Japan International Cooperation Agency (JICA)

Republic of Bolivia
Ministerio de Desarrollo Sostenible y Planificación

THE STUDY ON EVALUATION OF ENVIRONMENTAL IMPACT OF MINING SECTOR IN POTOSI PREFECTURE OF THE REPUBLIC OF BOLIVIA

FINAL REPORT

(MAIN)

Septiembre, 1999

MITSUI MINERAL DEVELOPMENT ENGINEERING CO., LTD.
UNICO INTERNATIONAL CORPORATION

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PREFACE

In response to a request from the Government of Bolivia, the Government of Japan decided to conduct and entrusted the study to Japan International Cooperation Agency (JICA).

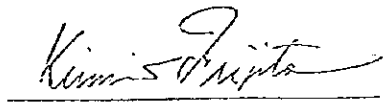
JICA sent a study team led by Mr.Hisamitsu Ooki of Mitsui Mineral Development Engineering Co., Ltd.(MINDECO) and organized by MINDECO and Unico International Corporation to Bolivia six times from September 1997 to August 1999.

The team held discussions with the officials concerned to the Government of Bolivia, and conducted related field surveys. After returning to Japan, the team conducted further studies and complied the final results in this report.

I hope this report will contribute to the improvement of the situation of Mining Sector in Potosi Prefecture and to enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Bolivia for their close cooperation throughout the study.

September 1999



Kimio FUJITA
President
Japan International Cooperation Agency

Mr. Kimio FUJITA
President
Japan International Cooperation Agency

Dear Mr. Fujita,

Letter of Transmittal

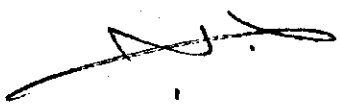
We are pleased to submit the report of The Study on Evaluation of Environmental Impact of Mining Sector in Potosi Prefecture of the Republic of Bolivia

The report contains proposals on technical aspect and administrative aspect for prevention and reduction of mining related pollution. The report has compiled after discussion with Bolivian counterpart officials of Ministerio de Desarrollo Sostenible y Planeamiento, Viceministerio de Recursos Naturales, Medio Ambiente y Desarrollo Forestal; Direccion de Recursos Naturales de la Prefectura del Departamento de Potosi; Viceministerio de Inversion Publica y Financiamiento Externo; Viceministerio de Mineria y Metalurgia and Corporacion Minera de Bolivia through several meetings held in La Paz and Potosi.

This report proposes twelve countermeasures on environmental improvement against mining pollution around Cerro Rico de Potosi mine and along the De la Reberta River and the Tarapaya river, which are upstream tributaries of the Pilcomayo River. We highly recommend establishing Environment and Safety Research Center, which will become the core of countermeasure network.

The study team recommends urgent establishment of Environment and Safety Research Center for integrated and systematic execution of pollution prevention and improvement of mining related pollution in Bolivia.

Lastly the survey team thanks Japan International Cooperation Agency and Ministry of Foreign Affair of Japan, which have given us an opportunity to execute such an important and challenging project. The team appreciates keen cooperation of Viceministerio de Recursos Naturales, Medio Ambiente y Desarrollo Forestal; Direccion de Recursos Naturales de la Prefectura del Departamento de Potosi, and many institutions associated with the project.



OOKI Hisamisu
Leader of the Study Team
The Study on Evaluation of Environmental Impact of Mining Sector in Potosi Prefecture of the Republic of Bolivia

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Abbreviations List

1. Organizations

AAPOS	Administración de Agua Potable y Saneamiento (Water supply administration)
ASTM	American Society for Testing and Materials
CDR	Centro para el Desarrollo Regional (NGO for regional sustainable development aids)
COMIBOL	Corporación Minera de Bolivia (Bolivian public mining company)
ITC	International Tin Council
LME	London Metal Exchange Market
MDSP	Ministry of Sustainable Development and Planning)
MEDMIN	Environmental aid programs for small and medium scale mining activities organization
ONG	NGO: Nongovernmental organization
UATF	Tomas Frias Autoonomous University
VMDSMA	Viceministry of Sustainable Development and Environment

2. General Terms

BOD	Biochemical Oxygen Demand
CCA	Environment Quality Control

COD	Chemical Oxygen Demand
CRF	Capital Recovery Factor
DCSA	San Antonio Tailings Dam
DDA	Declaration of the Environmentally Adequacy
DIA	Environment Impact Declaration
DO	Dissolved Oxygen
EEIA	Environmental Impact Assessment Study
EIA	Environment Impact Assessment
EIRR	Economic Internal Rate of Return on Investment
FIRR	Financial Internal Rate of Return on Investment
FA	Environment Note
IPR	Impact – Process - Response
Ig.Loss	Ignition Loss
LIBOR	London Interbank Offered Rate
MA	Environment Manifesto
SS	Suspended Solid

1 PREFACE

1-1 Background

Mining has been the main export industries for long time in Bolivia. More than one thousand mines, from small to large mines, concentrated on the Andes mountain range from La Paz city, the capital, to Tupiza city through Oruro city and Potosi city at the best mining days. However, worldwide catastrophe of Tin market and big scale labor strike in the middle of 1980 forced almost mines to quit mine activity.

On the other hand, environmental pollution caused by mining activity is serious lacking of consideration for the environment. In particular, acid water from the waste rock piled in open-air by mines around the Potosi city and alkaline tailings discharged directly into the rivers by Ingenios around the Potosi city contaminate De la Ribera river which runs down through the Potosi city, Huaynamayu river etc, joining acid water spring out from abandoned mines.

Furthermore, this river contamination has raised export of pollution and international problems as the origin of the river contamination which has influenced on the down stream of the Pilcomayo river through neighbor countries of Paraguay and Argentina up to the La Plata river.

International organizations included World Bank has begun to assist to improve the problem. On the other hand, intense considering on the environment of the owner of mines and civilian level is low. NGO, international organization such as World Bank etc. slightly called attention. In addition, environmental administration has just been begun and is under condition of trial and error learning forerunners.

Under this situation, the accident has happened that waste dam of Porco Mine, which was under operation, collapsed contaminating the Pilcomayo river in September 1996.

Argentina, which is one of countries located along the down stream of the Pilcomayo river, pointed out the environmental pollution through international river.

The origins of water quality contamination and environmental pollution around the Potosi city area are considered as follows,

① tailings (SS and alkaline liquid) which is released from operating

"Ingenios" and include heavy metal

②acid water, which springs, out from the tunnels of operating mines or abandoned mines.

③acid permeable water comes from waste rock which are piled and left under open air.

④surface collapse (landslide) of tailing dam of operating mines or abandoned mines with erosion of rain falls.

The Bolivian Government has finally established Vise-ministry of Environment in 1992 also accepting indications of neighboring countries. At the same time, it has begun consolidation of organization setting "National Environment Action Standard" and "Environment Basic Law".

At present, Ministry of Sustainable Development and Planning (MDSP) takes in charge the planning and execution of national policy related environment, and the arrangement of law and regulations are being advanced through Vice Ministry of Sustainable Development and Environment (VMDSMA), the lower organization.

In parallel, MDSP has taken counter measures to protect environment around the Potosi City putting the VMDSMA as the core. However, the situation becomes hard to treat quickly and enough by the country it self.

The Bolivian Government considered the situation serious and requested to Japan "The Study on Evaluation of Environmental Impact of Mining Sector in Potosi Prefecture of The Republic of Bolivia" through MDSP.

Japan International Cooperation Agency (hereinafter referred to as "JICA") executed preliminary study in October 1996. The Scope of Work (hereinafter referred to as "S/W"), which had taken into consideration the request of the Bolivian Government, was concluded between the JICA Preliminary Study Team and the Ministry of Sustainable Development and Environment (at the time) of the Republic of Bolivia in February 1997.

The Study is carried out with the Vice Ministry of Sustainable Development and Environment (hereinafter referred to as "VMDSMA") as a counter part (hereinafter referred to as C/P) based on this S/W. (the study area is shown in Figure 1-1-1and 1-1-2).

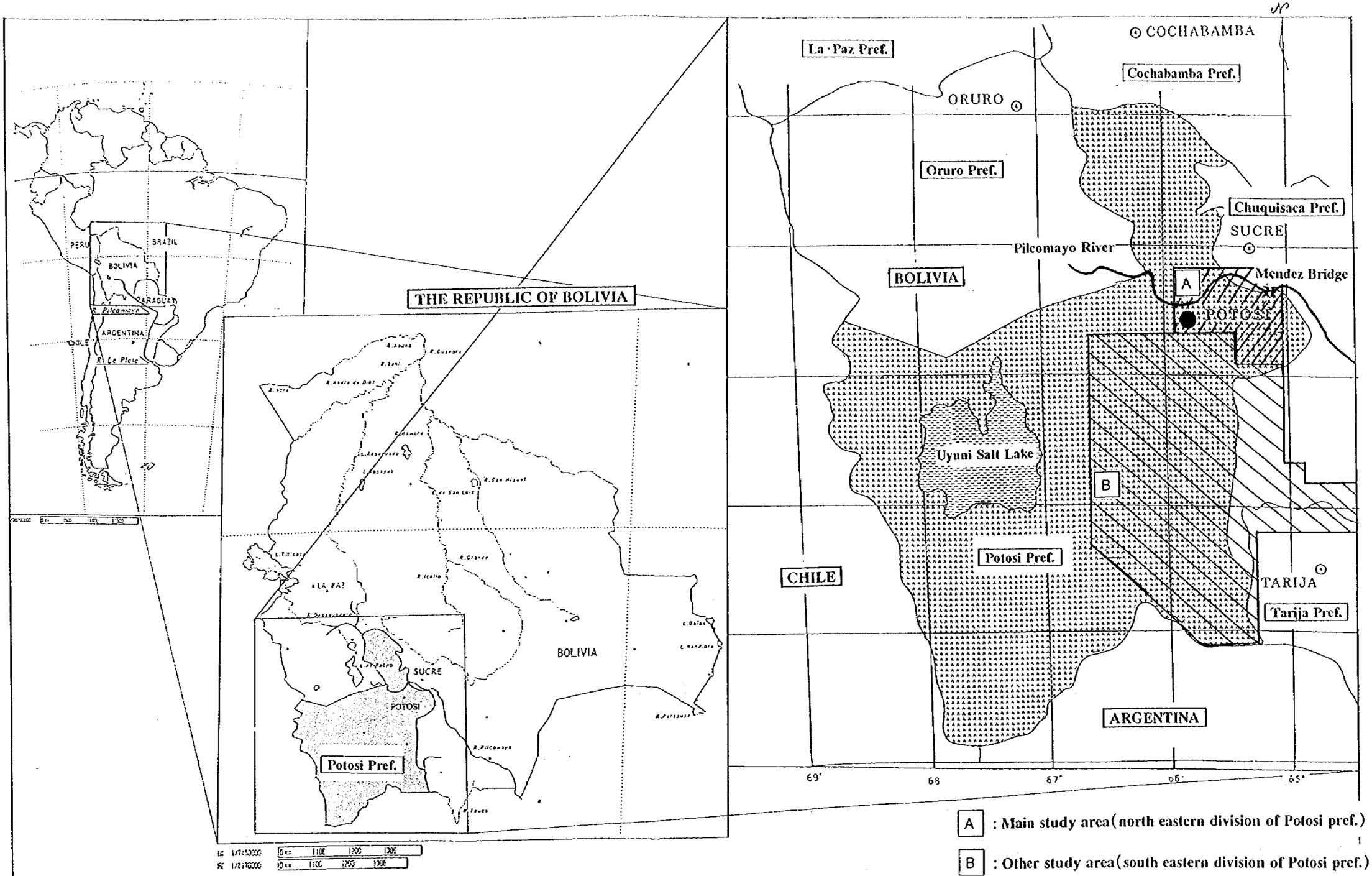


Figure 1 - 1 - 1 Location Map of The Study on Evaluation of Environmental Impact of Mining Sector in Potosi Pref.

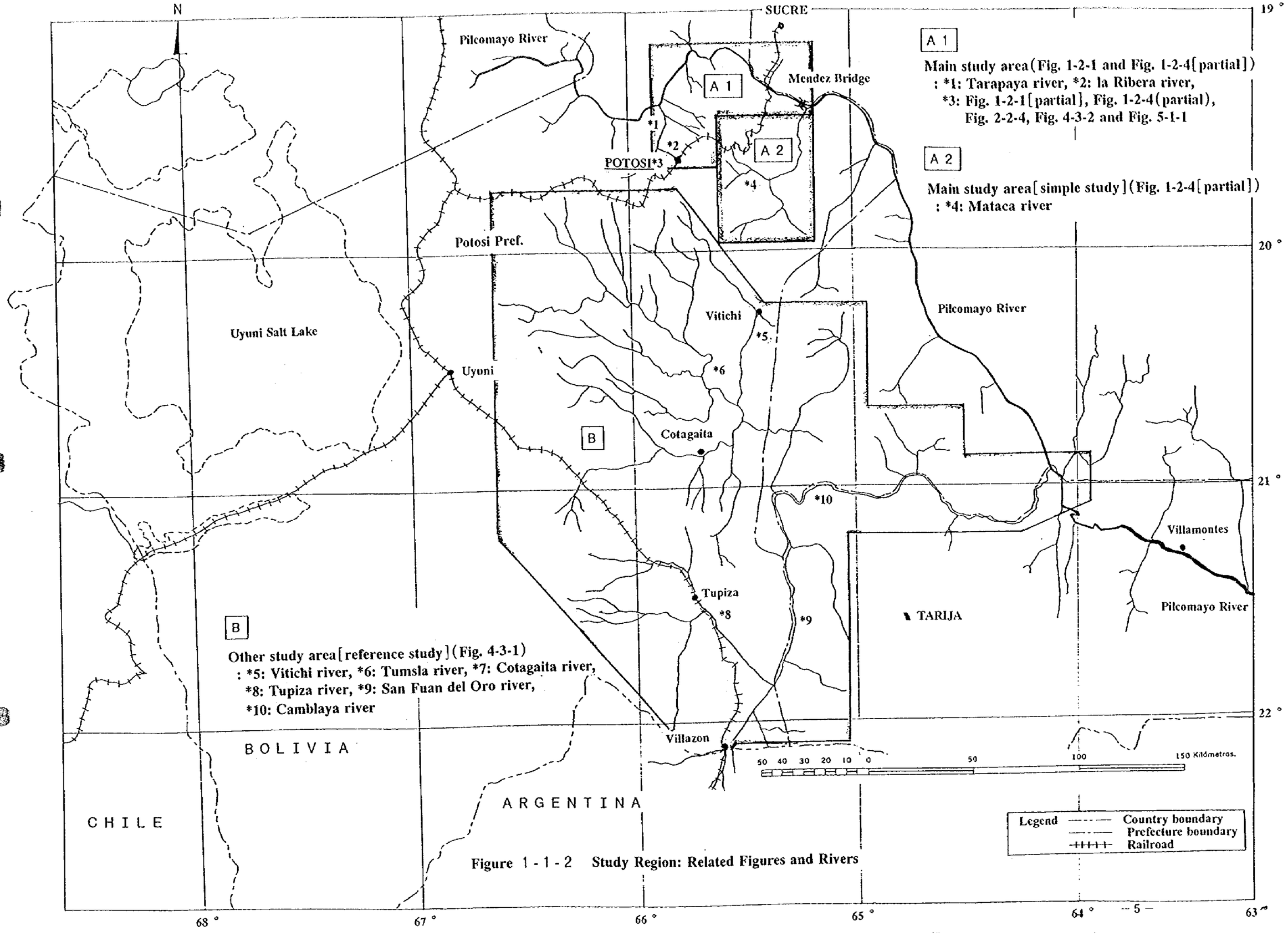


Figure 1 - 1 - 2 Study Region: Related Figures and Rivers

1-2 Objectives of the Study, Study Policy and Abstract of the Study

1-2-1 Objectives of the Study, Study Area and the Study Policy

(1) Objectives of the Study

Objectives of the Study are based on the S/W and M/M which has concluded in February 1997.The contents are mentioned below.

① to carry out the study the environment impact caused by mining activity at Potosi area

② to plan the environment monitoring and environment management program

③ to propose the political and technical recommendation relating to manage and to mitigate the mine pollution at the study area.

