(6) Selling expenses :

Carriage	US$	210	(31.39 x 6.70)
Loading charges	US$	94	(31.39 x 3.00)
Bag costs	US$	735	(628 x 1.17)
Total	US$	1,039	

(7) Net income US$ 1,976

3. Revenue amount US$ 152,808 / day
US$ 45,842,400 / year
US$458,424,000 / 10 years
US$ 19.101 / ton of crude ore

7–3–2 Operating Costs

The labor cost has been estimated on the basis that the man-hours are determined from usual efficiency and are added to the traditional on-site man-hours, and the wages are 8 to 18 dollars per man-day. As a result, the average monthly labor cost per head is about 500 dollars for 10,000 t/day treatment, and this figure is larger by some 35% than the peak in 1980 and 1981.

The expenses for materials are so calculated that the necessary quantities are estimated for each of the major materials, and actual unit prices are applied to those to be procured on-site while standard unit prices in Japan are adopted for imported materials. The electric power cost, among the other costs, is determined from the actual unit price.

In Bolivia, the exchange rate is fixed at 200 pesos per dollar at present and commodity prices are relatively stable, although the country itself is in a somewhat unstable condition. For the estimate of operating costs, unit prices in 1980 have been mainly adopted, and all prices are given in dollars.

The estimated operating costs are 28,804,000 dollars for (A)–1, 26,098,000 dollars for (A)–2, 25,670,000 dollars for (B), and 23,744,000 dollars for (C), and the details of these are shown in Table II–7–5.

The corresponding costs per ton of crude ore are \$9.601 for (A)–1, \$8.699 for (A)–2, \$9.507 for (B), and \$9.894 for (C). Naturally, the cost is lowest for (A)–2 where the ratio of extraction of Desmonte is biggest.

7–3–3 Depreciation Costs

Because the whole construction cost, 131 millions dollars (for 10,000 t/day), has been taken as having been raised by loans, the interest costs for this, 15 millions dollars, are also included in the depreciation costs.

The depreciation cost has been calculated on the basis that the loans and interest will be repaid within a 10-year operation term, while expenses for the replacement of some heavy machines have been estimated in the operating costs.

The construction costs are 122 million dollars for 9,000 t/day treatment, and 115 million dollars for 8,000 t/day treatment; thus the costs per ton of crude ore are 4.37 dollars (10,000 t/day), 4.53 dollars (9,000 t/day) and 4.80 dollars (8,000 t/day).

A 10% increment of the construction cost raises the costs per ton of crude ore by $0.44 (10,000 t/day), $0.45 (9,000 t/day) and $0.48 (8,000 t/day) respectively.

7–3–4 Interest

The interest costs have been calculated on the premise that all of the debts, 131 million dollars for the construction cost, will be repaid within 10 years, in equal amounts at the end of each fiscal year, and that the interest rate is 6% per annum. Additionally, the operating costs for six months should be kept as the working capital, which is also included in the debts, provided that the interest rate for this is 10% per annum.

The estimated interest amounts for 10 years are 57 million dollars for 10,000 t/day, 53 million dollars for 9,000 t/day and 50 million dollars for 8,000 t/day, corresponding to $1.91, $1.97 and $2.08 per ton of crude ore respectively.

A one percent increment of the interest rate raises the interest costs by 8.6, 8.0 and 7.5 million dollars and the cost per ton of crude ore by 0.29, 0.30 and 0.31 dollar respectively.

7–3–5 Profit

From the estimates given above, the following profits will be obtainable during the 10 years operation term.

Table II-7-5 Details of Operation Cost (In the case of 10,000 t/day)

7 years since first of operation

Item		Mining	Concentration	Maintenance	Administration			Total
					Laboratory Safety	Adminitt-ration	Labour and Soci. Welf.	
Personnel	Salary Worker	49^{per}	65^{per}	41^{per}	9^{per}	86^{per}	137^{per}	387^{per}
	Daily Labour	289	185	160	16	62	55	767
	Total	338	250	201	25	148	192	1154

(In 1000 U.S.$)

	Item	Mining	Concentration	Maintenance	Laboratory Safety	Adminitt-ration	Labour and Soci. Welf.	Total
(By Elements)	Labour Cost	2,522	1,515	1,065	131	755	948	6,936
	Material	2,914	8,647	939	218	244	209	13,171
	Other Expense	740	6,941	190	26	550	250	8,697
	Total	6,176	17,103	2,194	375	1,549	1,407	28,804
(By Costs)	Development Cost	1,172	(@1.26 x 6,510 $^{1000t/7 years}$)		@1,116/ton of Extraction		–	1,172
	Mining	3,505	(@4.246 x 1,050 ^{1000t})		–	–	–	3,505
	Mining Cost of Desmonte	546	(@0.28 x 1,950 ^{1000t})		–	–	–	546
	Concentration Cost	–	17,103	(@5.70 x 3,000 ^{1000t})	–	–	–	17,103
	Cost of Swelling of Balk of Dam	–	–	478	–	–	–	478
	Subtotal	5,223	17,103	478	–	–	–	22,804
	Common Cost	953	–	1,716	375	1,549	1,407	6,000
	Total	6,176	17,103	2,194	375	1,549	1,407	28,804
(Cost per Ton of production of Crude Ore)		5.059	5.701	0.731	0.125	0.516	0.469	9.601

Table II-7-6 Details of Operation Cost (In the case of 10,000 t/day)

3 years since the 8th year of operation

Item		Mining	Concentration	Maintenance	Administration: Laboratory Safety	Administration: Administration	Administration: Labor and Soci. Welf.	Total
Personnel	Salary Worker	38 per	65 per	41 per	9 per	86 per	132 per	371 per
	Daily Labor	161	185	160	16	62	53	637
	Total	199	250	201	25	148	185	1,008

(In 1000 U.S.$)

Item		Mining	Concentration	Maintenance	Laboratory Safety	Administration	Labor and Soci. Welf.	Total
By Elements	Labour Cost	1,660	1,515	1,015	13.1	755	926	6,002
	Material	1,520	8,647	866	206	244	209	11,692
	Other Expense	500	6,941	137	26	550	250	8,401
	Total	3,680	17,103	2,018	363	1,549	1,385	26,098
By Costs	Development Cost	211	(@1.26 x 504 1000 t/3 years) @0.352/t of Extraction —				—	211
	Mining	2,003	(@3,338 x 600 1000t) —		—	—	—	2,003
	Mining Cost of Desmonte	651	(@0.271 x 2,400 1000t) —		—	—	—	651
	Concentration Cost	—	17,103	(@5,701 x 3,000 1000t) —		—	—	17,103
	Cost of Swelling of Balk of Dam	—	—	319	—	—	—	319
	Subtotal	2,865	17,103	319	-	-	-	20,287
	Common Cost	815	—	1,699	363	1,549	1,385	5,811
	Total	3,680	17,103	2,018	363	1,549	1,385	26,098
(Cost per Ton of production of Crude Ore)		1,227	5,701	0.673	0.121	0.516	0.461	8,699

Table II-7-7 Details of Operation Cost (In the Case of 9,000 t/day)

10 years since the first year of operation

Item		Mining	Concentration	Maintenance	Administration: Laboratory Safety	Administration: Administ-ration	Administration: Labour and Soc. Welf.	Total
Personnel	Salary Worker	49 per	65 per	41 per	9 per	86 per	132 per	382 per
	Daily Labour	228	171	155	16	62	53	685
	Total	277	236	196	25	148	185	1,067

(In 1000 U.S.$)

