they have become remarkably deteriorated, bringing about the current decline in efficiency.

Incidental facilities are various repair shops, electrical facilities and water equipment, among which the ones worthy of note are a foundry accepting orders from mines under the control of COMIBOL, and two hydro-electric power stations. The production capacity of the foundry is 2,000 t/year which provides one half of the entire requirement for castings of COMIBOL, and the foundry is now under the control of Catavi Mine although it is under the self-accounting system. Public welfare facilities are highly developed, with COMIBOL's largest hospital having 265 beds, a school of nursing, 17 grade, junior-high and high schools with 416 teachers and 14,000 daytime and evening students, distribution stations, theaters and movie houses.

Along with the deterioration of the ore grade, the operation of Catavi Mine has become extremely difficult, and is steadily worsening. Hence it is a great problem now not only for COMIBOL itself but also for the Government.