Concretely, to make sure the situation of heavy metal contamination etc. at main point of the De la Ribera river and the Pilcomayo river, and to make the pollution protection plans for pollution origin.

Furthermore, to execute the technical transfer to the counter pert (C/P) that C/P will be able to carry out similar study, planning pollution protection program, reviewing of environment management plan (environment regulation) by themselves forming environmental monitoring system of the De la Ribera river.

(2) Study Area

The study area of the Study The study is Potosi City area and 180km of the De la De la Ribera river basin which covers from the origin in the Potosi city to the Mendez Bridge changing the name, Aljamayu, Molino and Tarapaya, and finally joining into the Pilcomayo (see Figure 1-2-1).

Since the water basin in the study area is very complicated, however, it is very important to understand the study method and the study results. Therefore, the relations between each river and its branch are explained as follows.

There are De la Ribera River and the three branches, Chectakala, Huaynamayu and Korimayu in the Potosi area. The De la Ribera river changes the name to Aljamayu after runs down to west through Potosi city and goes to north-west. On

the other hand, Quebrada Jayajmayu which originates at west mountain slope of the Cerro Rico de Potosi mountain and the branch river Huakajchimayu run into the Agua dulce river and it joins with Aljamayu river at outskirts of Potosi city.

The De la Ribera river, the Aljamayu river, the Molino river, the Tarapaya river are the same water basin, and it changes the name introducing village name nearby every time when each branch joins. Viewing the Tarapaya river basin from upper stream, name of the De la Ribera river is used during Potosi city up to confluence with the Jesus Valle at suburbs of the city. The Aljamayu is called between the confluence point of the De la Ribera river and the Jesus Valle river and confluence point of the Huancarani river at the La Palca village. The Molino is named after the confluence point of the Aljamayu river and the Huancarani rive up to the Molino village, and the Tarapaya is used all of down stream area of the river up to the confluence with the Pilcomayo river including the Molino river.

The Agua Dulce river and the branch river Villacomayu river run down to North passing through the west part of Cerro Huakajchi and Juckuy Huakajchi mine.

Three water basins, the Huaynamayu river, the Korimayu river and the Quebrada Jayajmayu river (Jayajmayu ravine) include water from the Cerro Rico de Potosi Mountain. Former two water basins run into the De la Ribera river and latter one water basin run into the Aljamayu river through the Agua Dulce river.

The Study Team carried out also simple inspection on the Samaza river and the down stream the Mataca river basin, which runs from the suburbs of the Potosi city down to east in northern part of the Potosi prefecture.

(3) Study Policy

The Study was executed based on the technical main process mentioned below.

① Recognition of mine pollution mechanism

Contamination and impact mapping, and clarification of the pollution mechanism are carried out in this field.

② Grasp the expansion and grade of impact

Establishment of the monitoring system and grasp the expansion and grade of impact.

③ Construction the example of the forecast model of the river water quality

④ Review the mine pollution protection method and recommendation (Conceptual design of Model Plant, Financial Analysis)

⑤ Design and propose the environment managing plan (Environment monitoring plan, environment management index and environment management policy)

⑥ Plan of enlightenment, education and raise talent (OJT[On the Job Training], C/P training in Japan, technical transfer seminar)

The Study is separated into four stages as follows,

① Stage 1 (Preliminary Survey)

② Stage 2 (Detail Survey)

③ Stage 3 (Designing)

④ Stage 4 (Technical and Policy-Making Recommendations) and is carried out six time site survey and domestic works (see Table 1-2-1).

1-2-2 Abstract of the Study

(1) Study Field and their Role

The technical fields to achieve the study policy and study objectives mentioned above are eight and their roles are mentioned below.

The concept of the Study scheme is illustrated in Figure 1-2-3.

The Study fields and the experts are as follows,

Team Leader	OOKI Hisamitsu
Water Quality/Hydrology	MORI Toshio
Mine Geology	NAKAMURA Kiyoshi
Mineral Processing	ITO Kneji

Waste Water Treatment	TANAKA Yoshiharu
(Chemical Analysis)	
Data Base/Statistic	Ricardo ORTIZ
Equipment Designing	KIMURA Soichiro
(Mechanical)/Estimation	
Economic/Finance	KOSUGI Yoshio
Environment Management	YAMAUCHI Ken
Plan/Organization・System	

1) Water Quality/Hydrology

Grasping the river water pollution condition, Mapping the pollution condition, Making clear the pollution mechanism, Submitting the data for forming data base which contributes as the base to form example of estimation model, Transfer of monitoring technique

2) Mining Geology

Presumption the Potosi mine life (Ore reserves) which contributes to keep mining activity and to provide basic data for financial and economic analysis, Execution of estimation on the waste rock and old tailing dam.

3) Mineral Processing

Execution of mineral processing test for improvement of operation result and mine pollution protection aiming compatible of "production" and "environment", Study on the process improvement of "Ingenio" for raising income which contributes to environment cost, Study the most appropriate processing flow for the Potosi mine ore, Execution of investigation and analysis on the data for designing and estimation the model/integrate plant, Technical transfer of mineral processing testing technology and the analysis.

4) Waste Water Treatment (Chemical Analysis)

Study the pollution origin, Mapping the pollution origin, Execution the waste water treatment test which contributes for clearing the pollution mechanism,

Technical transfer of waste water treatment test and analysis of the result, Carry out the check and guidance the analytical method for environmental monitoring

5) Data base/Statistic

Statistic grasping of pollution condition and data arrangement, Forming the data base for monitoring system (software), Construction of simulation model (software) which contributes environment management, Technical transfer to input/output and utilize above mentioned software.

6) Plant Design (Mechanic)/Estimation

Execution of equipment estimation and mechanical design which is required designing for model plant, processing plant for tin recovery from tailing, integrate plant, processing plant for precious metal recovering from waste etc., Technical transfer on plant design (mechanic) and estimation

7) Economic/Finance

Execution of financing analysis for introducing the process improvement of "Ingenio", processing plant for tin recovery from tailing and integrate plant, Execution of economic evaluation with applying the improvement measure, Technical transfer on the financing/ economic analysis.

8) Environment Management Plan/Organization·System

Execution of analysis for the monitoring system of Potosi prefecture, environmental standard/discharge of Bolivia and Potosi prefecture, environment index, reformation plan of environment administration organization, technical transfer for environment management/monitoring system.

(2) Study Method for each Field

1) Water Quality/Hydrology

River water and sediment sampling at 25 sampling points, 2 monitoring points through the year and main element analysis were carried out.

At the same period, hydrological study was also carried out.

Data for the environment improvement plan and management were submitted analyzing upper mentioned study results, grasping river water contamination condition.

Executed analytical items are as follows.

① Water Quality (14 items):

pH, SS, As, Sb, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Zn, CN, COD

② Sediment (15 items):

Ag, As, Sb, Cd, Cr, Cu, Fe, Hg, Mn, Sn, Pb, Zn, CN, S, Ignition Loss (Ig.Loss)

Simultaneously, river section survey was carried out at 5 points in the study area, and river water flow at main points including above mentioned 5 section survey points were studied.

The abstract study area is shown in Figure 1-2-4.

Furthermore, water quality analysis at several points in southern area of Potosi prefecture was carried out and abstract water quality contamination of each river was studied.

2) Mining Geology

Annual report of COMIBOL, operation report of Pailaviri mine, literatures related etc. were studied focusing on the Cerro Rico de Potosi mine ore reserves and geological information. And, Cerro Rico de Potosi mine ore reserves were estimated and data for financing analysis were submitted analyzing answer for the questionnaire, site survey results, literature study result, existing data study result.

3) Mineral Processing

The study for actual state and the presumption of ideal condition of "Ingenio" collecting answers for questionnaire and executing interviews, and analysis of the differences between actual state and ideal condition applying the mineral processing test result were carried out.

Following those studies, proposal of mine pollution protection plan relating tailing and improvement plan relating operation of "Ingenio" were arranged.

The most appropriate processing flow for Potosi ore and out put from the flow were presumed and the data for plant designing and estimation were submitted.

4) Waste Water Treatment (Chemical Analysis)

Water quality surveys for contamination origin during rainy season and dry season were carried out. Water quality analysis was done based on ASTM. Simple water flow surveys were done at several sampling points.

Neutralization tests were tried and appropriate water treatment method for mine and permeable acid water from the Potosi mine and around was proposed.

5) Data base/Statistic

Data base for compiling monitoring data was constructed collecting and analyzing statistically the information and the data of water quality, hydrology, contamination origin, wastewater treatment test, tailing, meteorology etc.

Furthermore, the software which contributes to construct example of future estimation model experimenting to form the simulation model and utilizing real sampling data from some of 25 sampling points.

6) Plant Design (Mechanic)/Estimation

The survey for under mentioned items were carried out.

①capacity and operation life of the plant

②equipment

③installation

④utility

⑤safety

⑥working condition

⑦others

Conceptual designing of model plant and integrated plant were done with the data from upper mentioned study and mineral treatment test result. Data for financing analysis were submitted estimating equipment cost.

7) Economic/Finance

On the view point of finance, based on the data which can be obtained at the moment, mineral processing and equipment cost estimation, three plans (in this analysis, referred to as "Project Case") mentioned below as" A", "B", "C" from operation improvement plans of "Ingenio", were studied

Case No.	Project Case	Planned Term
A	Operation improvement of "Ingenio"	short
B	Construction of tailing treatment plant (tin recovery)	middle
C	Construction of integrate plant	long

Following precondition were set for analyzing upper mentioned study.

① construction and operation of the tailing dam (DCSA)

② applying the fixed cost at 1998

③ conceptual estimation with main items (selling price, investment cost etc.)

In addition, on the view point of economic analysis, quantitative analysis adding water quality improvement effect on the Pilcomayo river basin was tried.

8) Environment Management Plan/ Organization·System

(A) Literature Study

"Instruction for execution of National System on the Environment Impact Analysis and Environment Quality Control" prepared by VMDSMA was used as the basic literature of the Study.

(B) Study with interview for collecting information and data

Interview with key persons related besides hearing with Bolivian side counterparts was carried out.

(C) Impact study entrusting

Impact studies related to environment were entrusted to the consulting firm which is Bolivian agent of Transtec Co. in Belgium and CDR (NGO) for

obtaining reinforcement data to study/analyze area and grade of environment impact.

Table 1-2-1 Table of Work Schedule (1/2)

Format-5 WORK PLAN

TABLE OF WORK SCHEDULE (1)

Fiscal Year: Japanese Fiscal Year

Working Items	Fiscal Year	1997									1998												1999					
	Calendar Month	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	6	7
1. Domestic Preparatory Work in Japan																												
(1) Collection and review of data and information																												
(2) Preparation and submission of Inception Report																												
(3) Preparation of technical transfer plan																												
(4) Procurements of equipments and materials (for domestic procurement)																												
(5) Preparation and submission of questionnaire				▲																								
2. The First Site Investigation in Bolivia																												
(6) Presentation of Inception Report																												
(7) Collection and review of data and information																												
(8) Site investigation																												
(9) Preparation of domestic contractor																												
(10) Procurements of equipments (for site procurement)																												
(11) Collection of questionnaire																												
3. The First Domestic Work in Japan																												
(12) Analysis of data and information collected in the first site investigation																												
(13) Examination of mine pollution with Impact Process Response model (IPR model): the dry season / the rainy season																												
(14) Examination of elements and techniques of environmental management																												
(15) Selection of elements and techniques of environmental management																												
(16) Examination of elements and techniques of mine pollution protection																												
(17) Selection of elements and techniques of mine pollution protection																												
(18) Preparation of total system plan of environmental management and mine pollution protection																												
(19) Preparation of manuscript for Progress Report																												
4. The Second Site Investigation in Bolivia																												
(20) Investigation of domestic contractor (1)																												
(21) Basic investigation of environmental management																												
(22) Basic investigation of mine pollution protection techniques																												
(23) Preparation, submission, presentation and discussion of Progress Report																												
5. The Second Domestic Work in Japan																												
(24) Examination of the site investigation																												

Legend: ——— Preparatory work, ■ Site investigation in Bolivia, ▭ Domestic work in Japan, ▲ Submission of reports

Table 1-2-1 Table of Work Schedule (2/2)

TABLE OF WORK SCHEDULE (2)

Fiscal Year: Japanese Fiscal Year

Working Items	Fiscal Year	1997									1998												1999					
	Calendar Month	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
6. The Third Site Investigation in Bolivia																												
(25) Investigation of domestic contractor (2)																												
(26) Investigation of environmental management (1)																												
(27) Investigation of mine pollution protection																												
7. The Third Domestic Work in Japan																												
(28) Examination of the site investigation																												
(29) Cost estimation of proposed measures																												
(30) Preparation of the first technical transfer seminar																												
(31) Preparation of Interim Report																▲												
8. The Fourth Site Investigation in Bolivia																												
(32) Presentation of Interim Report																												
(33) Investigation of environmental management (2)																												
(34) Presentation and discussion of mine pollution proposed measures to identify issues																												
(35) Analysis of water quality forecast using river quality model																												
(36) Hold the first technical transfer seminar																												
9. The Fourth Domestic Work in Japan																												
(37) Examination of the site investigation																												
(38) Preparation of technical and political proposal (draft)																												
10. The Fifth Site Investigation in Bolivia																												
(39) Presentation and discussion of technical and political proposal: preparation of proposal																												
11. The Fifth Domestic Work in Japan																												
(40) Preparation of Draft Final Report																												
(41) Preparation of the second technical transfer seminar																												
12. The Sixth Site Investigation in Bolivia																												
(42) Presentation and discussion of Draft Final Report																												
(43) Hold the second technical transfer seminar																												
(44) Preparation of Final Report																												
(45) Submit Final Report																												▲

Legend: ——— Preparatory work, ■ Site investigation in Bolivia, ▭ Domestic work in Japan, ▲ Submission of reports