Item		Mining	Concentration	Maintenance	Laboratory Safety	Administ-ration	Labour and Soc. Welf.	Total
By Costs	Labour Cost	1,988	1,444	1,064	131	755	926	6,308
	Material	2,090	7,772	931	209	244	209	11,455
	Other Expense	616	6,249	216	26	550	250	7,907
	Total	4,694	15,465	2,211	366	1,549	1,385	25,670
By Elements	Development Cost	730	(@1.26 x 5,791 1000t/10 years) ton of Extraction			—	—	730
	Mining	2,543	(@3.39 x 750 1000t)	—	—	—	—	2,543
	Mining Cost of Desmonte	546	(@0.28 x 1,950 1000t)	—	—	—	—	546
	Concentration Cost	—	15,465	(@ 5,728 x 2,700 1000t)		—	—	15,465
	Cost of Swelling of Balk of Dam	—	—	411	—	—	—	411
	Subtotal	3,819	15,465	411	—	—	—	19,695
	Common Cost	875	—	1,800	366	1,549	1,385	5,975
	Total	4,694	15,465	2,211	366	1,549	1,385	25,670
(Cost per Ton of production of Crude Ore)		1,739	5,728	0.819	0.136	0.574	0.513	9,507

Table II-7-8 Details of Operation Cost (In the Case of 8,000 t/day)

Item		Mining	Concentration	Maintenance	Administration: Laboratory Safety	Administration: Administ-ration	Administration: Labour and Soc. Welf.	Total
Personnel	Salary Worker	49 per	65 per	37 per	8 per	86 per	132 per	377 per
	Daily Labour	221	162	145	15	62	53	658
	Total	270	227	182	23	148	185	1,035

(In 1000 U.S.$)

		Mining	Concentration	Maintenance	Laboratory Safety	Administ-ration	Labour and Soc. Welf.	Total
By Elements	Labor Cost	1,972	1,402	966	122	755	926	6,143
	Material	2,050	6,908	816	206	244	209	10,433
	Other Expense	609	5,554	179	26	550	250	7,168
	Total	4,631	13,864	1,961	354	1,549	1,385	23,744
By Costs	Development Cost	730 (@ 1.26 x 5,791 1000t/10 years) @ 0.973/ton of Extraction					–	730
	Mining	2,543 (@ 3.39 x 750 1000t) –			–	–	–	2,543
	Mining Cost of Desmonte	483 (@ 0.293 x 1,650 1000t) –			–	–	–	483
	Concentration Cost	–	13,864 (@ 5,777 x 2,400 1000t) –			–	–	13,864
	Cost of Swelling of Balk of Dam	–	–	343	–	–	–	343
	Subtotal	3,756	13,864	343	–	–	–	17,963
	Common Cost	875	–	1,618	354	1,549	1,385	5,781
	Total	4,631	13,864	1,961	354	1,549	1,385	23,744
(Cost per Ton of production of Crude Ore)		1,930	5,777	0.817	0.148	0.645	0.577	9,894

Table II-7-9 Details of Construction Cost

	The case of 10,000 t/day	The case of 9,000 t/day	The case of 8,000 t/day
Mining Equipment	6,772 1,000$	5,612 1,000$	5,436 1,000$
Mineral Concentration Equipment	78,257	73,209	67,961
Water Service Equipment	3,534	3,318	3,092
Waste Heap Equipment	4,732	4,023	4,479
Offices and Houses	1,633	1,633	1,633
Business Equipment	455	455	455
Other Expense	20,942	19,842	18,688
Subtotal	116,325	108,092	101,744
Payment of interests during period of construction	14,886	14,175	13,340
Total	131,211	122,267	115,084
(Per ton of Crude Ore)	(4,374$)	(4,528$)	(4,795$)
For 1% up of interes (Per ton of Crude Ore)	2,481 1,000$ (0.083$)	2,362 1,000$ (0.087%)	2,223 1,000$ (0.093$)
10% up of total cost (per ton of Crude Ore) (10% up for per ton of Crude Ore)	144,332 (4,811$) (0.437$)	134,494 (4,981$) (0.453$)	126,592 (5,275$) (0.48$)
10% down of total cost (per ton of Crude Ore) (10% down for per ton of Crude Ore)	118,090 (3,936$) (0.438$)	110,010 (4,076$) (0.452$)	103,576 (4,316$) (0.479$)

Table II-7-10 Statement of Income and Expenditure

Item	The case of 10,000 t/day	The case of 9,000 t/day	The case of 8,000 t/day
Net Income (Income after discounted Sales Cost)	532,126 1,000$ (18,449)	507,729 1,000$ (16,935)	458,424 1,000$ (15,288)
Operation Cost	279,922	256,700	237,440
Depreciation	131,211	122,267	115,084
Payment of Interest	57,300	53,183	49,850
Profit	63,693	75,579	56,050
(Per ton of Crude Ore)	(2.123)	(2.799)	(2.335)

PART Ⅲ EXPLORATION PLAN FOR THE FUTURE

CHAPTER 1. GENERAL GEOLOGY AND GEOLOGICAL STRUCTURES IN INVESTIGATED AREA

1–1 Outline of Investigation (See Fig. III–1–1)

The investigated area, including Catavi Mine, Haununi Mine, San Florencia Deposit, Morococala Mine, Santa Fé Mine, Japo Mine, San Luis Deposit, etc., forms a major tin ore deposit zone in Bolivia. Especially, the Llallagua Deposit of Catavi Mine and the Huanuni Deposit of Huanuni Mine are world-famous for their large scale. The area covered by this investigation including these ore deposits, is a rectangular shaped area of 1,500 km² (25 km x 60 km) bounded on the north-west. 18°–8′–19″ south latitude and 66°–59′–34″ west longitude, a north-east 18°–00′–33″ south latitude and 66°–47′–51″ west longitude, a south-east 18°–26′–35″ south latitude and 66°–28′–48″ west longitude, and a south-west 18°–34′–22″ south latitude and 66°–39′–26″ west longitude.

As it was impossible to actually survey the whole area to prepare new geological maps because of the short time period allotted for the investigation promising areas were selected and the exploration plan for the promising area was established by preparing geological maps on a scale of 1 to 100,000 based on investigation data prepared beforehand by COMIBOL, Servicio Geologico de Bolivia, Metallic Mining Agency of Japan, etc., and also investigating various existing geophysical exploration data, etc. The time alloted for the investigation was about one week.

1–2 General Geology (See Fig. III–1–1)

The sedimentary rocks forming this area are divided from the bottom to the top into the Cancañiri formation, Llallagua formation, Uncia formation, Catavi formation, Cretaceous formation, Tertiary formation, and Quaternary formation, and these formations are distributed with strikes almost from north-northwest to south-southeast. The periods of these sedimentary rocks are said to be as follows: the formations from the Cancañiri to the middle part of the Uncia formation belong to the Silurian period, and those to the Catavi formation belong to the Devonian period. About igneous rocks, La Salvadora quartz porphyry, quartz porphyry dikes around Huanuni, and in addition, rhyolite lava which erupted in the Pliocene epoch and covers the eastern half of the investigated area exist.

(1) Cancañiri Formation

The formation has a thickness of + 1,000 m and belongs to the middle part of the Silurian period. The lithofacies is a dark gray to black colored conglomerate of massive form without bedding planes. Pebbles are polygonal or round quartz, black slate, shale and granite of 5 ~ 20 mm in diameter. The matrix is black sand, belonging to graywacke. The formation has a characteristic eroded topography and rock surfaces look like the skin of an elephant. This formation is widely distributed in the anticlinal axes of the investigated area.

(2) Llallagua Formation

This formation has a thickness of + 200 m and belongs to middle Silurian period to the lower Devonian period. A type locality being the Llallagua region in the south of the investigated area, and this formation forms anticlines by uniformly covering the Cancañiri formation. The formation has developed into three continuous zones spread over the entire region from the northern end to the southern end. The rocks generally consist of dense and hard gray sandstone, but in the lower part, the sandstone intercarates alternately with slate of dark green gray color containing much mica. The middle part of this formation, being formed of light gray fine particle siliceous sandstone, is dense, hard and massive without bedding, forms a long continuous and hard ridge, and this feature makes it very easy to interpret this layer from aerophotographs. In the upper part, slate and siliceous sandstone alternate again with each other, forming a thin bedding and gradually merge into the Uncia formation.

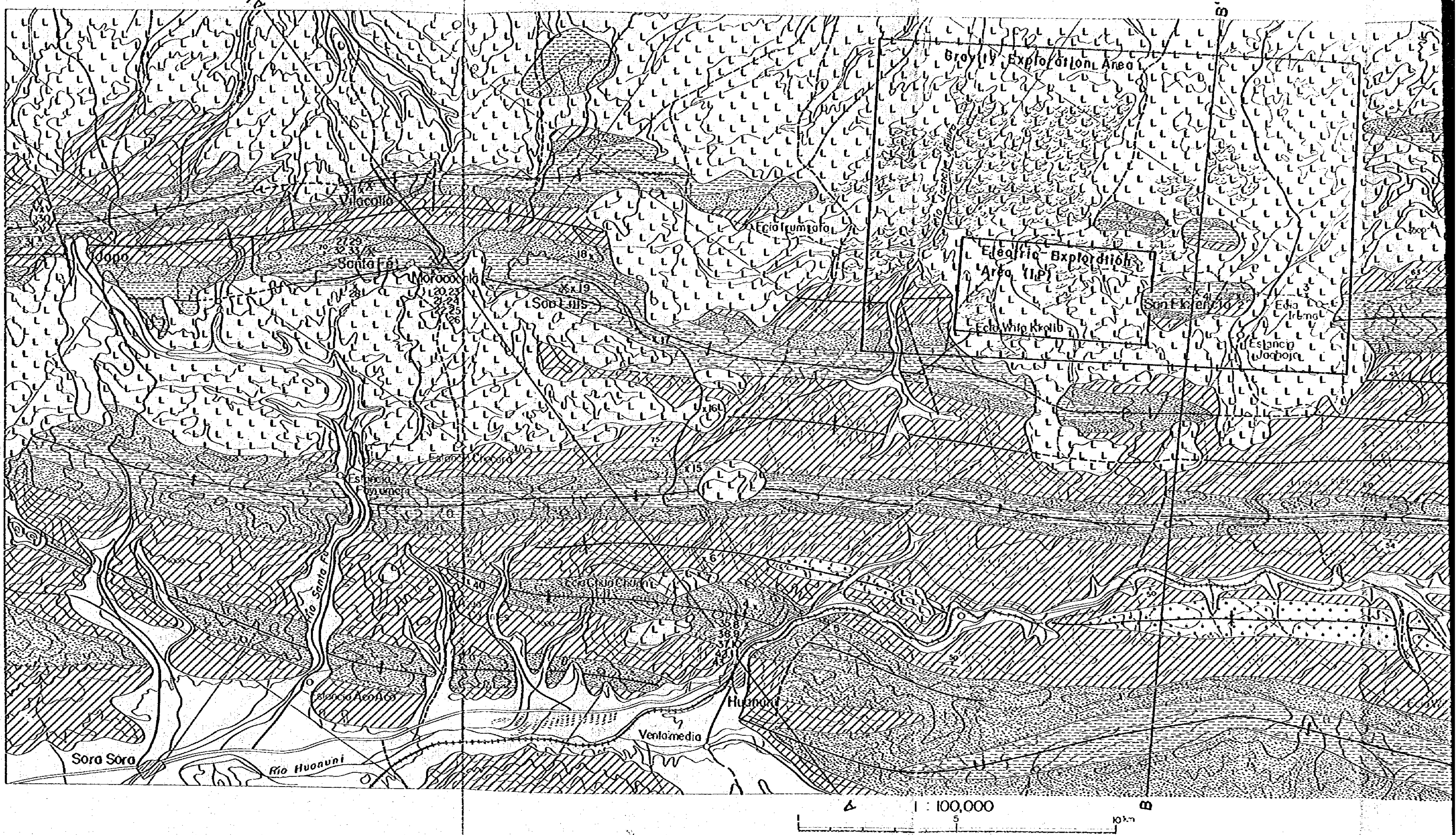
(3) Uncia Formation

This formation has a thickness of + 1,000 m and belongs to the lower Devonian period. A type locality being the Uncia town near the south-eastern end of the investigated area. In the investigated area, this formation is distributed mainly in synclinal parts or on both sides along them, and is distributed in several zones in parallel to the above-mentioned Llallagua formation in the western half of the investigated area.

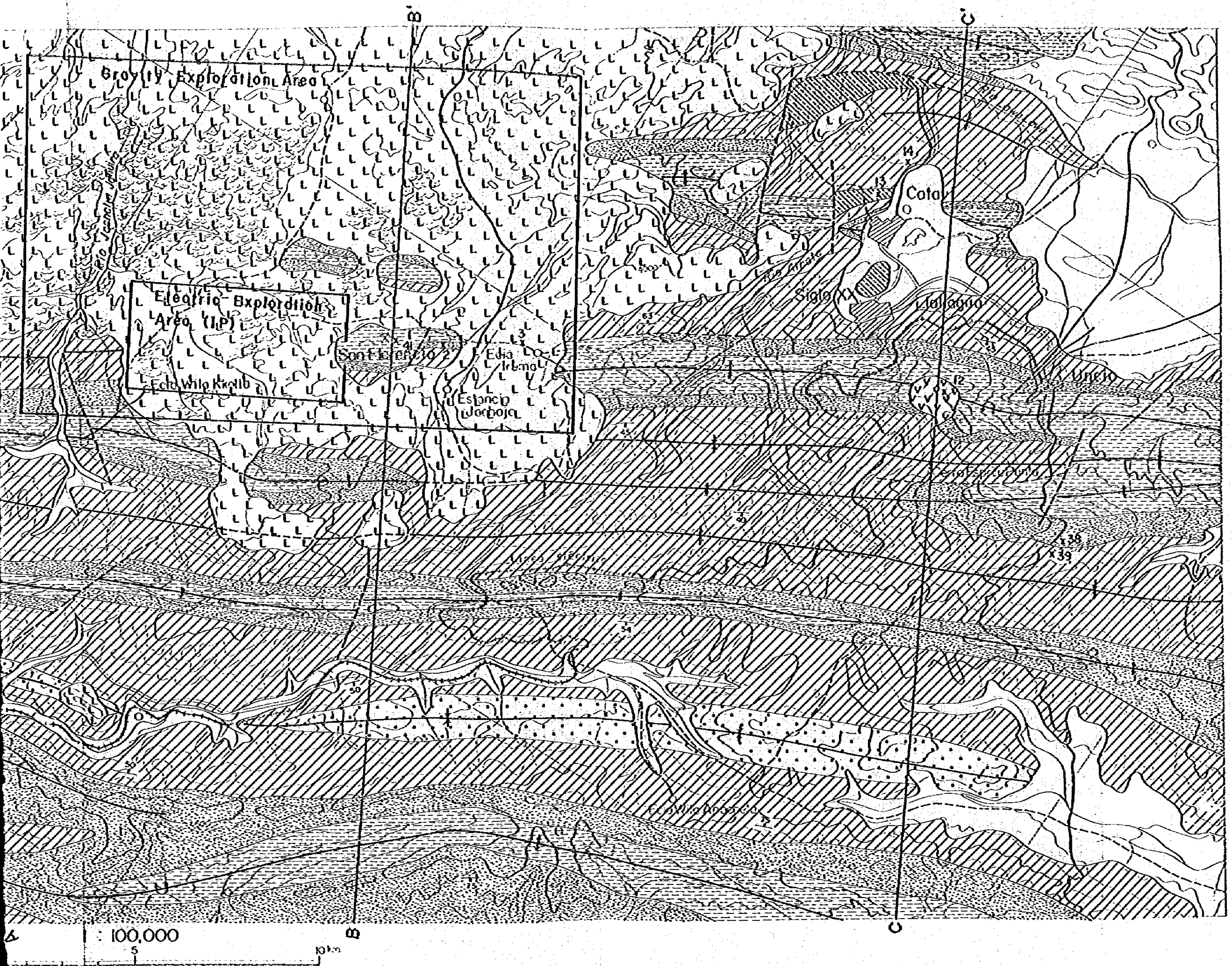
The rocks are mainly dark gray or dark green shale, and slate, containing much mica, and are soft. As a result of this quality, the formation forms a rounded topography owing to erosion, and from this clear geological feature in aerophotographs, the formation can be known easily. In the lower part of this formation, there are alternate layers of siliceous sandstone and dark green slate which merge gradually into the Llallagua formation, and the boundary with the Llallagua formation is unclear. In the lower shale, lamination structure has developed. Towards the upper part, the ratio of shale increases and again the alternation of sandstone and shale appears. Although not collected during that investigation, it has been reported that fossils from the Silurian period to the lower Devonian period can be found from this formation and this formation therefore is said to belong to the Mid-Silurian to the lower Devonian.