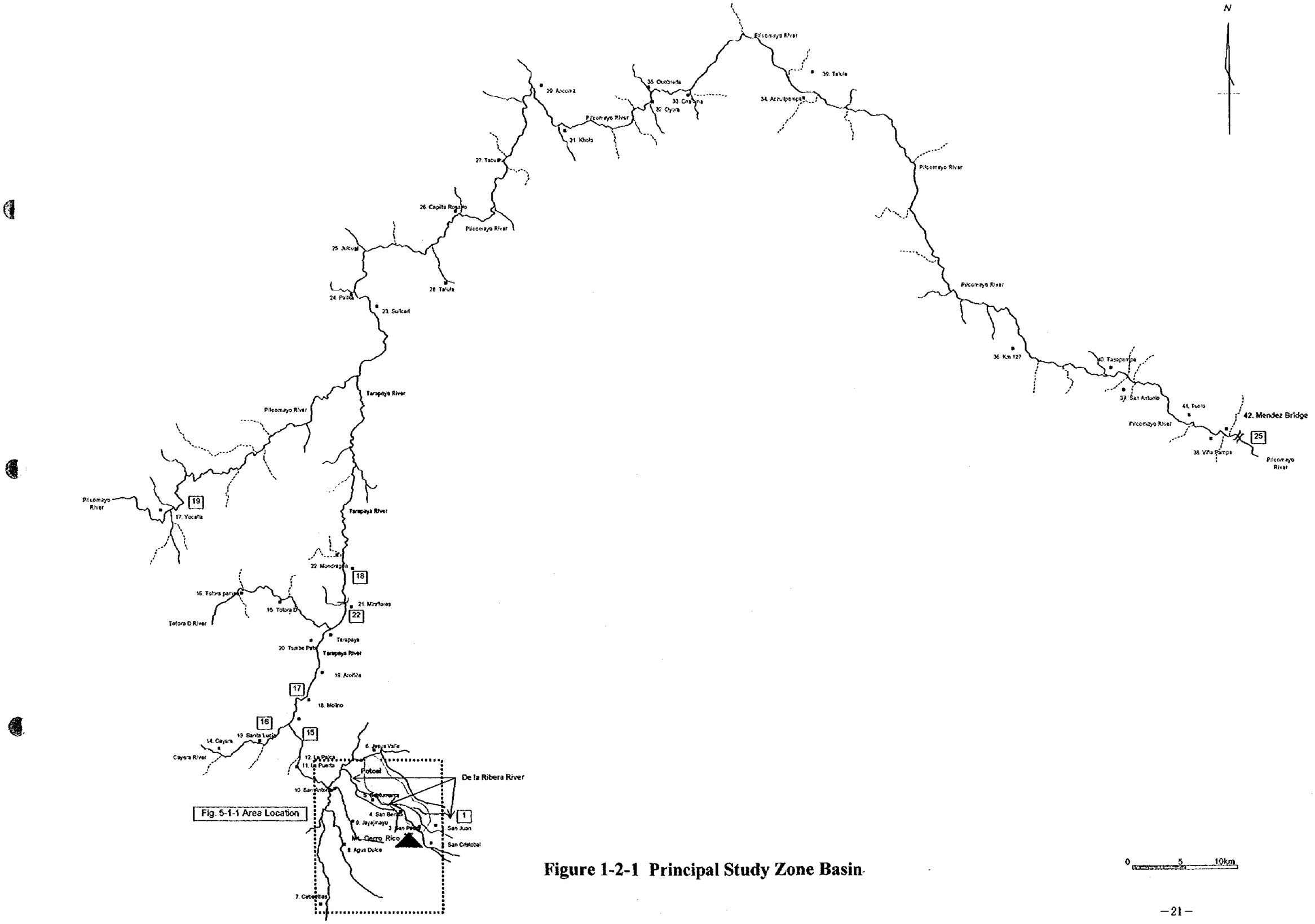


Figure 1-2-1 Principal Study Zone Basin

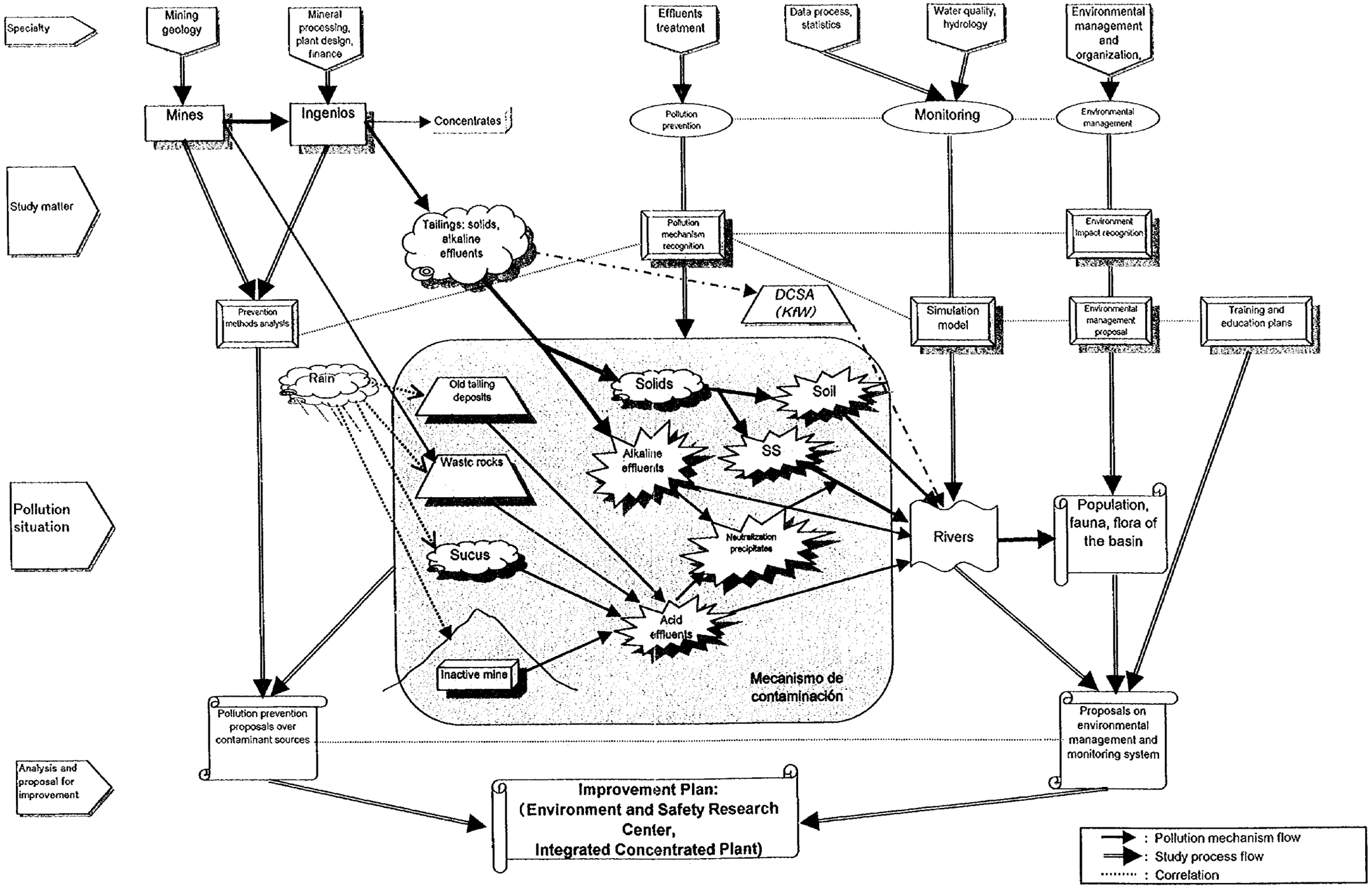


Figure 1-2-2 Study Context

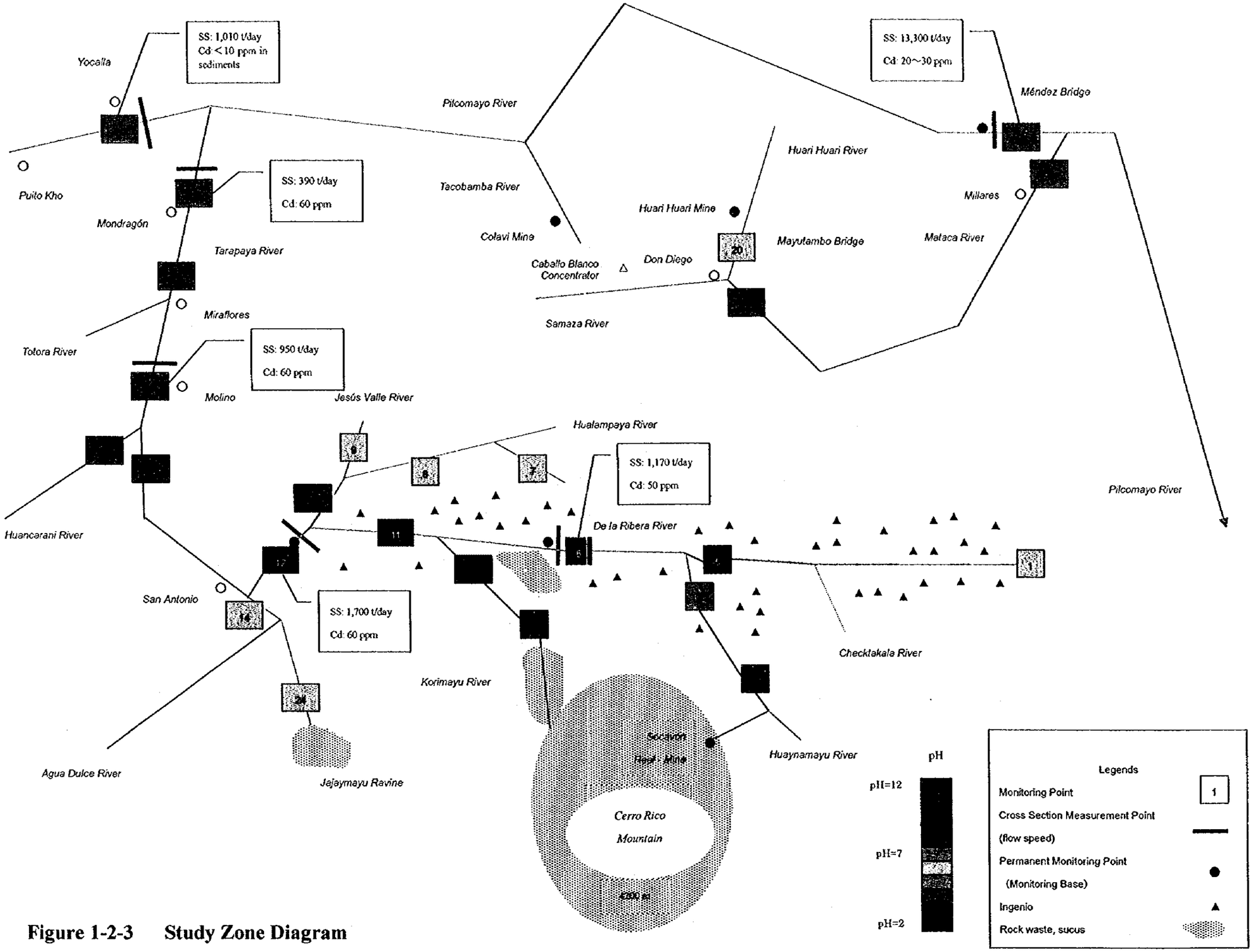


Figure 1-2-3 Study Zone Diagram

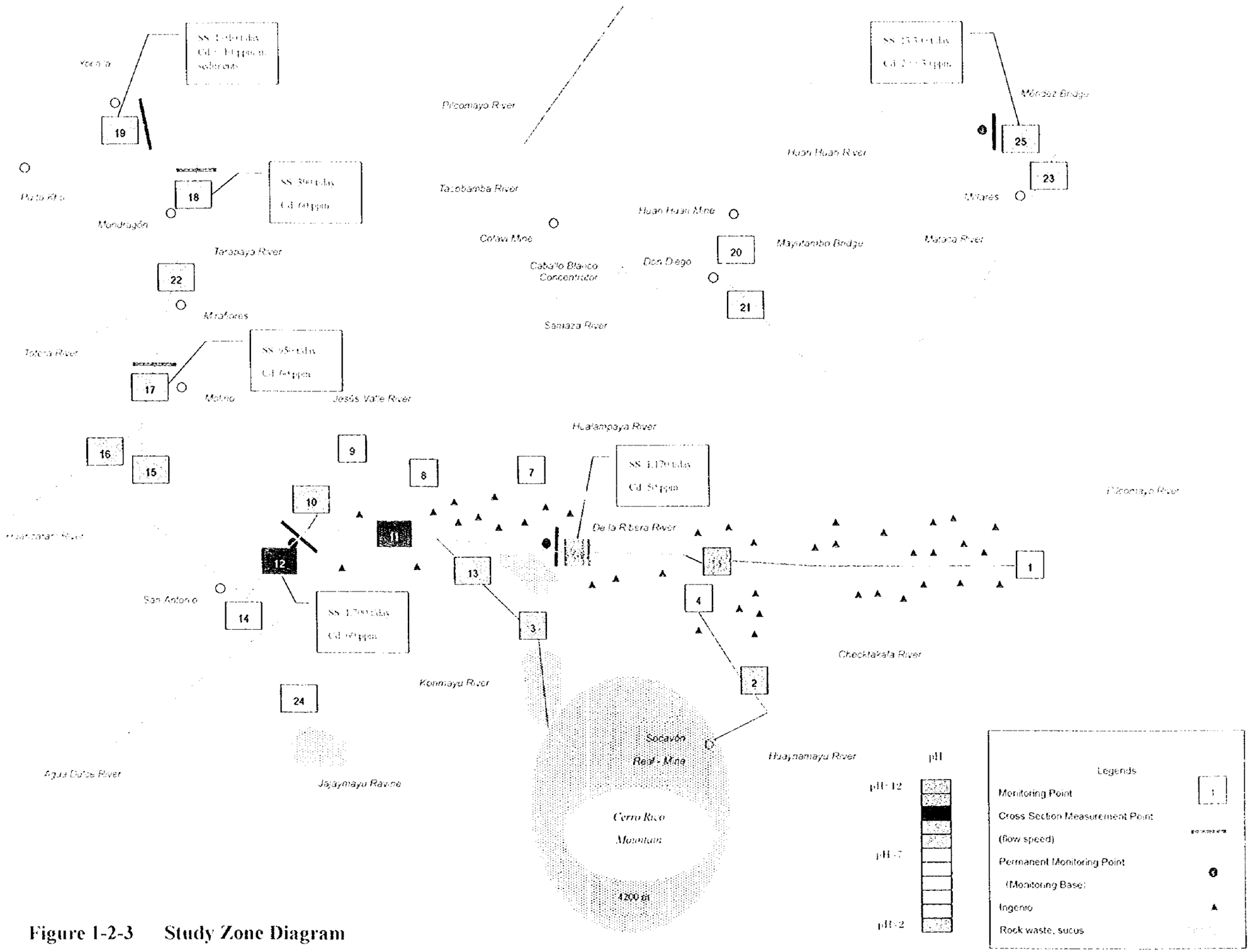


Figure 1-2-3 Study Zone Diagram

2 General View and Mining Affair in Bolivia and Potosi Prefecture

2-1 General View of Bolivia and Potosi Prefecture

This section describes the general view such as political, social and economical trends, and natural and environmental situation in Bolivia and Potosi Prefecture.

The numbers of figure and table shown in this section refer those mentioned in ANNEX (4).

2-1-1 Politics and Society

(1) History of Politics

① Around 2,000 years before Christ, Aymara tribe had their settlement around the Lake Titicaca.

② Around 1,000 years before Christ, Inka (Quechua) tribe came this country from their original field, around Cuzco.

③ By the end of 15 century Inka completed their conquest of Aymara.

④ On 1532 by Spanish, Inka empire was terminated.

⑤ On 1532, Sucre city was founded as a center of Spanish colonization.

⑥ On 1545, the silver mine was founded in Potosi.

⑦ On 1825, Bolivia got her independence from Spain, as a result of Independence War.

⑧ During 1879/1883, there was the Pacific Ocean War with Chile.

⑨ As the negative result of the war with Chile, on 1904, Bolivia lost the coastal area.

⑩ During 1964-1982, the military regimen administrated Bolivia.

⑪ On 1997, August 6th, the democratic regime President General in Retired, Mr. Hugo Banzar Suarez got the position of Presidency.

(2) Society

Social Data of Bolivia and Potosi Prefecture

Item	Unit	Bolivia	Potosi
Population 1995	1,000 persons	7,414	728
Population (Forecast:2000)	1,000 persons	8,329	774
Annual Population Increase	%, ave. 1995-2000	2.3	1.2
Birth Rate	%, ave. 1995-2000	3.3	3.4
Expecting Life in Birth	year ave. 1995-2000	61.4	56.3
Number of beds of Hospitals for 1,000 habitants	unit, 1995	1.5	1.4
Illiteracy	%, more than 15years old, 1995	20	38

The above Social Data of Bolivia and Potosi Prefecture and the Table 1 'National and Prefecture Level Population' show the prefecture-wise population. And the annual increase of population, is also shown in the Table 2 'Annual Increase of Population with Birth Rate, Average Life and Mortality'.

From these two tables it can be seen easily that Potosi Prefecture should expect to be an elder people's prefecture in the near future, even though the average life expectancy is the lowest in Bolivia.

The distribution race are indicated in the Table 3 'Race Distribution for Nation and Prefecture.

As to religion, according to the public opinion poll of 1992, 85% of the habitants are Catholic and 11% are Evangelist. The devotees of Evangelism are more numerous in rural areas where they can be more than 13% of the total inhabitants.

The number of hospital beds per capita and numbers of patients for typical diseases are shown in the Table 4 'Hospital Capacities and Diseases'. Regarding the number of hospital beds per capita, Bolivia is far below the other South American countries, like as Bolivia has 1.5 per capita compared to 3.1 in Chile. In Potosi the number of the beds ratio have been raised recently but the incidence of diseases is still one of the worst in Bolivia. In the case of cholera and malaria, due to the high altitude, the number of patients are lowest.

Regarding the illiteracy and educated attainment you can see in the Table 5 'Rate of Illiteracy and Number of Graduates in University', Potosi has relatively high illiteracy and a low number of university

graduates.