(4) Catavi Formation

This formation has a thickness of + 300 m and is exposed typically at the south of



A
A'
B
B'
Gravity Exploration Area
Electric Exploration Area (I.P.)
Vilacollo
Japo
Santa Fe
Morococala
San Luis
Estancia Pairumani
Rio Santa Fe
Estancia Arenales
Huanuni
Ventamedia
Sora Sora
Rio Huanuni
Estancia Jachoja
1 : 100,000
5
10 km



LEGEND

Quaternary
Rhyolite Lava
Cretaceous F.
Catavi F.
Uncia F.
Llallagua F.
Cancañiri F.
Quartz porphry
Fault
Folding axis
Bedding
mine
Road
River
Village
Town
x 35 Sampling point and sampling No.

Fig III-1-1 Geological Map

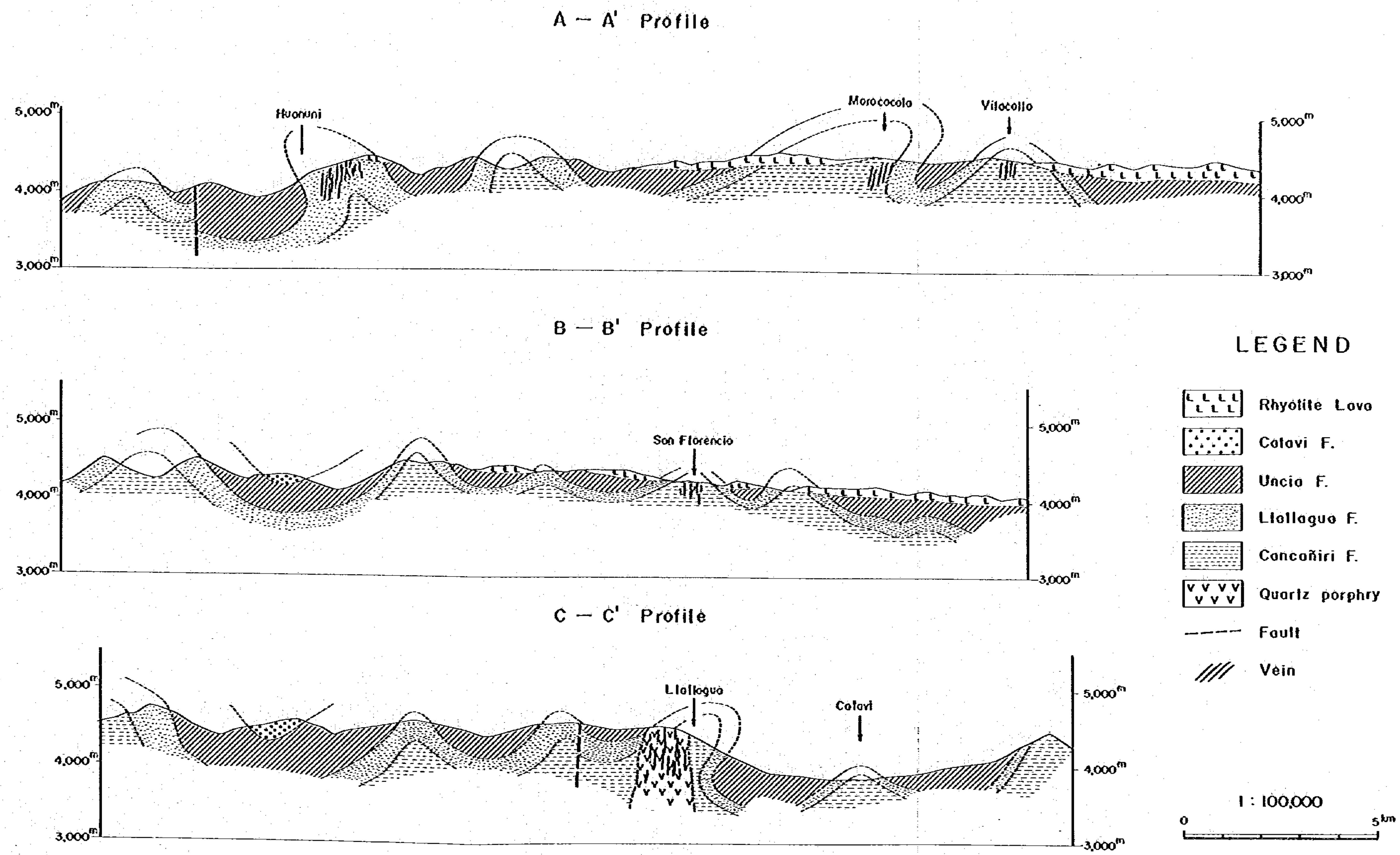


Fig. III-1-2 Geological Profile

Huanuni. It has widely developed in synclinal axes and continues in strip shapes parallel to the above formations from the northern part to the southern part of the investigated area. The facies is a alternation of purple gray sandstone and shale, but in some regions it has a reddish-brown color. The formation has clear bedding planes and the thickness of a layer changes from 10 cm to 5 m. This formation integrates into the lower Uncia formation and gradually changes into this formation. From the fossils found in this formation, this formation is thought to belong to the lower Devonian period.

(5) Cretaceous Formation

This formation has a thickness of + 300 m and is distributed only in the synclinal part in the north of Catavi. The formation rests unconformably upon lower formations. The facies is composed of red sandstone, dolomite and shale, and its lower part is composed of conglomerate. The conglomerate includes pebbles of sandstone and shale of over 10 cm diameter which have clearly come from the Catavi formation. Compared with the lower Palaeozoic formation, this formation is softer and more reddish, and its dip is gentle, so that it can be distinguished from the lower layers. Although fossils have not been found from this formation, it is thought to be a Cretaceous period formation from its facies.

(6) Tertiary Formation

This formation with a thickness of + 50 m occupies the eastern half of the area and is the most widely distributed formation in the investigated area. This formation covering the whole Morococala plateau forms a flat area. The formation consists of rhyolite lava, its white gray facies is coarse and soft and shows containing of quartz and biotite. This formation is called Morococala formation. According to J. Nigel Grant et al, this formation is said to be 6.3 ± 0.1 million years of age and belongs to the latest Pliocene epoch. As this formation erupted at the end of orogenic movements, and no serious folds occurred after that, this formation is nearly horizontal and covers lower layers, and the thickness of the formation varies with the forms of the eroded surfaces of the lower layers.

(7) Quaternary Formation

This formation is composed of sediments of the river flowing from the south to the north, colluvial, talus and alluvial deposits etc.

(8) Igneous Rocks

Igneous rocks distributed in the investigated area consist of El Salvadora stock embedding the Llallagua deposit, San Pablo stock adjoining the Japo deposit, and dykes which have developed near the Huanini deposit and the Llallagua deposit. These are closely related with mineralization, and their distribution and intrusion time must be examined carefully. Other than the above-mentioned intrusion rocks, Morococala rhyolite lava forming the Morococala plateau exists as effusine rocks, but it is not related with the formation of ore deposits, and the igneous rocks to which importance must be attached in relation to mineralization ore the above-mentioned stocks and dykes.

(1) La Salvadora Stock

This stock is about 1 km in diameter, and intrudes into the Cancañiri formation and the Llallagua formation. The part of the stock still remaining is the part of the volcanic vent, and the uppermost part is thought to have been eroded. Most part of the stock has been seriously altered, so that the materials of the stock are unclear, but a part of the stock periphery unaltered is quartz-latite porphyry. Altered minerals contain sericite, tourmaline, quartz and other clayey minerals, and the mineralization of tin and pyrite has accompanied this. According to Grant et al., the time of intrusion of this stock is said to be 21 m.y. (the earlier period of Miocene epoch), and mineralization is also said to have occurred approximately at the same time.

(2) San Pablo Stock

This stock which outcrops about 2 km in the northwest of the Japo Mine is quartz porphyry of about 700 m in diameter. Like the Salvadora stock, this stock has intruded into the center of the anticlinal axis, cutting the lowest Cancañiri and Llallagua formations of the investigated area, and although its scale is small, this stock has the same intrusion form as that of La Salvadora stock. This stock is quartz latitite porphyry comparatively unaltered in which quartz phenocrysts have developed and which have a light gray color. In altered part, sericite, pyrite and tourmaline are distributed generally. The time of intrusion of this stock is said to be 23.3 ± 0.4 m.y. (J. Nigel Grant et al. 1979) and almost the same as that of La Salvadora stock.

(3) Morococala Ryolite

This rock is distributed over a wide area which occupies nearly the whole of the eastern half of the investigated area and forms the Morococala formation together with the essencial tuff. Boundaries between lava and tuff are often unclear. This rock is coarse and a little hard, and has a gray white color and columnar joints. The facies shows partly clear flow structure and partly massive bloks, and is therefore non-uniform. Phenocryst minerals are fresh. Places where this rock is distributed form characteristic plateaus, but it was impossible to clearly analyze the volcanic activity which erupted this rock.

(4) Dikes

Dikes which appear in the investigated area are the dikes intruded into La Salvadora stock and its perphery, and quartz porphyry dikes which have developed on the eastern rim of

Huanuni deposit, quartz porphyry dikes, found in Santa Fé and Japo mines, and they all have developed near ore deposits and are closely related with the formation of the ore deposits.

i) Dykes around of La Salvadoar stock and its environment

Into La Salvadora stock and sedimentary rocks around it, quartz porphyry dikes have intruded as vein like bodies and they look like usual dikes in their shapes, but their shapes and strike dips change very irregularly. Much sandstone is contained, which seems to be the main element of the dikes. The dikes intersect with veins in obtuse angles or run parallel to them. Places where dikes have developed are very limited and the dikes have developed characteristically from 411 level to 446 level.

ii) Dikes Developed on the Western Edge of Huanuni Ore Deposit

At the eastern wing of the anticlinal axis passing above Huanuni deposit are found quartz porphyry dikes in a echronform showing characteristic distribution. This rock has become white gray as a result of hydrothermal action, and plagioclase has changed to kaolin, biotite has changed to chlorite, so it is difficult to judge what their original rocks were. Other than the above, altered dykesare said to be found in Santa Fé and Japo Mines, and from these dykes the age of 21 m.y. ~ 20 m.y. were measured (Grant et al) and the mineralization in this area and the intrusion time of these dykes are said to have occurred approximately at the same time.

1–3 Geological Structure

The folding structure are all controlled by the orogenic movements of Andes all over the investigated area, and they all have a direction from north north-west to south south-east. Paleozoic formation, which underwent folding actions two times by the orogenic movement of Variscan and that of Alps, are folded heavily and show folds like inclined folds, overfolds and over turned folds especially, Llallagua and Uncia formation show strong folds. Near Huanuni a little north from the center of the investigated area, an inclined fold is seen, and near Morococala and Vilacollo in the north of Huanuni, inverted anticlinal and synclinal structures are seen. Also near La Salvadora stock of Llallagua has developed an inverted fold. A narrow structure of repeating anticlines and synclines in a width of about 2 km from east to west extends long from north-west to south-east. Folding actions from Cretaceous period and afterwards occurred in the same direction as that of Plaleozoic formation, but the dips of strata are far gentler than that of Paleozoic formation. The Morococala formation in the most upper part of Neogene Terciary is almost horizontal, and there was no folding action after the period.

Most of the faults in the investigated area cut the axes of folds obliquely, and they are mostly shear faults which intersect with the lateral compression accompanied by folds in the angle of about 45°. As described later, these shear faults have an important role in the formation of veins in this area.

CHAPTER 2. DESCRIPTION OF ORE DEPOSITS

2–1 Huanuni Mine

Ore deposits are embedded in the siliceous sandstone of Llallagua formation, the area including ore deposits is 1,500 m x 1,200 m, and in the western part of the ore deposits exists an anticlinal axis of N10°W. Most of the ore deposits concentrate in the eastern wing of this anticlinal axis, and there are more than 20 parallel veins in the direction NE–SW, and in addition, intersecting obliquely with them, innumerable branch veins have developed reticulately, forming a huge group of ore veins.

Grande vein, one of the main veins, has a strike of N50°E, is 600 m in length and its depth under surface is confirmed to be 1,000 m. In the 160 level of Patiño mine now in operation, there are Bandi and Notaft veins developed in an ENE direction. Notaft vein is locally over 1 m in thickness and abounds in cassiterite and sphalerite. These veins fill faults and fissures and usually have the structure of breccia. There are also breccia veins which are about 20 m wide, and they are distributed irregularly in the ore deposits. The mineralization in the central part of the ore deposits has the following order of occurrence, i.e., tourmaline and quartz fluorite → cassiterite → pyrrhotite → arsenopyrite → shalerite → stannite → siderite, but there is very little wolframite. In the deeper part, however, veins usually contain milky white quartz, are porous and simply contain cassiterite. Veins have changed in such a way that narrow veins of high grade exist reticulated.

Also in the west of the anticline exists Maria Francisca vein with a strike of N70°E. Minerals include sphalerite, and high yellow cassiterite. In the Haununi ore deposit, mineralization differs horizontally. The central part is composed of cassiterite, pyrrhotite, tourmaline, wolframite, etc., but around that part exist mesothermal veins including pyrite, cassiterite and sphalerite. Further around them exist veins including sulfantimonious minerals abounding in sphalerite, galena and silver, and also stannite, but including little cassiterite. These are the characteristics of Maria Francisca vein. For the production of Huanuni Mine, refer to Table III–2–1 Production of Concentrate.