2-1-2 Industries and Energy

Industry and Energy Data of Bolivia and Potosi Prefecture

Item	Unit	Bolivia	Potosi
Farming Area	1,000ha, 1993	1,362	116
Agricultural Production value per area	Bs/ha, 1993	1,723	1,353
Comparison of Agricultural Production Value between Bolivia and Potosi Prefecture	1,000Bs, %, 1993	2,347,200Bs	6.7%
Comparison of National Gross Production and National Agricultural Production	%, 1993	12.4	-
Comparison of Livestock Breeding Production Value between Bolivia and Potosi Prefecture	1,000Bs, %, 1993	1,044,266Bs	4.3%
Comparison of National Gross Production and National Livestock Breeding Production	%, 1993	5.5	-
Comparison of Forestry Industry Production Value between Bolivia and Potosi Prefecture	1,000Bs, %, 1993	259,013Bs	0.5%
Comparison of National Gross Production and National Forestry Industry Production	%, 1993	1.4	-
Annual Tin Production Volume (share in the world)	1,000t, 1992	16.5 (8.4%)	3.6
Annual Zinc Production Volume (share in the world)	1,000t, 1992	143.9 (2.0%)	80.1

(1) Agriculture

Bolivia has an area of 1,098,581 km^2 but the cultivated area is just 14,000 km^2 that is currently only 1.3% of total area is used for agriculture. The above Industry and Energy Data of Bolivia and Potosi Prefecture and the Table 6 "Farming Area and Agricultural Production Value in Bolivia and Potosi" gives the agricultural production in Bolivia and in Potosi, with their farming areas. In Potosi the highland area, farming productivity is very limited. The area per farm is very limited e.g. 1 to 2 ha for each farmer against 5 to 10 ha in case of lowland area, and the farming method in the highland area is very old fashioned e.g. rotation three crops, potato, quinua, barley and rest. Instead of fertilizer, farmers use the sheep dung. Owing to the agricultural reform movement that started in 1953, many highland farmers have emigrated to the lowland area, and especially to Santa Cruz; this shift has the agricultural production improvement on a national basis.

(2) Stockbreeding

Bolivian raise cow, sheep, pig and camels. The numbers of each livestock are presented in the Table 7 'Livestock Breeding and Production Value'. Highland farmers, they work with these livestock for the agricultural purpose around 7 years and after that these livestock shall be commercialized.

(3) Forestry

In Bolivia there are 564,684 km^2 of forest, producing the annual value of forestry products of around Bs 300 million, which is shown in the Table 8 'Production Value of Forestry Industry in Bolivia and Potosi'.

With 40 other species of wood, the main species of wood to be industrialized would be MARA (50-57%), laurel (16-22%) and Ochoo (8-16%). This wood is used for the sleepers (22,000 m^3), telegraph poles (14,800 m^3), mining purposes (135,000 m^3) and others. Beside the wood, as the forestry business nuts, latex, vegetable carbon and firewood are important products.

(4) Fisheries

Since Bolivia has no access to the sea, and bad infrastructure for a cool and cold food delivery system, there is very limited consumption of fish as an aliment. It is estimated that the per capita consumption of fish is around 1.1 kg, in total around 7,400 tons/year. Around 60% fish are supplied domestically and rest of the consumption is imported. Meantime, the estimated surface of rivers where the fishes can be cultivated is around 14,192 km^2, which is more than enough to support the national consumption at 40,000 tons/year increasing the domestic production capacity from 5,000 tons/year to 35,000 tons/year, which can correspond with 6 kg/capita. At this stage the biggest fishing area is Rio Pilcomayo which correspond to around 48% of total production of the nation and 38% and 14% in the rivers of Amazon area and Titicaca area respectively.

(5) Industry (Manufacturing Products)

The share of manufacturing industries in the gross domestic product in 1993 was 18.8% at the national level and 6.7% at the Potosi level. As national level industries, excluding mining, crude oil and electricity, gas and water, the following industries are the largest groups at the national level: Oil Refinery, Tire and Tube, Meat Processing, Jewelry, Sugar Refinery, Alcoholic Drinks, Vegetable and Animal Oil.

In Potosi they are: Meat Processing, Powder Processing, Alcoholic Drinks, Bakery, Plastic Products.

In Bolivia there are three oil refineries operated by Bolivian Fiscal Petroleum Mine Company (YPFB), at Cochabamba, Santa Cruz and Sucre with 27,000 barrel/day, 15,000 barrel/day and 3,000 barrel/day capacity respectively. There are five cement manufacturers, SOBOCE (Viacha), COBOCE (Cochabamba), FANCESA (Sucre), El Puente (Tarija) and CAMBA (Santa Cruz), whose production in 1995 were 285, 204, 246, 43 and 90 respectively in thousand MT.

In Potosi, the following three companies are leading manufacturers: National Potosi Beer Company, Potosi Industry and the beverage company Centenario.

(6) Energy

In 1993, Bolivia consumed energy to the extent of 340 kg equivalent of petroleum per capita per day, which is very low compared with average of Latin America, 1,000 kg. The rural people of Bolivia use of only 262 kg, because the low density of the population makes it very difficult to provide good energy supply service.

In 1992 energy production was 53,869,000 barrels equivalent of petroleum and 26.5% of that was exported principally to Argentine as natural gas, and other 46.8% of primary energy was used for the production of energy, so only 30.3% on 16,344,000 barrels equivalent to petroleum energy was used domestically. The composition of use of the energy was 40.2% for residential and commercial use, 34.4% for transportation use, 1.3% for farming use, 23.7% for industrial use and 0.4% for others uses.

The Table 9 'Electricity Production Capacity, Production and Sales Volume' shows the name of companies who provide the electricity. Electricity produced by type of source, was hydraulic energy 56%, gas 37%, diesel 5% and others 2%.

Distribution of electricity has been managed by the several electricity distribution companies. Half of the stock of the state owned electricity generating company (ENDE), who is the biggest supplier of the electricity, was sold out to three United State electricity companies in July 1996.

2-1-3 Economy

Economic Data of Bolivia and Potosi Prefecture

Item	Unit	Bolivia	Potosi
Gross Domestic Products	million Bs, 1993	21,941	1,207
Comparison of Mining Industry Production and Gross Production in Bolivia and Potosi Prefecture	%	3.5	20.9
Yearly Income per Capita	US$ 1993	737	400

South American Country Yearly Income per Capita US$, 1993	Argentina	5,571
	Brazil	3,405
	Chile	2,812
	Peru	1,837

(1) GDP

The Gross Domestic Product of Bolivia in 1993 was Bs 21,941 million which corresponds to 114.7% of 1990 at 1990 value. The corresponding number for Potosi was Bs 1,207 million and 112.3% of 1990. The above Economic Data of Bolivia and Potosi Prefecture and the Table 10 'The Gross Domestic Product of Bolivia and Potosi', compared with the 1990 index, in 1993 we can see the remarkable increase in the items of Electricity, Gas and Water and Construction for Bolivia, and Construction for Potosi. Remarkable decreases can be detected in the Restaurants, Hotels and others for Bolivia and Electricity, Gas and Water and Public Service in Potosi. Potosi accounts for the 6.4% of the Gross

Domestic Product of Bolivia in 1993. And it is distinguished by the mining industry, which corresponds to 36.1% of the mining sector Gross Domestic Products in Bolivia.

The number of Bolivian Gross Domestic Product for 1996 is reported as Bs 31,840 million that corresponds with 125.5% of 1990 at 1990 value.

(2) Economic Development Policy

In Potosi there is no specific Economic Development Plan indicating the targeted index for coming years and even in Bolivia also there is no such plan but the following is a descriptive explanation about the latest Economic Development Plan of Bolivia. Based on this new policy and also getting the support of international developing agencies, it can be said the modernization of Bolivia has just started.

①Reform of National Bank System

②Reform of Procedure of Trading

③Privatization

④Public Participation

⑤Decentralization

(3) Employment

The Table 11 'The General View of Occupation in Bolivia', shows the types of jobs in which Bolivian peoples hold, and in the Table 12 'Age and Sex wise Employment in Bolivia', is employment by age and sex of them with the unemployment rate.

(4) Prices and Wages

The Table 13 'The Prefecture-wise Per Capita Yearly Income', shows the prefectural per capita yearly income trend in US dollars, from that it can be recognized that the people in Potosi have the lowest income in Bolivia. The Table 14 'Purchasing Power Parities Base Income of South American

Countries', shows the per capita income of the Bolivian people, even using the purchasing power parities base, Bolivia is the lowest group, in the countries of South America. The yearly inflation is steady the last five years with 10 %.

The Table 15 'The Minimum Salary and Average Salary' presents the Bolivian minimum salary and average in recent years.

(5) Exchange Rate and External Debt

The Table 16 'Latest 5 Years Exchange Rate Movement, Yearly Exchange Balance and Yearly Finance Debt Balance', gives the last five years movement for the exchange rate, the exchange balance and the year end foreign currency debt balance.

It shows the Bolivian currency, in average, is devaluate yearly around 7% against US currency. And the negative balance of trade is adjusted with loan from abroad.

(6) Trading

The Table 17 'Yearly Trading Balance', the Table 18 'Yearly Products wise Export Amount', the Table 19 'Yearly Products wise Import Amount' and the Table 20 'Yearly Main Trade Partners' shows the trading balance with the main export and import products in detail. During the last five years, even though it was not large, the trade balance of each year was negative, so the official foreign exchange debt is increasing.

(7) Traditional Rule

By law in 1952, it was made clear that all agricultural land can only belong to the persons who actually cultivate the land. This law was prepared to promote the efficient usage of the farming land.

Regarding the usage of farming water, there is a system of 'judges of irrigation water', by which all farmers cooperate in using community farming water fairly, and even sometimes participate in the

irrigation channel cleaning works.

In Bolivia, beside the administration units, like as the prefecture and municipal city, whose leaders would be appointed by the state president and selected by the habitants respectively, there is a social organization in province, community and villages, whose leaders are selected by the habitants, and to assume the function of coordinators under the name of 'Curaka' and 'Leader'.

(8) Environmental Infrastructure

Each city of Bolivia has an self-standing water supply and drainage service administration. In the case of Potosi, the Autonomous Administration for Sanitation Work (AAPOS) is responsible for the potable water supply and City Administration is responsible for drainage service in the city. At this time the potable water is supplied to the 15,819 contracted parties which correspond more than half of habitants in the city, and in the case of rural area around 26% of requirements are met by the administration of UNASBA.

The municipal office is also in charge of the city urbanization planning, who is now preparing the new city urbanization plan taking the environmental issue into the consideration.

2-1-4 Natural Standing Description

(1) Nation

The official name of the country is;

Republic of Bolivia, which has SUCRE as an official capital and La Paz as the practical capital.

(2) Geography

Republic of Bolivia locates in the center of South America, having her land extension with 1,098,591 km^2 between 69°8'and 58°25' of longitude west and 9°38' and 22°53' latitude south. The Potosi prefecture, having her land extension with 118,218km^2 and the location of the capital of Potosi, is

68°12'00" longitude west and 16°30'30" latitude south.

The Figure 1 'Country Map of Land Elevation' indicates the height of land from which, the country can be divided into three regions because of the geographic nature, as the high land area, the valley area and the plain area and their occupation in the country is 16%, 19% and 65% respectively. The nine of the prefectures of the country can be classified into these three area as the Table 21 'The list of Name of Prefectures and their Capitals with Name of Provinces in Potosi'. The sixteen provinces of the prefecture Potosi are indicated in the Figure 2 'Potosi prefecture Political Map'.

(3) Weather Condition

The weather characteristics of the country can be introduced with four different aspects, which are;

①High Land weather:

This area can be characterized as typical high land climate, hot day time and cold night time with small precipitation and limited plantation, like as potato, broad bean, oat etc.

②Valley weather:

This area is in the semi-tropical weather the average temperature and precipitation are 15°-20°C and 690-790mm respectively which offer the relatively good weather for the living.

③East North Plain weather:

Having high temperature and high precipitation, it is typical tropical rainy weather area

④East South Plain weather:

This area is dry and mild weather condition can be considered as savanna weather area.

The Figure 3 ' Country Map of Type of Climate' and the Figure 4 'Country Map of Precipitation' and the Figure 5 'Country Map of Temperature' can present the climate, rain condition and temperature of the country. The Table 22 'The Data of Temperature and Precipitation in Potosi' can demonstrate the past 15 years average of the temperature and precipitation of the area.

(4) Forest

As shown in the Table 23 'Prefecture wise Forest Area' , Bolivia occupies the 8th position in the world for the size of forest area in one country, that is 564,684km² as 51.4% of total area.

The forest in Bolivia is administrated by Ministry of Agriculture, Stock Breeding and Rural Development under the General Law of Forest with the collaboration of Ministry of Sustainable Development and Planning.

(5) Hydrology

The rivers and the lakes are main hydrological resources in Bolivia, in case of the rivers form the valleys, in the Table 24 'The Hydrological Surface of Valleys' can see the size of valleys in comparison with the total land area of Bolivia. In the Table 25 'The Bolivian Main Rivers with their Length' can see the size of the river Pilcomayo which is the targeted river for this study.

In Bolivia there are several important lakes, which are Titilcaca, Poopo , Uru Uru, Salt Lake in Uyuni and Salt Lake in Coipasa. The superficial size of these lakes are 8,300km², 1,337km², 214km², 10,582km² and2,218 km², respectively.

The Figure 6 'Country Map of Hydrology' shows the main valleys and lakes in Bolivia with three zoning of water flow, the valleys of North or Amazon, the valley of Center or Lacustre and the valley of South or Plata. The rivers and lakes in Bolivia is administrated by Ministry of Sustainable Development and Planning.

(6) Wild Animals, Plants and Protected Areas

In the Environment Law, Article No.52 to No.57 clearly mentioned about the protection, conservation and recuperation of the Wild Animals and Plants.

As in Bolivia there are 2,342 species of vertebrate, including 1,274 species of birds and 282 species of

mammal, 250 species of reptile, 110 species of amphibians and more than 500 species of fishes, and 50 species of them are only can be seen in this country. And there are many species of plants in the country.

As the Table 26 'The number of camel family in South America' , in Bolivia 'llama 'alpaca', 'vicunas' and 'guanaco' are important animals in the economical reason of peoples lives.

To administrate these special species, based on the above mentioned law, there are 21 Protected Areas in Bolivia which are shown in the Figure 7 'Map of Reserved Areas' and the Table 27 'List of Protected Animals'. The Wild Animals, Plants and Protected Areas in Bolivia is administrated by Ministry of Sustainable Development and Planning. In Potosi Prefecture there are four protected areas, one of them is 'Eduardo Avaroa', which has as area 714,475 ha and the geological position is between 22°00', 25°53' and 22°00', 22°56' of latitude south and 66°56', 68°02' and 67°58', 68°40' longitude west, where the two species of camel family, Vicunas and Guanacos and four species of flamingo family, Chilensis, Andinus, Jamesi and Nandu Petizo are main target for the protection.

(7) Soil

In the Environment Law, the protection of soil for the forest and agriculture is clearly mentioned. And especially the Potosi area has such character to create the sandy land because of the erosion to be made by the strong wind and the dry climate. One of the preventive movement promoted by the administrations is the works for the Program National for against desert and drought (PRONARDE).

The soil in Bolivia is administrated by Ministry of Agriculture, Stock Breeding and Rural Development under the General Law of Forest with the collaboration of Ministry of Sustainable Development and Planning.

2-1-5 Special Environment Outline

Cerro Rico Mountain for its geographic viewpoint and Potosi City for its historic viewpoint were nominated as world heritage for its nature and culture by UNESCO on December 7th, 1987.

After being explored the mineral by COMIBOL in the Cerro Rico Mountain, Potosi Citizen are anxious in general being explored again dramatically and modifying the shape of the mountain.

2-2 Mining condition of Bolivia and Potosi Prefecture

2-2-1 Mining condition of Bolivia

GNP par capita of Bolivia is $770 (1994), and mining is one of main industries. Bolivia is one of the great mining countries in the world that mining productions, zinc, lead, tin, oil, LPG etc., occupy more than half of its export industrial goods.

Mining field is the most important in historically and economically.

Mining in Bolivia was boosted by the tin production since the end of silver production era under Spanish occupation. In particular, discovery of silver at Potosi in 1545 and began large-scale silver production, nonferrous metal era came to Bolivia.