2–2 Morococala Mine

Morococala ore deposit exists in a series of ore deposit zones which continue to the old mines scattered around Santa Fé and Japo described later herein.

The country rocks of this ore deposit are the siliceous sandstone and slate of Cancañiri formation, and the deposit has developed along two fissure systems, NS system and EW system. Main veins are Crucero Vein and San Francisco Vein, and the former is comparatively a stable vein with a strike N75°W which is 600 m long and 10 ~ 15 cm wide. The latter has a strike N30° ~ 40°E extending over 500 m and a vein width of 10 ~ 15 cm, and this vein is also comparatively a good quality vein. Branch veins crossing the main veins have also developed forming a network veins and the whole veins form a columnar ore deposit. Mineralization is limited in this cylindrical region. In relation to the geological structure, the veins concentrate in the sheared zones of the axes of the anticlined structure (Morococala Anticline inclined eastwards. This cylindrical region has been altered heavily and become bleached porous massive altered slate. Gangue minerals are quartz, tourmaline, apatite, andalusite, etc., which are characteristic minerals accompanying high temperature mineralization. Morococala Mine is an old mine, one of the ore deposits which has been developed from old times in Bolivia.

2–3 Santa Fé Mine

This ore deposit exists on the northern extension of the anticlinal axis embedding Morococala Deposit and is an ore deposit developed along three fissure systems with the siliceous sandstone of Cancañiri formation as its country rock. Main veins in N40°W have developed parallel to the bedding planes of the country rock, other two systems are in N45°E and N10°E and accompany narrow branch veins respectively, and the whole veins form a reticulate vein ore deposit. Although these veins are narrow ones, there is a tendency that their grade becomes higher in the deeper parts. Main ore minerals are composed of cassiterite, sphalerite and pyrite, and gangues are mostly quartz. The enriched part of the mine is the part known as "Clavo Fortuna" where three vein groups are intersecting, but the part has already been mined.

2–4 Japo Mine

This ore deposit is situated at a position 9 km NNW of Santa Fé. The mother rock of this ore deposit is the siliceous sandstone of Cancañiri formation, and is embedded concentratedly in Japo anclinal axis which has grown in parallel on the eastern side of Morococala anticline. Main veins have grown in the direction of NS system ~ NE system, and, like Santa Fé and Morococala deposits, have many narrow branch veins and look like reticulate ore deposit.

The most important ore mineral is cassiterite, but pyrite and sphalerite are also accompanied, and locally, arsenopyrite is also found. In the upper part, oxidation has proceeded, so that minerals have changed into oxides in many places. The main gangue is quartz.

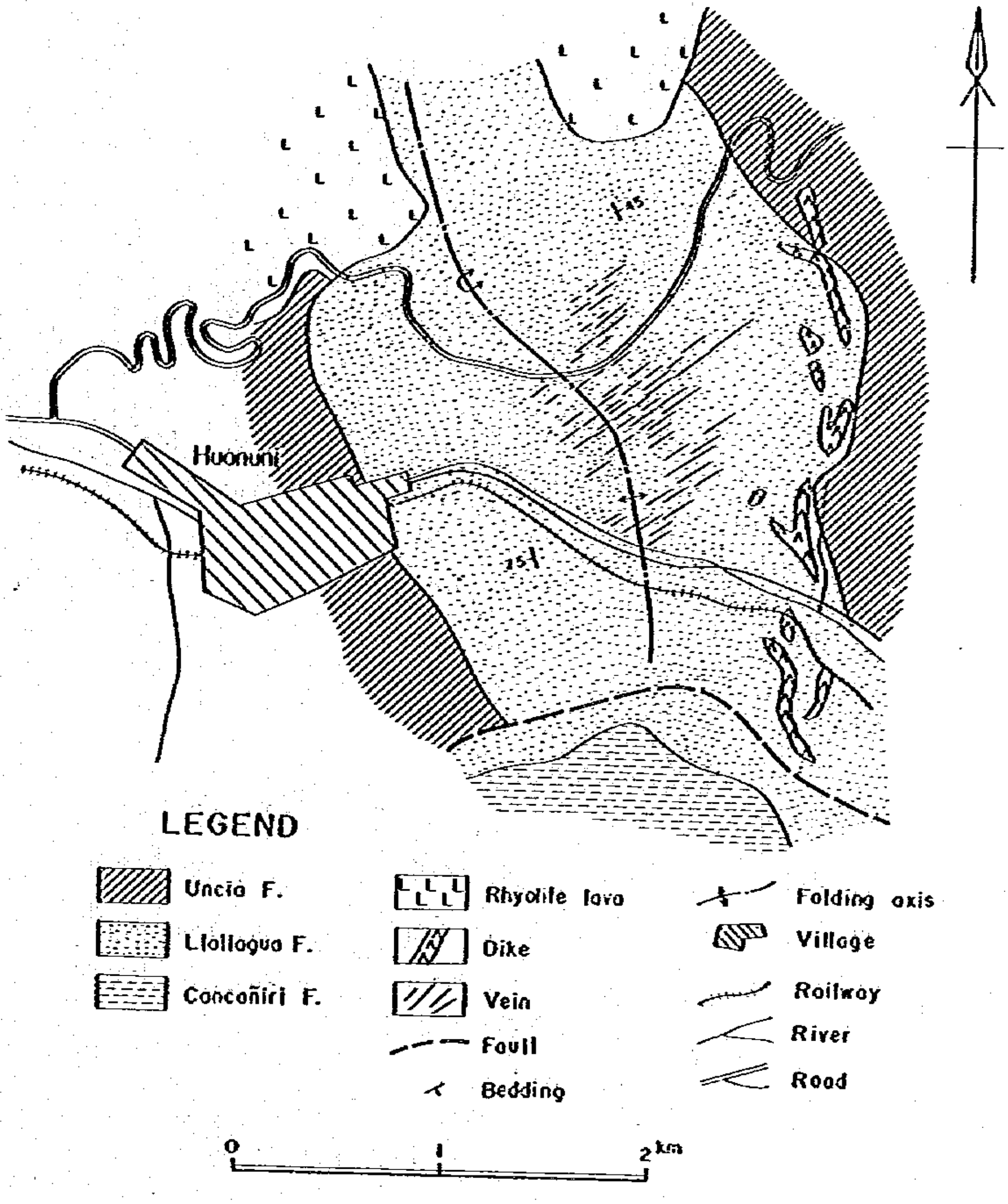


Fig. III-2-1 Geological Map of the Huanuni Mine.

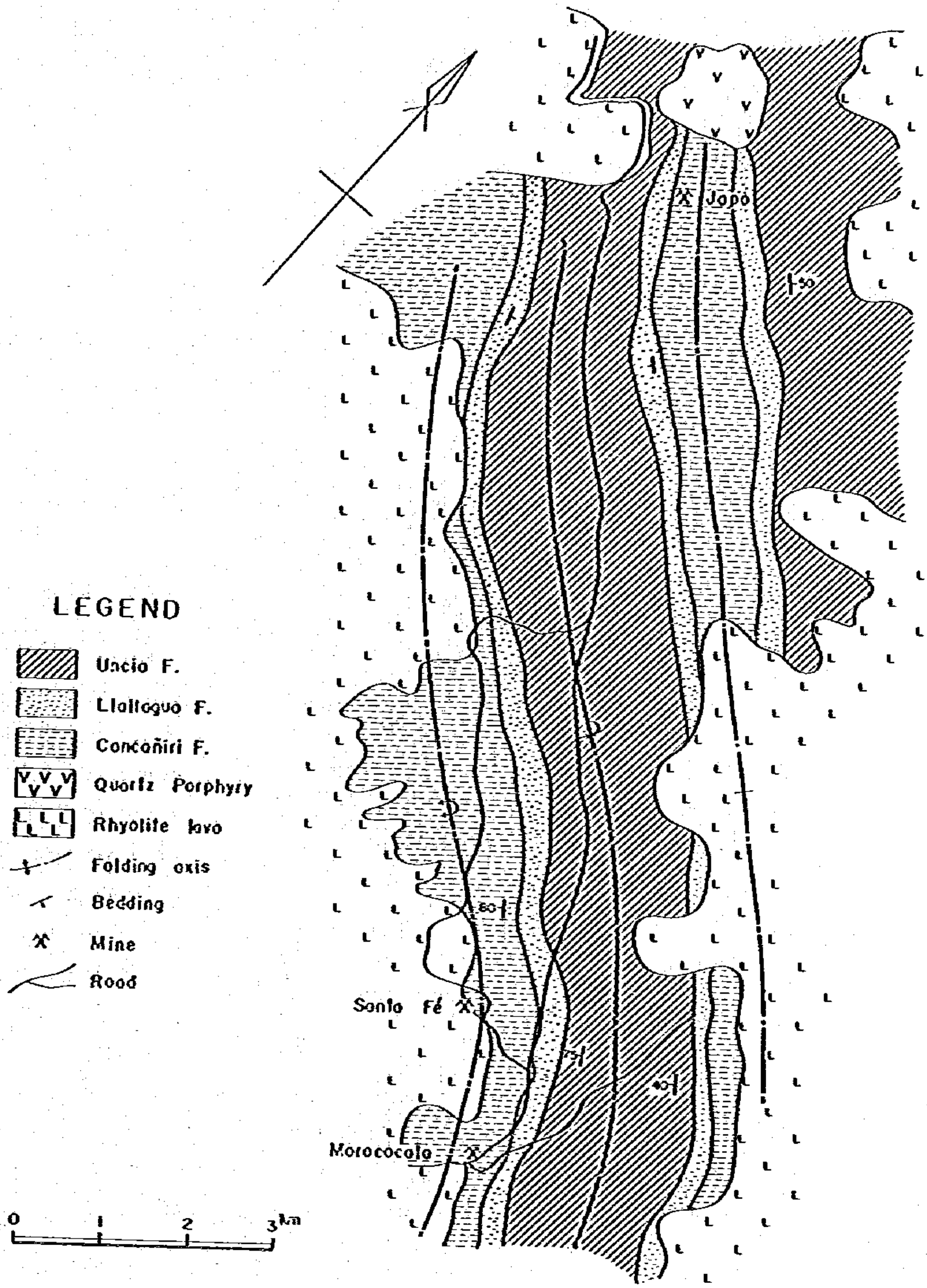


Fig. Ⅲ-2-2 Geological Map of Morococala, Santa Fé and Japo Mines.

2–5 San Luis Mine

This ore deposit is situated at a place about 4 km in the south south-east of Morococala. This is the deposit which has grown in the NW system fissures of the sandstone of Cancañiri formation. The major ore is stibnite and accompanies pyrite and chalcopyrite.

This is an abandoned mine at present and its details are unknown but more than ten waste dumps are scattered on the surface.

2–6 San Florencio Mine

San Florencio Deposit is situated at a place 14 km in the north-west of Catavi. The deposit is a network one which develop in the Silurian sandstone and slate which crop out in some part of tertiary ryolite lava broadly covered paleozoic formation.

From such an ore deposit pattern the place where ore deposits are distributed is called a ventana. The mother rock has been changed to white clay. Mineralization has developed in a cylindrical range with a diameter of 35 m. Main ore minerals other than cassiterite are sphalerite, pyrite, etc., and quartz exists as gangues.

Table III–2-1 Monthly Production of Concentrate (January ~ June 1982)

Mine	Concentrate (t)	S n (%)	Metal Quantity (t)
Huanuni	981.474	32.78	321.694
Santa Fé	39.467	25.87	10.211
Morococala	70.057	22.58	15.819
Japo	67.149	27.70	18.598
Total	1,158.147	31.63	366.322

Table III–2-2 List of Principal Ore Deposits in the Region

Ore Deposists	Tapes of Ore Deposis	Principal Ore Minerals	Country Rocks	Dips and Striks of Principal Veins	Note
Huanuni	Vein	Cassiterite, Sphalerite, Pyrite, Vivianite, Quartz, Kaolinite, Tourmarin, Chlorite	Siliceous Sandstone, Slate	NE, N30° W 70°~80°SE	Recentry the deposit is called tin porphyry
Santa Fé	Vein and Network	Cassiterite, Sphalerite, Pyrite	Graywacke Siliceous Sandstone	NE 70°–80° SW NW	
Morococala	Vein and Network	Cassiterite, Sphalerite, Pyrite Quartz	Graywacke Siliceous Sandstone	NNE 70°~80° SE NW	
Japo	Vein and Network	Cassiterite, Sphalerite, Pyrite, Arsenopyrite, Quartz	Graywacke Siliceous Sandstone	NS NE 80°~85°	
San Luis	Vein	Stibnit, Quartz, Pyrite, Chalcopyrite	Graywacke	NW 70°~80° SW	
San Florencio	Network	Cassiterite, Sphalerite, Pyrite, Quartz	Slate Siliceous Sandstone	NW	

CHAPTER 3. CONSIDERATION CONCERNING PLACES EMBEDDING THE DEPOSITS

3–1 Structure Controlling Distribution of Ore Deposit

As described in 1–3, the geological structure of this area is a very regular one which repeats long and narrow anticlinal and synclinal structures extending from north north-west to south south-east. Main metal ore deposits in Bolivia are embedded in the intrusion rocks of the elevated part which extends from Cordirella Muñecas to Argentine or Palaeozoic formation. In the sedimentary basin of Altiplano, where the Tertiary formation is widely distributed, the number of ore deposits is very small except stratified copper ore deposits. Accordingly, the embedding of ore deposits is thought to be deeply related with elevating and rising movements accompanied by orogenic movements. This area exists in elevated parts where Paleozoic formation is widely distributed and ore deposits especially exist on anticlinal axes which are elevated higher in those elevated parts, and are embedded in Concañiri formation, the lowest formation of this area. Llallagua Ore Deposit, the largest in this area, is also embedded in Concañiri formation of anticlinal axis, Huanuni Deposit has also developed in the anticlinal axis and its eastern wing, and its mother rock is embedded in Llallagua formation which forms the anticline. Santa Fé, Morococala and San Luis Deposits are on the same axis or in the wings near the axis of the long anticlinal structure extending over 30 km. Japo Mine is on an anticlinal axis called Japo Anticlinal Axis, and in the northern extension of the same axis are distributed Japo quartz porphyry stocks. San Florencia Deposit is located on the extension of the anticline passing over Llallagua Deposit dislocated on the way by a fault. As mentioned above, it is clearly supposed that the anticlinal structure is closely related with the embedding of ore deposits and the intrusion of quartz porphyry, and the geological structure controls the places of embedding ore deposits. Some of the faults are strike faults formed as a result of overflod along the strike of the geological structure, but most of them cross the geological structure obliquely.