However, in 18 century, mining in Bolivia and Potosi has shrunken lack of silver resources and independent war. Then, tin boom in 19 century occurred. COMIBOL (Corporacion Minera de Bolivia) had begun to operate as national company in 1952.

However, tin price corruption in October 1985 inferred on tin and related industries serious impact. In particular, COMIBOL which grew up the biggest mining company suffered strongly, and the labors decrease drastically into 1/20, while nearly 30,000 labors has worked at its peak.

Since the tin price corruption, each mining company has progressed modernization with introduction of foreign investment, privatization etc. COMIBOL has also been decomposed and privatized by shortage of resources and increase of cost.

Circumstances of mining are still severe. Mining Bank, Exploration Fund etc. are closed by lowering of mechanism. Under this situation, administration of small-scale miners become harder by lost of supporting system.

On the other hand, Vivid and long history of mining activity, particularly putting priority on the production, have caused mining pollution problem, and occurs precaution of pollution export.

Environmental law was established in 1995, VMDSMA was reinforced in MDSP putting their power on the environmental issues. However, MDSP annoys how to balance dilemma of

economical development and environmental protection.

2-2-2 Mining in Potosi Area

The mining activities in the Potosi area included in the scope of the study are mainly composed of the followings;

① Mines : The Empresa Minera Pailaviri R.C., a medium scale company in the COMIBOL group, and the Mining Co-operative Association composed of 30 small scale companies.

② Ingenios : Medium and small scale concentrators amounting to 42 in total.

The followings are the descriptions concerning the geology, ore deposit, mining and mineral processing in the area.

Intention of research

This research have been done to define the potential reserve of hard rock ores, surface dumps, colluvial and alluvial ores, in the Cerro Rico de Potosí mining area. This research will contribute not only to grasp ore reserves but also the study on evaluation of environmental impact.

Procedure of research

To get information about mining and geology on the Cerro Rico deposit, we studied information about annual operation on the mine, and literature about this mine. Also we follow the first site survey and analysis on the reply to our questionnaire. At the same time we make field survey around and inside of the mine.

Studying about the operation on veins, we have got some part of important information about annual operation on the mine from 1969 to 1993, presented by COMIBOL both in Potosí and La Paz.

Information about reserves on bulk mining, we have gotten some reports, which are available

to calculate potential reserve on disseminated silver type hard rock ores, dumps and colluvial/alluvial ores.

General information

a) Name of the deposit ;

Cerro Rico de Potosí

b) Address ;

Concepción, Tomás Frias Province, Potosí Department, Bolivia

c) Coordination ;

65°45'W, 19°37'S

d) Location;

The deposit is located 3 to 5 km south from Potosí City. The mining area is located in more than 4,000m above sea level. The top of the hill is described as 4,824m above sea level on the 1/50,000 topographical map, and as less than 4,800m in some literature.

e) Access;

The railway is connected from La Paz, Oruro, and Sucre and up to ports of Antofagasta and Arica in Chile. Distance by road from Potosí to La Paz is 574 km, 335 km to Oruro and 166km to Sucre. Regular domestic flights are available from Sucre airport.

f) Mining history;

The Cerro Rico de Potosí is the world's largest known silver deposit. Recorded production of silver since mining began in 1545 to 1995 has been 30,000 to 60,000 tons in average grade 500 to 650 g/t of silver. It is said that there was 5,000 mine entrances, but now there are about 450.

In the early years, oxide ores of 30 to 50% silver were mined from 4 principal veins with 4m in width near the top of the hill "Cerro Rico".

In 1572, super high-grade silver ores have almost mined out and began to mine silver sulfide

ores in underground. Then amalgamation method was applied importing mercury most from Peru. After that, silver production remained relatively high till end of the 18th century.

In the early 19th century, in which 1825 is a year of the Bolivian independence from Spain, silver mining in this deposit drew to an end, because of reduction of silver ore reserves and falling down silver market price, and changed gradually to tin mining.

In 1920's, a demand on tin rose up and it was mined actively.

In 1952, a public corporation COMIBOL was established and the Cerro Rico de Potosí mine was nationalized as a government property.

During 20 years from 1960, tin recovery from tin-bearing cobble on surface of the mountain, so called colluvial deposit, was performed in large scale by conventional gravity separation method with hose water. Burying valleys of flanks, huge volume of remnants by this activity, named "Sucu", was formed.

In 1985, falling heavily the tin market price, target mineral of mining from this mine has changed from tin-silver ores to zinc-silver ores. At the same time, flotation method has introduced to mineral dressing, and grain size of treated ores became to fine-grained from coarse-grained.

In 1987, UNESCO specified Potosí City including Cerro Rico as "Human cultural and natural inheritance". Therefore the shape of hill "Cerro Rico" should be maintained as it is even mining activity exist.

In 1994, COMIBOL have got out of operation for the mine, and leased her mining claims to small mining operators.

g) Names of operating groups;

1) Empresa Minera Pailaviri R.C. (hereinafter called Pailaviri R.C.) 2) About 30 groups of mining cooperatives.

h) Mining claim (1987 at present);

There are about 50 mining claims in the mining. The largest one "La Boliviana", which covers about 6 km² of the most part of the hill, is owned by COMIBOL. COMIBOL owns much of the alluvial deposit but a large part belongs to others. At present, mining claims are leased to operating groups.

General geology

The Potosí deposit is located in central portion of tin mineralization belt in the Eastern Cordillera of Bolivia. Geology of this deposit consists of Ordovician formation, Miocene formations and Cerro Rico dacite stock. (Fig 3-1, 3-2)

Sugaki, et al. (1985) is described about general geology of this area as follows.

The Ordovician formation is composed mostly of slate with small quantities of sandstone and quartzite. It generally strikes northwest and dips gently southwest

The Miocene formations covered near flat on the Ordovician slate with unconformity consist of conglomerate, dacitic tuff and tuff breccia (Pailaviri Formation), and dacitic fine tuff with shale (Caracoles Formation) in ascending order.

The Cerro Rico dacite stock intrudes into Ordovician slate, dacitic tuff, tuff breccia, and fine tuff of the Miocene formations. Dacite porphyry of the Cerro Rico Stock has quartz, orthoclase and biotite, as phenocrysts, but is affected by hydrothermal alternation of sericitization, kaolinizaton and chloritization. Also pyritization is often found in the rock.

Geology of the Cerro Rico de Potosí deposit

a) Related volcanic rock

The Potosí intrusive, which is a dacite stock, is the principal host rock for the mineralization, and forms the Cerro Rico dome.

The dacite intrusive is now recognized to be a ring dome. It appears that the Cerro Rico dome was emplaced along a zone of pre-existing structural weakness related to an anticlinal

flexure in the pre-caldera Palaeozoic section and/or a ring fracture associated with the formation of the Kari Kari Caldera (20.8Ma) (Bernstein, 1989).

The surface dimensions of the dome are approximately 1,800 × 1,200meters, narrowing sharply with depth, until at 1,150 meters below the surface, it becomes a dike-like body only 100 meters wide. At this level the "dike" is parallel with the axis of an anticline in the Paleozoics (Bernstein, 1989).

b) Mineralization

Ore deposit of the Potosí mine are composed of hydrothermal veins filled up innumerable fissures developed in Ordovician slate, dacitic tuff, and tuff breccia and dacitic intrusive dome. They also occur well in dacitic fine tuff of the Caracoles formation rather than in tuff breccia of the Pailaviri formation. Although veins run as roughly parallel, there are found the fractures of two systems: one is NNE-SSW or N-S direction and other, NE-SW strike (Sugaki, et al., 1985).

The tin veins, which are frequently only 5 cm wide, occur in the dacite porphyry. The 0.5 to 1.5 m wide Ag-Zn veins occur in the surrounding Caracoles breccias and tuff and only very rarely in the porphyry. Ag-Zn veins show about 500 to 600 g/t Ag, 10% Zn in average ore grade.

However, because of the low temperature deposition, the silver is finely disseminated throughout the wall rock. Average grades between the main veins are 100 g/t Ag (Keith, 1988). In this study, a sample of silicified dacitic porphyry from parking lot, where is 100m below from the top of the hill of the North Slope, showed 186 g/t Ag and was not detected gold.

The dimensions of the principal veins in the Potosí deposit are given in the following table.

Principal veins and their dimension in the Potosí deposit

Veins	Strike	Dip	Length	Depth	Width
Bolivar	N35°E	70°W	500m	420m	0.25m
Bolivar 1 ramo 1		N10°-20°E	80°W	150m	60m+
0.3m					
Bolivar 2	N25°E	80°W	400m	400m	0.2m
Bolivar 4	N20°E	85°W	500m	200m	0.2m
Bolivar 5	N30°E	75°W	300m	420m	0.4m
Bolivar 6	N25°E	80°W	600m	300m	0.2m
Bolivar Nueva		N25°E	80°W	500m	450m
0.2m					
Utne 2	N40°E	85°W	400m	450m	0.4m
Utne 3	N45°E	85°W	300m	420m	0.4m
Utne 4	N40°E	65°W	950m	450m	0.5m
Tajo Polo 1	N-S	75°W	500m	370m	0.8m
Rica 2	N40°E	90°	450m	250m	0.3m
Rica 2A	N25°E	90°	450m	290m	0.3m
Mendieta 2	N60°E	85°W	460m	400m	0.3m
Don Mauricio		N20°-30°E	75°-80°E	650m	490m
0.5m					

(Sugaki, et al., 1985)

c) Hydrothermal alteration

Alteration of the dome is pervasive, so that the original rock type is difficult to identify. The rock has been alternately described as dacite, rhyodacite, and latite porphyry. Pre-mineralization alteration is dominated by sericite at depth, and silicification near the top (Sillitoe, 1975).

Upper part of the Cerro Rico is intensely silicified. The top of the hill is porcelain-like silicified. At lower levels, silica, sericite, and clays are the principal minerals, which have replaced most of the dacite, although original quartz is very common. Tourmaline is present at depth.

d) Mineralogy

Towards the center of formation of the intrusive are high temperature minerals such as cassiterite, pyrite, wolframite, and arsenopyrite. And toward the outside are low temperature silver minerals and Pb-Zn-Ag sulphosalts. The mineralogy is extremely complex with pyrargyrite, sphalerite, galena, tetrahedrite, jamesonite, boulangerite, stannite, and others.

These ore minerals occur in intimate association with gangue minerals of quartz, tourmaline, alunite, kaolinite, sericite, phosphophyllite and siderite etc. (Sugaki, et al., 1985).

The oxide zone in upper part and the sulphide zone in lower part are lined at about 4,400m level.

Cerro Rico ores contain very little gold. A sample from the Mendieta Vein on the Pailaviri Level was assayed 6,210 g/t Ag, a ratio of about 5,500 g Ag to one gram Au (Bernstein, 1989).

Mining

A) Exploration

In recent years, mining company and groups did not realize exploration by diamond drilling, crosscut and drift. A few geologists are working for sampling at cutting faces for assay map in the Pailaviri mine, where Pailaviri R.C. is operating.

In the Potosí deposit, where cooperatives are operating, it seems to be no geologist or underground map. But some geologists are temporally employed and make a geological recommendation. Therefore it seems that it can not be calculated for enough ore reserves, but of only about one more year.

b) Production

COMIBOL have been producing tin crude ores of the Cerro Rico de Potosí deposit from 1952 to 1985. The latter half of these 34 years, she produced 200,000 to 450,000 tons of ores containing 0.5 to 0.6 % Sn every year. Because of a slump of tin market price in 1985,

COMIBOL began to produce silver instead of tin. From 1986 to 1993, COMIBOL produced about 50,000 tons of ores containing 260 to 330 g/t Ag, 3 to 7 % Zn every year. In 1994, COMIBOL have got out of operation for the mine, and leased her mining claims to small mining operators. Before the getting off of COMIBOL, mining cooperatives have already begun to mine. In 1993, they 28 groups produced 1,000 to 1,500 tons of crude ores by 10,000 workers (Chavez, J.M. 1994?).

PAILAVIRI R.C. and 25 groups of mining cooperatives are mining silver-zinc ores from the Cerro Rico de Potosí deposit. Total producing tonnage is estimated about 1,300 to 1,600 t/d, while Pailaviri R.C. produces about 300 t/d and cooperatives produce rests of them. The mining area of Pailaviri R.C. and cooperatives are separated basically.

A part of mining production record is as follows.

Mining production in Cerro Rico de Potosí

Year	tonnage (t)		ore grade		
	COMIBOL	(others*)	Sn (%)	Zn (%)	Ag (g/t)
1972	268,571	--	--	--	--
1976	279,835	--	0.97	--	--
1980	422,578	--	0.46	--	--
1985	194,886	--	0.63	--	--
1988	75,232	(*250,000?)	--	3.20	271
1993	47,436	(*250,000?)	--	6.82	328

(COMIBOL, Annual report)

* Estimated production by cooperatives

* Ore grades are only of COMIBOL product

The other hand, waste rocks in mine dump, which contains low grade tin but 100 to 200 g/t Ag, has been sent to the COMCO heap leaching plant for silver, which is located 5 km south of the mine. The COMCO plant treated ores about 300,000 t/y containing 150 g/t Ag with its

capacity 1,000 t/d, in 1997. During ten years from the beginning of this plant to 1997, about 2,700,000 tons of ores were treated.

c) Mining method

Cut and fill stopping and shrinkage stopping method are adopted in the Pailaviri mine. They have two shafts equipped with electric winches, trolley trains, compressed air drills etc., but heavy machines as LHD or jumbo drill.

In the Potosí deposit, where cooperatives are operating, it is not applied a systematic modern mining method but a kind of gophering. Hands do most of operations and it is recognized many points which are out of the Japanese safety standard in mining.

d) Structure of the mine

The Pailaviri level in 4,205m above sea level is called the 0 (zero) level. In intervals of every about 30 m of elevation, major drifts were constructed, and the 15th level is the lowest.

Two shafts connect adits from the 0 level to the 10th level. Levels below the 10th level in 3,900 m are submerged. It was certified to be 437 mine mouths in 1993.

e) Mined veins

Tin oxide ores in the oxide zone of up to 4,400 m have almost entirely mined out. Most part of tin ores between levels of 4,200 to 4,400 m, most of them are tin sulphide, which are difficult to treat in dressing plant, have mined out.

Silver ores in levels up to 4,400 m have mined out till the 19th century. At present, silver-zinc ores are being mined actively in levels between 4,200 to 4,400 m. Silver-zinc veins are situated in tuff breccia and tuff of Caracoles formation surrounding dacite dome, but are rare in dacite dome. Veins under operation are located in the southeastern part of the mine at present. They, the Don Mauricio Vein (0.5 to 2 m width), the Tajo Polo Vein (0.5 to 1 m), the Santa Rosa Vein (0.5 to 1 m), the Mendieta Vein (0.5 m) etc., have been discovered years ago and were mined for long years. Therefore they are not expected to be remained considerable

ore reserves. The other hand, the Plomo Vein was recently discovered and expected having high ore grade and enough reserves.

Ore reserves on vein type silver-zinc deposit

a) Information for ore reserves by COMIBOL (Jan/1993)

Yearly information for Calculation of reserves on the Cerro Rico de Potosí was realized for Ag-Zn veins by COMIBOL until 1993, when they have got out of operation on the mine following year.

Resume of Calculation of reserves on 1993 is given in the following table.

Resume of Calculation of reserves

In Cerro Rico de Potosí on 1993 (Ag-Zn veins)(Original report)

TYPE OF RESERVES	TONNAGE t	Ag g/t	Zn %
PROVED	43,823	635	8.48
PROBABLE	33,593	657	14.79
POSSIBLE	88,686	487	9.25
TOTAL	166,102	559	10.16
PROSPECTIVE	563,613		
GRAND TOTAL	729,715	559	10.16

(COMIBOL, Jan/1994)

b) Information for ore reserves by COMIBOL (Mar/1993)

After above-mentioned report, COMIBOL recalculated ore reserves on this deposit as follows, because of declining of silver metal prices.

Resume of Calculation of reserves In Cerro Rico de Potosí on 1993 (Ag-Zn veins)

(Recalculated report)

TYPE OF RESERVES	TONNAGE t	Ag g/t	Zn %
PROVED	29,826	812	15.26
PROBABLE	161,585	732	12.98
RESIDUAL MINED ORE	55,570	297	5.52
TOTAL	246,981	644	11.58
PROSPECTIVE	770,740		
GRAND TOTAL	1,017,721	644	11.58

(COMIBOL, March/1994)

c) Information for ore reserves by Pailaviri R.C.

Information on ore reserves at present was not encountered. If there is an information on calculation of ore reserves, it might inform about 50,000 to 150,000 tons of ore reserves, because exploration by boring is not performed for long years.

d) Information for ore reserves by cooperatives

It seems that there is no information about ore reserves.

Ore reserves on silver disseminated type deposit

The Cerro Rico de Potosí has being mined to Ag-Sn-Zn-bearing veins of 10 cm to 2 m in width. However in the wall rock of these veins are disseminated with silver bearing minerals, which are recognized as a huge tonnage of disseminated silver ores, and expected to exploit with a bulk tonnage mining method, as open pit or stopping.

Bernstein, M. reported about ore potential reserve on silver disseminated type deposit as follows. This report was prepared for "UNDP Project Bol/87/012", on June 30th in 1989.

Potential Hard Rock Ore Reserves in Cerro Rico de Potosí (Silver disseminated type deposit)

High Grade Ore	Low Grade Ore		Waste			
Orebody	>90 g/t Ag		30~89 g/t Ag			<29 g/t Ag
(t)	(g/t Ag)	(t)	(g/t Ag)	(t)		
Above 4,400m level	132,466,400	174	259,893,700	72.9		51,394,860
4,400-4,205m level	10,156,740	174	39,105,495	73.9		9,057,455
TOTAL	142,623,140	174	298,999,195	73.0	60,452,315	
GRAND TOTAL	441,622,335 t		105.6 g/t Ag			

(Bernstein, 1989)

Ore potential reserve on colluvial /alluvial deposit

On the slope and foot of the "Cerro Rico" hill, there are colluvial and alluvial deposit. "Sucu" containing low graded silver occupies most part of them, which are remnants by conventional gravity separation method with hose water.

And also, in front of numerous mine entrances, there is waste dump from underground containing low-

grade tin and silver.

In the report mentioned above, Bernstein (1989) also reported about ore reserve potential on colluvial/alluvial deposit and mine dump as follows.

Potential Colluvial/Alluvial Ores in Cerro Rico de Potosí

Deposit	Tonnage (t)	Ag (g/t)	Sn (%)
Santa Rita	25,000,000	72.1	0.13
El Diablo	30,000,000	71.4	0.14
Huakajchi	45,000,000	80.7	0.10
Total	100,000,000	75.7	0.12

(Bernstein, 1989)

Cerro Rico Mine Dump Estimate

	Tonnage (t)	Ag (g/t)	Sn (%)
Dumps	5,600,000	213.1	0.1～0.25*

(Bernstein, 1989)

Ore reserves on vein type tin deposit

In 1986, COMIBOL got off tin mining and started silver-zinc mining.

Resume of Calculation of reserves for tin on 1986 is given in the following table.

Resume of Calculation of reserves. In Cerro Rico de Potosí on 1986 (Sn veins)

TYPE OF RESERVES	TONNAGE t	Sn %
PROVED	275,708	1.23
PROBABLE	843,482	0.97
RESIDUAL MINED ORE	186,667	0.86
TOTAL	1,305,857	1.01
WAST DUMP	759,549	0.50
TAILING	5,201,840	0.81
TOTAL	5,961,389	0.77
GRAND TOTAL	8,668,908	0.91

(COMIBOL, 1987)

Analysis of research

It could not be obtained enough data regarding to ore reserves to forecast future operation, because it has

not reported information about calculation on ore reserves since 1993, and it has not performed exploration by boring and tunnel in about ten years. It is required a systematic exploration to form an exploitation plan and ore treatment plan for future.

Analyzing above-mentioned data, the life of this mine is estimated as follows.

a) Silver and zinc vein type deposit (Objective of current mining)

The COMIBOL calculated the ore reserves of silver and zinc vein type deposit at the end of 1993 as 1,017,721 tons, with 644 g/t of Silver and 11.58 % of zinc, including prospective ore reserves, and, since then, has not made any further exploration. The scope of the said calculation of ore reserves was limited only to those associated with the Pailaviri. The life of the ore reserves will be for 11 ~ 17 years after 1994, if the current grade of crude ore and ore production of 60 ~ 90 thousand tons/year would be continued at the Pailaviri. In order to secure a stable ore production in the long terms, it is necessary to lower a cut-off grade of ore in view of resultant expansion of minable ore reserves. It is necessary as well to perform new explorations in the surrounding districts aiming at possible substantial increase in ore reserves. As results of these performances, it will be possible to secure ore reserves required through the years until 2015~2020.

Meanwhile, the Mining Co-operative Association currently keeps ore production of 140~360 thousand tons/year, and has almost no data with regard to ore reserves. It is necessary to secure ore reserves similar to the case of the Pailaviri through the same performances as mentioned above.

b) Silver disseminated type deposit (No objective of current mining)

Bernstein. M. reported in 1989 the potential ore reserve of silver disseminated type deposit as 441 million tons, with 105.6 g/t of silver and 0.1 ~ 0.17 % of tin. Among the said ore reserve, high grade portion was reported as 143 million tons, Ag 174.0 g/t, Sn 0.1 ~ 0.25 %, which will be a future objective of silver recovery by means of heap leaching. Although open pit mining is required to develop

this type of ore deposit, the application of open pit mining will be difficult under the circumstance that Potosi City including the Potosi Mountain has been designated as one of the world heritages.

c) Colluvial/alluvial deposit (No objective of current mining)

Bernstein. M. estimated in 1989 as follows;

① Waste rock (Desmonte): 5,600 thousand tons, with 213.1 g/t of Ag and 0.1 ～ 0.25 % of Sn

② Sucu:100 million tons, with 75.7 g/t of Ag and 0.12 % of Sn

Among these deposits, the high grade portions will be able to become objectives or resources of silver and tin recovery. The test results in a model plant for silver recovery will clarify the minimum ore grade and ore reserves of possible future recovery.

d) Tin vein type deposit (No objective of current mining)

The last calculation of ore reserves concerning tin vein type deposit in 1986 indicated as 1,310 thousand tons in the underground with the tin (Sn) grade of 1.01 %. However, the mining was abandoned in 1986 due to unfavorable turn of the economic situation. It is necessary to look over again a mining possibility if, in the future, an economic situation would take a substantially favorable turn and a mineral processing technology with low cost would be applied for tin recovery.

Mining/Geology

Aiming to technical and political proposal

The life of the vein type silver-zinc underground mining deposit, where is under operation by Pailaviri R.C., is estimated more than 12 years, and where by cooperatives is estimated about 4 years.

But it is forecasted that, decreasing production, the mining activity of this mining area will continue for more than 10 years, and after that, small amount of production will continue more years.

The life of mine dump, which has being supplied to COMCO heap leaching plant, is more than 11 years.

To prevent pollution, more systematic and reasonable mining and mineral treating operations are required. In case of exploration and mining, mining companies or mining groups must have sufficient number of exploring geological team and do exploration in accordance with a systematic exploring program, and must make a more correct calculation of ore reserves. So that the mine life will be longer, it will able to operate more economically, and valuable resources will utilize more effectively.

3) Mineral processing

Mined ores are treated at the Ingenios which lie scattered both within Potosi City and in its suburbs.

The total number of the Ingenios was said to be 34 at the start of the survey, then grew to 39 during the survey and, to 42 at the time of the end of the 4th site survey (as of Oct. '98) as a result of new construction of Ingenios. Although the rise and fall of the individual Ingenio is bewildering, the total number of the Ingenios shows an increasing tendency as a whole.

As for their equipment capacities, most of them are in small and petty scale with less than 50 t/d, and even the largest one remains in medium scale with only 370 t/d. All of their productivities are low because, in addition to their small scales, the majority of their operations are based merely on their empirical technology.

Classification of Equipment Capacity of Ingenios

Equipment Capacity t/d	~50	51~100	101~	Total
Number of Ingenio	27	11	4	42

Note: Minimum 5 t/d, Maximum 250 → 370 t/d (After expansion).

The sum of the equipment capacity of the Ingenios amounts to 2,365 t/d excluding 8 Ingenios which suspend their operations. Actual treatment amount, however, is estimated to be between 1,277 and 1,568 t/d and, even if all the Ingenios were in operation, approximately between 1,300 and 1,600 t/d in

total.

The majority of Ingenios treat the ore out of the Potosi Mine*1 and some Ingenios treat as well the ore out of other mines*2.

*1: The Empresa Minera Pailaviri R.C. in the COMIBOL group and the Mining Co-operative Association composed of approximately 30 companies

*2: Such companies as the Propias, Comparas Part, Animas, Porco, Oruro, Prov, San Lucas and Adya

Every Ingenio only takes silver bearing galena (PbS) and silver bearing sphalerite (ZnS) as the objective of mineral*3 recovery, and produces two kinds of concentrates such as silver bearing lead concentrate and silver bearing zinc concentrate by means of mineral processing composed of crushing, grinding and flotation*4. The operational result is unsatisfactory and there is much room for improvement.

Some Ingenios install simple equipment like a settling pond for recycling of water for mineral processing. From the view point of mine pollution control, however, all the Ingenios have no facilities for tailing disposal, and discharge alkaline tailings directly into the rivers without any treatment.

*3 : Although efficiency is insufficient, only one Ingenio produces small amount of cassiterite (SnO_2) by means of gravity concentration of the tailing out of lead/zinc flotation.

*4 : Straight differential lead/zinc flotation method

The historical view of mineral processing of the Potosi ore is shown in Table 2-2-2, the survey results of the Ingenios (as of Oct. '98), in Table 2-2-3, the mineral processing results in the Ingenios (surveyed in Jan.~Mar. '98 and other times), in Table 2-2-4, the flotation reagents in use by the Ingenios (surveyed in Feb. '98), in Table 2-2-5, the locations of the Ingenios, rivers and sampling points for the analysis of fluvial water quality (as of Oct. '98), in Fig. 2-2-4, the process flow of mineral processing in the Ingenios, in Fig. 2-2-5 and the photographs associated with the Ingenios, in Photograph "Ingenios" 1 ~7 in ANNEX(2), respectively 3) Mineral Processing.

Table 2-2-1 Minerals

Japanese	Chemical Formula	Spanish	English
自然金	Au	oro nativa	native gold
自然銀	Ag	plata nativa	native silver
輝銀鉱	Ag_2S	argentita	argentite
濃紅銀鉱	Ag_3SbS_3	pirargirita	pyrargyrite
淡紅銀鉱	Ag_3AsS_3	proustita	proustite
マチルダ鉱	$AgBiS_2$	matildita	matildite
脆銀鉱	Ag_5SbS_4	estefanita	stephanite
自然銅	Cu	cobre nativo	native copper
黄銅鉱	$CuFeS_2$	calcopirita	chalcopyrite
硫砒銅鉱	Cu_3AsS_4	enargita	enargite
斑銅鉱	Cu_5FeS_4	bornita	bornite
銅藍	CuS	covelita, covelina	covellite, covellin
輝銅鉱	Cu_2S	calcocina, calcocita	chalcocite
赤銅鉱	Cu_2O	cuprita	cuprite
黒銅鉱	CuO	tenorita	tenorite
孔雀石	$Cu_2(CO_3)(OH)_2$	malaquita	malachite
珪孔雀石	$CuSiO_3 \cdot 2H_2O$	crisocola	chrysocolla
藍銅鉱	$Cu_3(CO_3)_2 \cdot (OH)_2$	azurita	azurite
四面安銅鉱	$(Cu,Fe)_{12}Sb_4S_{13}$	tetrahedrita	tetrahedrite
四面砒銅鉱	$(Cu,Fe)_{12}As_4S_{13}$	tennantita	tennantite
含銀四面銅鉱	$(Ag,Cu,Fe)_{12}$ $(Sb,As)_4S_{13}$		freibergite
胆ばん	$CuSO_4 \cdot 5H_2O$	calcantita	chalcanthite
方鉛鉱	PbS	galena	galena
硫酸鉛鉱	$PbSO_4$	anglesita	anglesite
白鉛鉱	$PbCO_3$	cerusita	cerussite
閃亜鉛鉱	ZnS	esfalerita, zinc-blenda	sphalerite, zincblende
鉄閃亜鉛鉱	(Zn,Fe)S	marmatita	marmatite
菱亜鉛鉱	ZnS	wurtzita	wurtzite
異極鉱	$ZnCO_3$	smithsonita	smithsonite
珪酸亜鉛鉱	$Zn_4Si_2O_7(OH)_2 \cdot H_2O$	hemimorfita	hemimorphite
紅亜鉛鉱	Zn_2SiO_4	willemita	willemite
紅亜鉛鉱	ZnO	cincita	zincite
錫石	SnO_2	casiterita	cassiterite
黄錫鉱	Cu_2FeSnS_4	estannita, estannina	stannite
磁鉄鉱	$FeO \cdot Fe_2O_3$	magnetita	magnetite
針鉄鉱	α-FeO(OH)	goetita	goethite
:(褐鉄鉱)		:(limonita)	:(limonite)
菱鉄鉱	$FeCO_3$	siderita	siderite
赤鉄鉱	α-Fe_2O_3	hematita	hematite
黄鉄鉱	FeS_2	pirita	pyrite
白鉄鉱	FeS_2	marcasita	marcasite
磁硫鉄鉱	$Fe_{1-x}S$	pirotina	pyrrhotite
輝安鉱	Sb_2S_3	estibina	stibnite
毛鉱	$Pb_4FeSb_6S_{14}$	jamesonita	jamesonite
自然砒	As	arsenico nativo	native arsenic
鶏冠石	AsS	rejalgar	realgar
石黄：雄黄	As_2S_3	oropimente	orpiment
硫砒鉄鉱	FeAsS	arsenopirita	arsenopyrite
自然蒼鉛	Bi	bismuto nativo	native bismuth
輝蒼鉛鉱	Bi_2O_3	bismutinita	bismuthinite
蒼鉛鉱	Bi_2O_3	bismita	bismite
石英	SiO_2	cuarzo	quartz
方解石	$CaCO_3$	calcita	calcite
石灰岩	$CaCO_3$	piedra caliza	limestone
明礬石	K-Al-SO_4	alunita	alunite
蛍石	CaF_2	fluorita	fluorite
	$CaAl_2(F,OH)_8$		prosopite
自然硫黄	S	asufre nativo	native sulphur

Table 2 - 2 - 2 History of Mineral Processing for Potosi Ore

Past

(Ag minerals : Mined high grade Ag minerals were directly smelted and refined at the beginning of the mine.)

↓

SnO_2 : Recovery by gravity concentration(primitive or regular)

↓

Sn metal price has been slumped substantially to about half because of the collapse of ITC(International Tin Council) in 1985. : After that, recovery of SnO_2 has been stopped because technology of flotation to recover SnO_2 could not be prepared, that is, unit price of the treatment could not be reduced largely.

⇓

Present

① PbS and ZnS both with Ag : Recovery by flotation as Pb concentrate and Zn concentrate both with Ag.

② SnO_2 and Cu_2FeSnS_4 : Discard without recovery

③ Abandoned huge quantities of waste - namely, refuses and mineral processing tailings, (particularly, tailings of primitive gravity concentration) containing Ag and Sn have been piled to be discarded.

Table 2-2-3 Ingenios Survey : '98.10.20 Updated*1

No.	Name of existing Ingenio*2	Ex-name of existing Ingenio	Facilities capasity t/d :this time deta (prefecture deta)	Remarks
1	Nanay		30 (60)	
2	San Jose	Petra Minerales	40 (60)	
3	OTTO:Vera Cruz OTTO	Star Yuntin Mineral Process	250 (100)	
4	San Miguel		45 (80)	
5	Bolivar		45 (75)	
6	San Juan		40 (40)	
7,8	E.M.C.A.	Vera Cruz I , II	130 (80)	
9	Denver		50 (45)	
10	Molino		40?(40)	*3
11	Santa Catalina I :Copacabana?	Santa Catalina	80 (80)	
12	San Silvestre?	Ingenio Mecanizado	20 (40)	
13	Candelaria	Don Quijote	15 (15)	
14	San Francisco		5 (5)	stopped
15	Zabaleta		40 (40)	
16	Ingenio Sagarnaga:EMPO		10 (10)	
17	Copacabana	Cortez	100 (50)	
18	Daniela	San Luis	50 (50)	
19	Palliris		20 (20)	Stopped
20	Dolores		30 (10)	
21	(Nova) Cruz del Sur		30 (15)	
22	Asuncion	Choque-Inclan(y Hnos)	60 (30)	
23	Velarde		250 (120)	
24	Andina	Alave	5 (10)	stopped
25	Thuru		50 (100)	
26	Gonzalez-Martinez		20 (10)	stopped
27	SOMIL(- La Chaca)	Tuntuco	250 (370)	
28	COMICEL	San Jorge	40 (30)	stopped
29	(Nova) Fortaleza	Tihuanacu	70 (50)	stopped
30	Compania Metalurgica Potosi		40 (80)	stopped
31	Mendosa	San Jose de Berque	60 (65)	
32	LAMBOL		200 (200)	
33	Santa Lucia		80 (60)	
34	Occidental		50 (40)	
35	IMSUR	Ingenio del sur	100 (60)	
36	Guadalupe		20 (20)	*4
37	Ingenio San Pedro Potosi		30 (35)	
38	Copacabana		25 (25)	
39	Santa Catalina II:San Cristobal?		40 (40)	*5
40	San Jorge		100 (120)	
41	SOMINKOR	INTI	100 (80)	
42	La Aliada		50 (60)	
total 42 Ingenios			2,710(2,520)	

(Refference : prefecture data)
Except stopped Ingenios(No. 1,10,14,16,19,24,26,39)

Facilities capacity(A)	2,365t/d
Treatment scale(B)	1,702 ~ 1,742t/d
Treatment ratio(B/A)	72 ~ 74%
Operation ratio	75 ~ 90%(supposition)
Treatment rate	1,277 ~ 1,568t/d(supposition)

Note *1: Ing. Itoh and Ing. Llanos : [reference data] other survey by the prefecture,
*2: Locations of Ingenios are showed in Figure 5-1-2.
*3: only grinding, *4: only crushing, *5: under construction

Table 2-2-4 Summary of Ingenios' Operational Result : '98.1~3, etc.

Name of Ingenios	Run of mine ore				Pb concentrate							Zn concentrate							Tailing			
	Ore quant.	Grade			Ore quant.	Grade			Recovery			Ore quant.	Grade			Recovery			Ore quant.	Grade		
		Pb	Zn	Ag		Pb	Zn	Ag	Pb	Zn	Ag		Pb	Zn	Ag	Pb	Zn	Ag		Pb	Zn	Ag
	t/y	%	%	g/t	t/y	%	%	g/t	%	%	%	t/y	%	%	g/t	%	%	%	t/y	%	%	g/t
1.Nanay *5	9,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
2.San Jose *5	12,000	---	9.0	200	---	---	---	---	---	---	---	---	---	52.3	932	---	---	---	9,600	---	0.89	---
3.OTTO *5	75,000	---	---	---	---	---	---	---	---	---	---	---	---	50.0	1,550	---	---	---	26,700	---	---	---
4.San Miguel *1	27,261	1.67	12.3	352	790	31.2	15.0	4,485	54.1	3.5	36.9	5,454	1.7	52.4	851	20.0	85.5	48.4	21,017	0.56	1.74	78
5.Bolivar *5	13,500	---	17.0	500	---	---	---	---	---	---	---	---	---	50.0	800	---	---	---	9,600	---	1.2	50
6.San Juan *5	12,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
7,8.E.M.C.A. *5	39,000	---	13.0	200	---	---	---	---	---	---	---	---	---	53.5	4,400	---	---	---	30,000	---	---	---
9.Denver *5	15,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12,300	---	---	---
10.Molino *5	12,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
11.Santa Catalina 1*2	24,000	---	15.0	400	---	---	---	---	---	---	---	6,840	---	52.0	400	---	---	---	20,400	---	1.9	---
12.San Silvestre *5	6,000	---	15.0	620	---	---	---	---	---	---	---	---	---	50.0	1,200	---	---	---	3,000	---	1.2	90
13.Candelaria *5	4,500	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
14.San Francisco *5	1,500	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
15.Zabaleta *5 *5	12,000	---	12.0	250	---	---	---	---	---	---	---	---	---	50.0	800	---	---	---	---	---	0.8	50
16.Inhenio Sagarnaga	3,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
17.Copacabana *5	30,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
18.Daniera *5	15,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
19.Palliris *5	6,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
20.Dolores *5	9,000	---	---	---	---	---	---	---	---	---	---	72	---	---	---	---	---	---	6,900	---	---	---
21.Cruz del Sur *5	9,000	---	15.0	---	---	---	---	---	---	---	---	420	---	50.0	---	---	---	---	---	---	3.0	---
22.Asuncion *5	18,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
23.Velarde *5	75,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
24.Andina *5	1,500	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
25.Thuru *5 *5	15,000	---	9.0	700	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	0.5	---
26.Gonzalez-Martinez	6,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
27.SOMIL *3	111,000	1.30	8.0	125	975	52.0	9.0	2,000	65.0	1.8	26.0	8,448	1.2	50.0	301	13.0	88.0	33.9	50,577	0.34	0.97	59
28.COMICEL *5	12,000	---	12.0	600	---	---	---	---	---	---	---	---	---	50.0	1,500	---	---	---	9,900	---	---	---
29.Fortaleza *5 *5	21,000	---	8.5	200	---	---	---	---	---	---	---	2,760	---	49.0	1,000	---	---	---	12,600	---	1.2	100
30.Comp.Meta.Potosi	12,000	---	10.0	300	---	---	---	---	---	---	---	---	---	50.0	700	---	---	---	---	---	0.9	---
31.Mendosa *5	18,000	---	14.0	500	---	---	---	---	---	---	---	3,000	---	52.0	---	---	---	---	---	---	1.2	50
32.LAMBOL *5	60,000	---	11.0	250	---	---	---	---	---	---	---	---	---	50.0	850	---	---	---	48,000	---	---	---
33.Santa Lucia *5	24,000	---	15.0	300	---	---	---	---	---	---	---	---	---	51.0	1,000	---	---	---	14,700	---	0.8	50
34.Occidental *4	9,321	2.46	11.2	271	220	48.3	12.8	3,270	46.5	2.7	28.4	1,699	3.1	52.6	646	23.1	85.9	43.4	7,401	0.94	1.60	96
35.IMSUR *3	23,640	0.85	9.0	300	263	30.0	20.0	6,000	40.2	2.5	22.8	3,583	2.0	49.0	950	35.7	82.6	48.0	19,793	0.25	1.65	105
36.Guadalupe *5 *5	6,000	---	16.0	350	---	---	---	---	---	---	---	1,320	---	52.0	700	---	---	---	---	---	1.0	50
37.Ing.San Pedro Pot.	9,000	---	10.0	---	---	---	---	---	---	---	---	1,116	---	50.0	800	---	---	---	6,300	---	0.8	---
38.Copacabana *5	7,500	---	10.0	---	---	---	---	---	---	---	---	1,248	---	51.0	700	---	---	---	6,300	---	2.2	---
39.Santa Catalina 2*5	12,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
40.San Jorge *5	30,000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
41.SOMINKOR *5	30,000	---	10.0	---	---	---	---	---	---	---	---	3,120	---	50.0	---	---	---	---	17,100	---	0.8	---
42.La Aliada *5	15,000	---	13.0	300	---	---	---	---	---	---	---	6,360	---	50.0	800	---	---	---	18,900	---	1.1	50

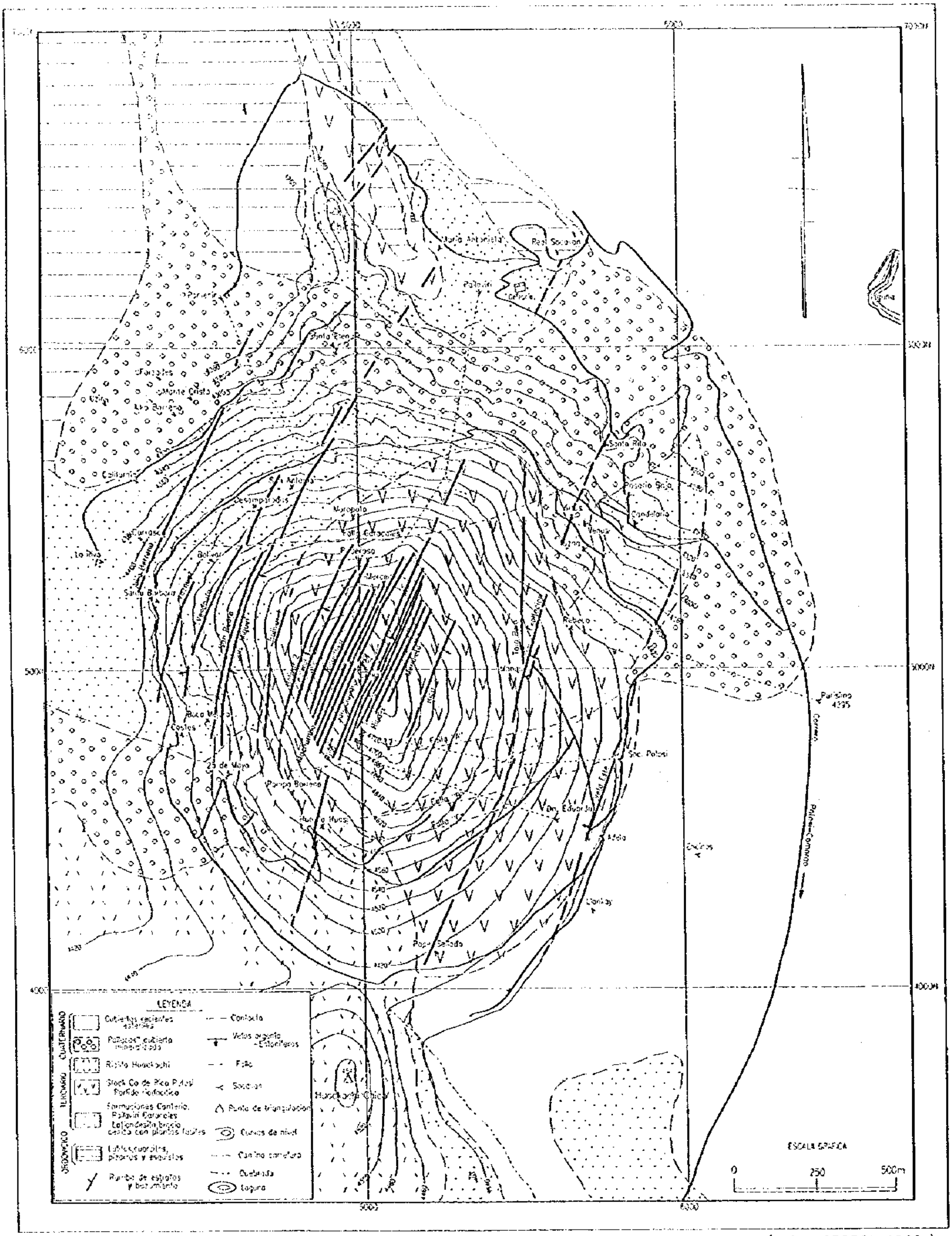
Note *1: approximate calculation(estimated with result of '97.11: Ing. Itoh's investigation), *2: approximate calculation(except above table, in '97, run of mine ore(Sn 1%), Sn concentrate(Sn35%) 7.2t/y: Ing. Itoh's investigation), *3: approximate calculation(300days operation), *4: actual result(1996.11.01 ~ 1997.10.31:Ing. Itoh's investigation), Ore quantity of No.27 SOMIL is quantity after production increase, *5: approximate calculation(300days operation[supposition]: Ore quantity was investigated by Ing. Itoh and Ing. Llanos in '98.10)

○ No.4,27,34,35 investigated by Ing. Itoh('98.1~3), others investigated by the prefecture('97.1)

Table 2-2-5 Reagents Used in Ingenios : '98.02.09

Item		1. SOMIL : ex- LA CHACA	2. LAMBOL	3. DEL SUR (SUD) : IMSUR	4. SANTA CATARINA	5. SAN MIGUEL	6. OCCIDENTAL
1. Installed Capacity		250t/d	200t/d	100t/d	80t/d	45t/d	30(/50)t/d
2. Flotation Method		Pb-Zn St./Diff.	Pb-Zn St./Diff.	Pb-Zn St./Diff.	Pb-Zn St./Diff.	Pb-Zn St./Diff.	Pb-Zn St./Diff.
3. Particle Size of Feed of Flotation (Pb Flotation)		-48 mesh 100% : +65mesh 約 10%	-150 mesh 75% : +65mesh 13%	①-65 mesh 85% ②-100 mesh 75%	-60 mesh 80%	-65 mesh 85%	-100 mesh 80%
4. pH							
(1) Pb Flotation		6~7: Natural	8: Natural	7.5~8.5	8~10	7.5~9	7.5
(2) Zn Flotation		10~11	10.5~11	10~11.5	13~14	11~12	10~11
5. Flotation Reagent		g/t	g/t	g/t	g/t	g/t	g/t
(1) Pb Flotation							
① pH Regulator		None*1	None*1	CaO*4(T 2,500)	CaO*4(T 5,500)	CaO*4(T 3,772)	CaO*4(T 6,790)
② Depressant	to activated ZnS,	NaCN 52	NaCN 50	NaCN 25	NaCN 40	NaCN 34	NaCN*6 40
	to FeS_2*2	$ZnSO_4$ 15	$ZnSO_4$ 100				+$ZnSO_4$
	to SiO_2, etc.	$NaSiO_4$ 23					
③ Collector	to PbS	Z-14*3 about 3	Z-14*3 about 30	SF-113*5 ab. 30	SF-113*5 ab. 40	SF-113*5 ab. 36	Z-11*5 about 9
	to Ag mineral	Aeroflot 242 17	Aeroflot 242 2.5				Aeroflot 208 17
④ Frother		Dow Froth 1012, 250 ab.39	Dow Froth 1012, 250 ab.15	Dow Froth 1012 about 50	Dow Froth 1012 about 35	Dow Froth 1012 about 40	Dow Froth 1012 about 35
		MIBC 37					
(2) Zn Flotation							
① pH Regulator		CaO 1,915	CaO 10,000	CaO*2 ---	CaO*2 ---	CaO*2 ---	CaO*2 ---
② Depressant (to FeS_2)*2		(ditto)	(ditto)	(ditto)	(ditto)	(ditto)	(ditto)
③ Activator (to ZnS)		$CuSO_4 \cdot 5H_2O$ 566	$CuSO_4 \cdot 5H_2O$ 386	$CuSO_4 \cdot 5H_2O$ 600	$CuSO_4 \cdot 5H_2O$ 500	$CuSO_4 \cdot 5H_2O$ 380	$CuSO_4 \cdot 5H_2O$ 370
④ Collector (to ZnS)		Z-14*3 about 73	Z-14*3 about 83	SF-114*3 ab.120	SF-114*3 ab.60	SF-114*3 ab.66	Z-14*3 about 51
⑤ Frother		DowFroth 1012, 250 ab.9	DowFroth 1012, 250 ab.3	DowFroth 1012 about 10	DowFroth 1012 about 5	DowFroth 1012 about 7	DowFroth 1012 about 5
6. Remarks					Recovery of SnO_2 with shaking table from Zn flotation tailing		

注) ○ Investigation by Itoh. No information was obtained from EMCA (EX-VERA CRUZ Ⅰ).
*1: Factory water may contain calcic component., *2: Depressant CaO, *3: Z-14 = SF-114 = Isopropyl Xanthate, *4: As for CaO, total of 5.(1)①+5.(1)②+5.(2)①+5.(2)② is showed in 5.(1)①., *5: Z-11 = SF-113 = Isobuthyl Xanthate, *6: In case of much quantity of PbS , only NaCN should be applied. In case of little quantity of PbS, NaCN[1]+$ZnSO_4$[3] should be applied.



(after GEOBOL 1968)

Fig.2-2-1 Geological Map of Cerro Rico de Potosi

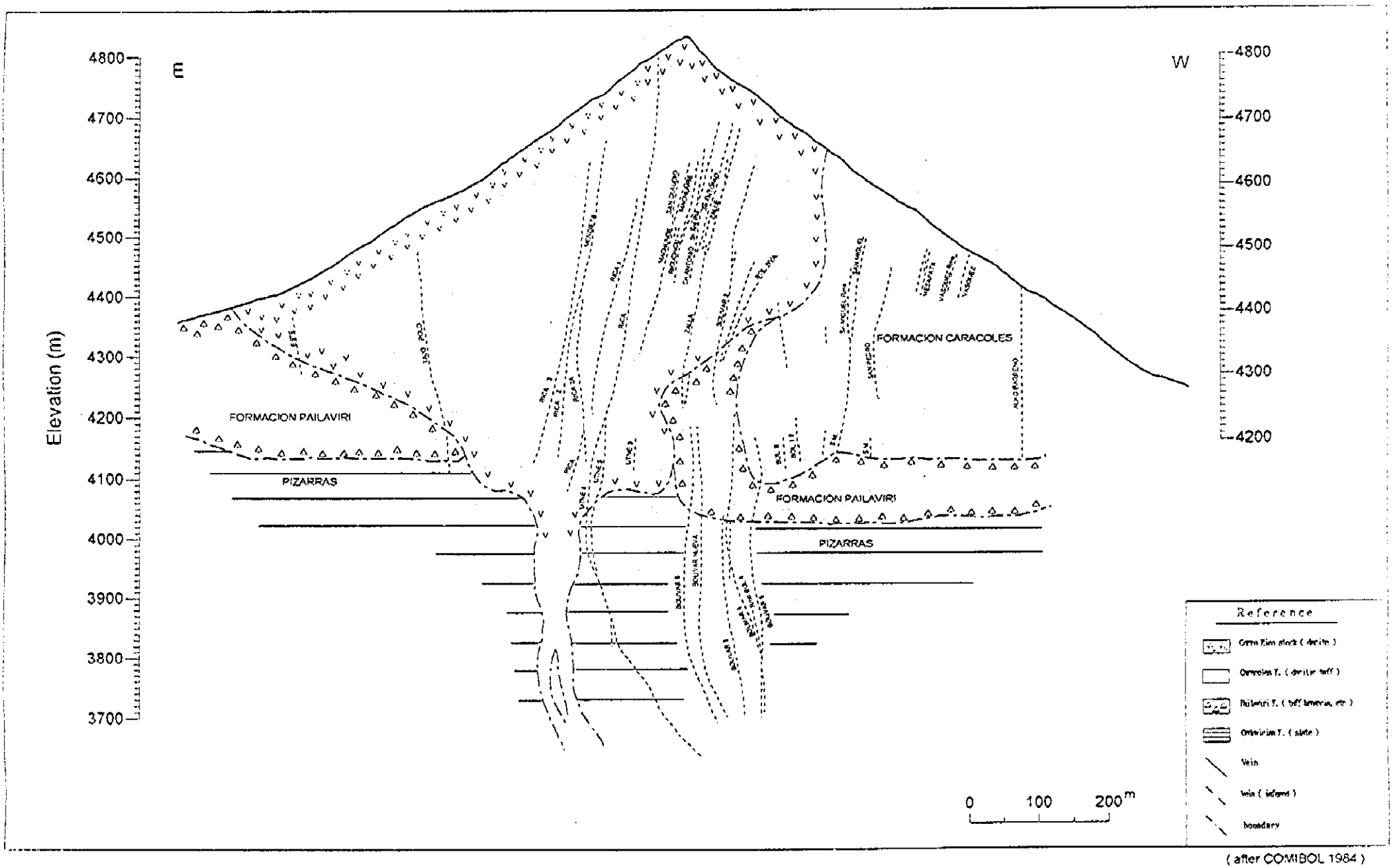


Fig.2-2-2 Perfil Geológico del Cerro Rico de Potosí

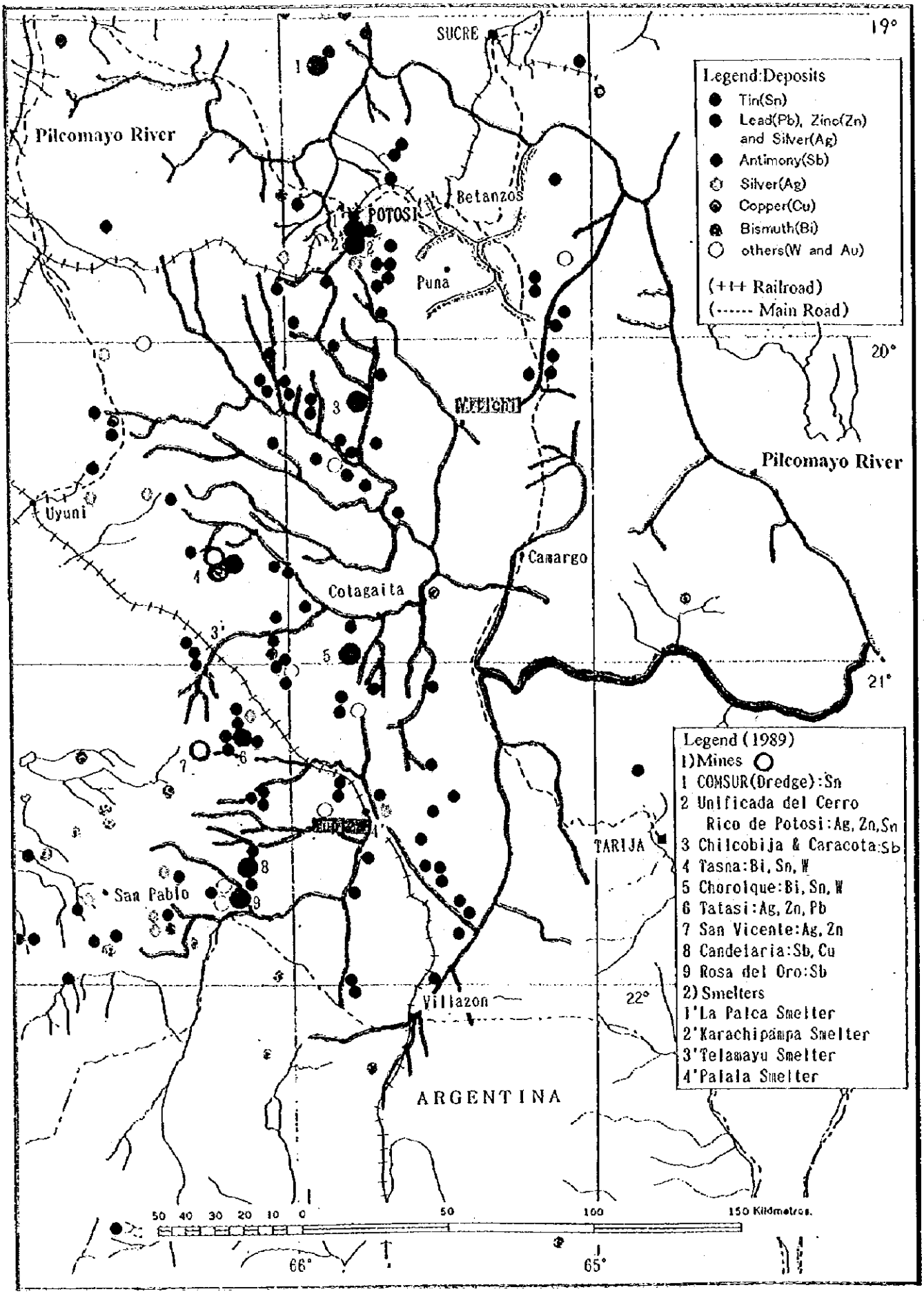
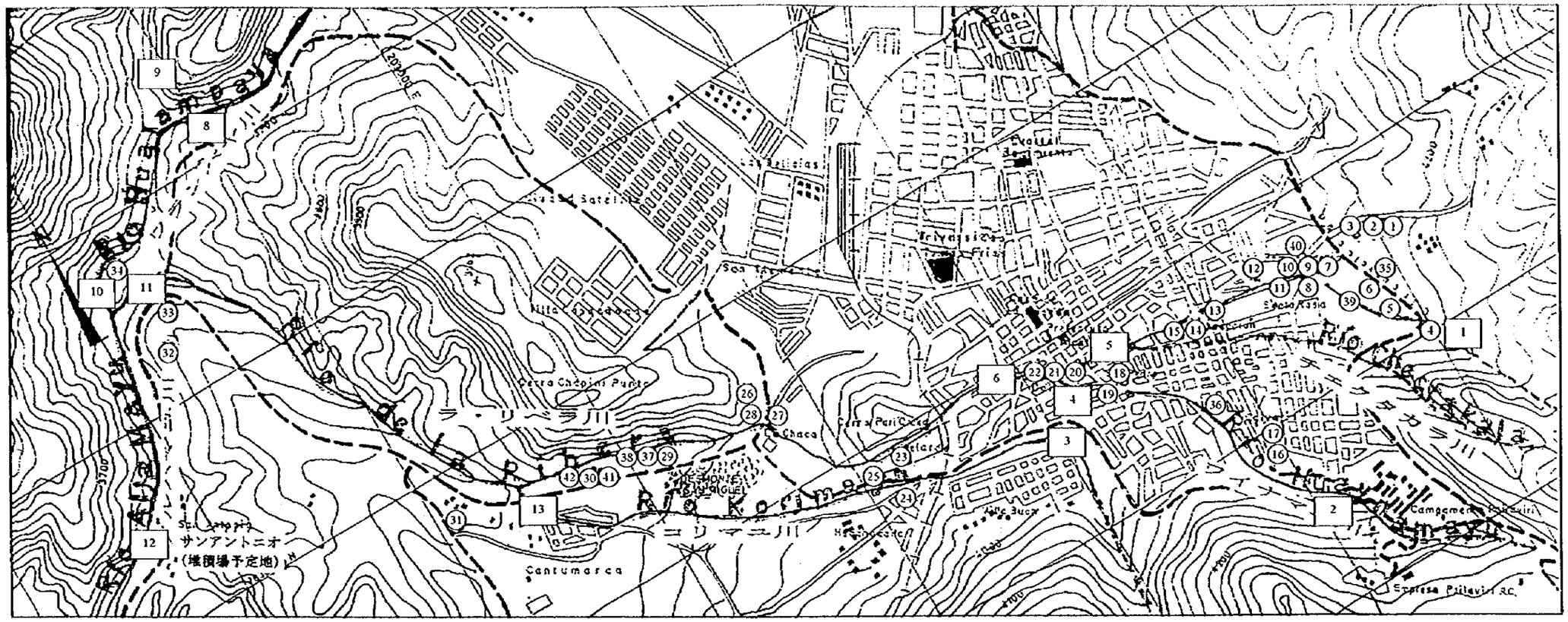


Figure 2-2-3 Location of Deposits, Mines and Smelters in Pilcomayo River Basin



No.	Ingenio (Concentrator)	No.	Ingenio (Concentrator)	No.	Ingenio (Concentrator)	No.	Ingenio (Concentrator)
1	Ñañay	12	San Silvestre	23	Velarde	34	Occidental
2	San José	13	Candelaria	24	Andina	35	IMSUR
3	OTTO: Vera Cruz OTTO	14	San Francisco	25	Thuru	36	Guadalupe
4	San Miguel	15	Zabaleta	26	González-Martínez	37	Ingenio San Pedro Potosí
5	Bolívar	16	Ingenio Sagárnaga: EMPO	27	SOMIL (- La Chaca)	38	Copacabana
6	San Juan	17	Copacabana	28	COMICEL	39	Santa Catalina 2
7	E.M.C.A.	18	Danicla	29	(Nova) Fortaleza	40	San Jorge
8		19	Palliris	30	Compañía Metalúrgica Potosí	41	SOMINKOR
9	Denver	20	Dolores	31	Mendosa	42	La Aliada
10	Molino	21	(Nova) Cruz del Sur	32	LAMBOL		
11	Santa Catalina 1	22	Asunción	33	Santa Lucía		

Legends	
(10)	Ingenio
	River
	Railroad
	Road
12	Sampling Points on Rivers

Figure 2-2-4 Location of Ingenios (Concentrators) and Rivers in the City of Potosi ('98.10 Updated)

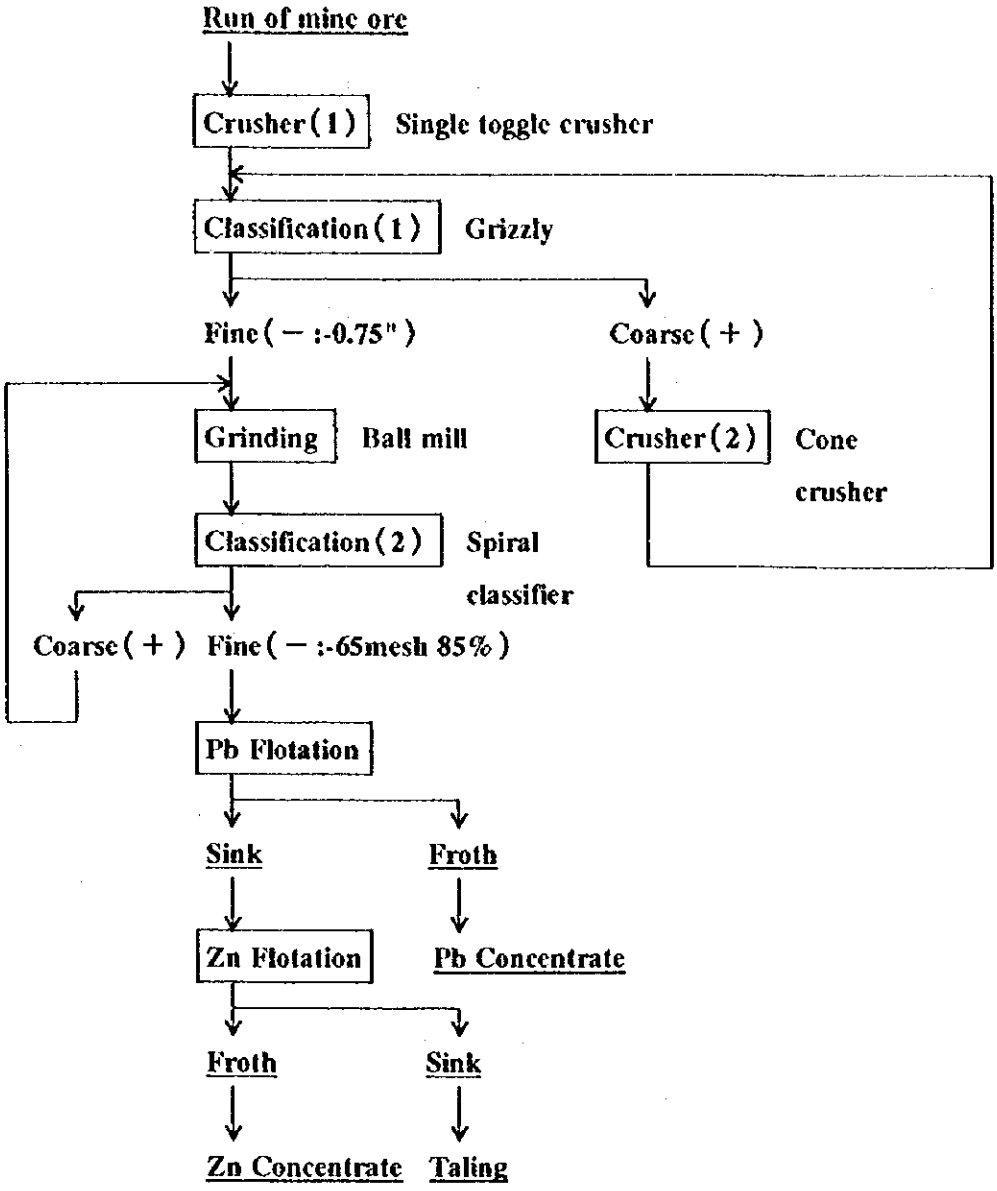


Figure 2 - 2 - 5 Flow Chart of Mineral Processing in Ingenios

: Typical specimen SAN MIGUEL