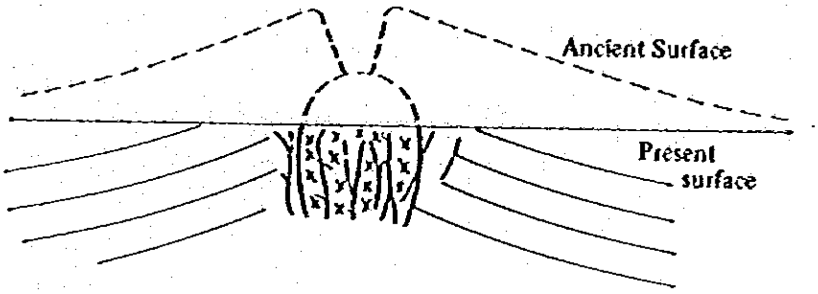
The veins of each ore deposit mostly cross the anticlinal axis obliquely as shown in Table III–2–2 and there are few veins which have developed in the direction of the strike of the geological structure. In Llallague Deposit, veins with the strikes of N40°E ~ N60°E in relation to the anticlinal structure of NNW have developed and many veins clearly intersect with the geological structure obliquely.

Also in Huanuni Deposit the anticlinal axis changes from N10°W to N40°W, but veins are mainly in NE–SW system and characteristically cross the anticlinal axis obliquely. The NW system veins of Santa Fé Deposit have developed parallel to the bedding planes of the mother rock, but the veins of Morococala, San Luis and San Florencia Deposits all have tendencies to intersect with anticlinal axes obliquely. By roughly observing these tendencies, these veins are thought to be those occurred by the lateral pressure which formed the geological structure that have developed from south to north, i.e., shear veins. To form a conclusion, detailed analysis about each vein is required, and it is impossible to confirm from the short investigation of this time, but it is clear that this lateral pressure contributed to the formation of these veins. From the above, it can be supposed that the formation of anticlines by lateral pressure made igneous rocks to intrude easily, fissures were also formed by the pressure and formed veins in relation to the intruded igneous rocks, so that the exploration on the anticline which continues to Santa Fé, Morococala and San Luis and the exploration in the northern area of San Florencia along the anticline extending from La Salvadora Stock to San Florencia will be important.

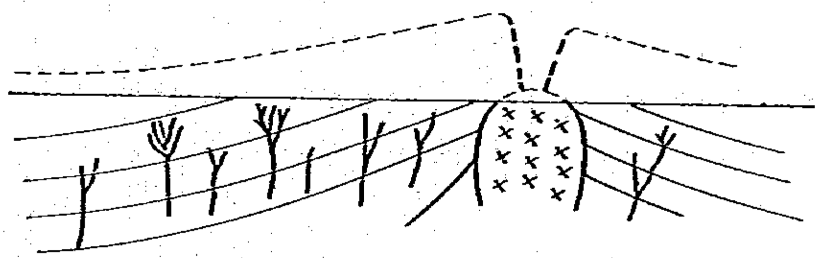
3–2 Igneous Activity and Mineralization

In the investigated area, the number of places where igneous rock crops out is small as mentioned above, but igneous rock is closely related with mineralization. Except Morococala rhyolite of more recent age San Pablo stock has direct relation with mineralization together with the La Salvadora Stock, and further, quartz porphyry dykes around Huanuni are also related with the mineralization of Huanuni Deposit. Not only in the investigated area, but also around the area, the intrusion of quartz porphyry has close relation with mineralization. Although outside the investigated area, around Bolivar Mine about 20 km in the south of Huanuni Mine, from intruded igneous rock towards its periphery, there is a tendency that the ore deposit whose main part is cassiterite transforms to the complicated sulfide ore deposits of tin, lead and zinc. Generally, veins formed in igneous rock are high temperature types compared with the ore deposits around. The above-mentioned tendencies are common phenomena seen in Chorolque, Potasi, Llallagua, San Pablo and Chualla stocks which have veins in the igneous rock of the tin ore deposit zone in Bolivia. As stated above, acid igneous activity in this area during Miocene epoch not only contributed to ore deposit formation but also affected the types of mineralization. From these viewpoints of igneous activity and mineralization, the positional relations of veins and igneous rock are summarized as shown in Fig. III–3–1. From these viewpoints, to explorate the veins, it is necessary to discover some indications which the hidden igneous rock exist with some method and it is thought effective to explorate these indications as center.

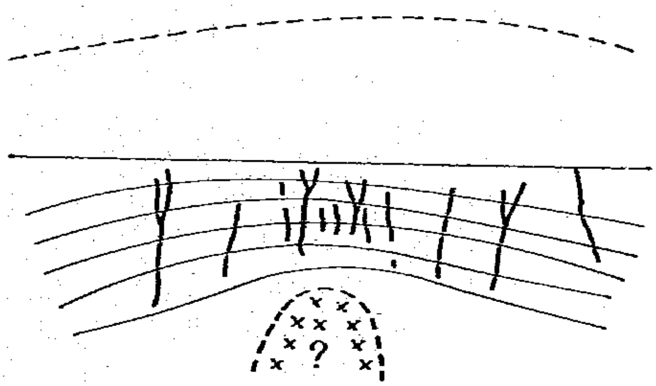
A
Catavi



B
Japo
Santa Fé
Morococala



C
Huanuni



(Source: ASAHIKO SUGAKI etal Geological Study on Polymetallic Hydrothermal Deposits in the Oruro District, Bolivia)

Fig. III–3–1 Models of Relations between Ore Deposits and Igneous Rock in the Investigated Area

CHAPTER 4. PHYSICAL PROPERTY TEST

By collecting rock samples from the investigated area and measuring their physical properties, the applicability of geophysical prospecting to this area was examined. For measurement, the under water measuring method was used for density measurement, and about elasticity wave velocity, p-waves were measured in a forced wet state with an ultrasonic wave transmission speedometer. For measuring IP and resistivity, values were measured with a sample measuring IP transmitter/receiver by Frequency Domain Method. Natural residual magnetism was measured with a Spinner magnetometer, and for measuring magnetic susceptibility, samples in a forcibly dried state after completing density measurement were used to measure mass magnetic susceptibility with a Bison AC susceptibility meter, and from the density determined as mentioned above, volumetric susceptibility was calculated. These measured values are shown in Tables III–4–1 and III–4–7.

Hereinafter, some consideration will be given to combining these values with the measured values of rocks around Catavi Mine obtained last year.

(1) Density

According to the statistics of density values measured for each kind of rock, the average

Table III–4–2 Statistic Values of Density Measurement of Rocks

Rocks	Average Value	Maximum Val.	Minimum Val.	Standard Deviation
Quartz Porphry	2.40	2.46	2.36	0.04
Sand Stone	2.60	2.69	2.55	0.04
Rhyolite Lava	2.29	2.40	2.16	0.12
Sedimentary Rock	2.60	2.69	2.55	0.12

values of the density of quartz porphyry which are the mother rocks of ore deposits, and sedimentary rock, are each 2.40 g/cm^3 and 2.60 g/cm^3. As the density difference is 0.2 g/cm^3, it is possible to estimate the position and scale of quartz porphyry in sedimentary rock by means of gravity exploration, and it is also possible to estimate the geological structure over a wide area. In addition, the density of the altered part of La Salvadora Stock measured last year showed 2.22 g/cm^3 in a heavily altered part, and 2.50 g/cm^3 in a lightly altered part, i.e., the density values differ from that of usual sedimentary rock, so that it is also possible to make clear the distribution of wide altered zone of quartz porphyry itself. From these points, gravity exploration is effective also for prospecting the blind deposits of Catavi type deposits.

(2) Elastic Wave Velocity

The average values of the elastic wave velocities for the kinds of rocks measured this time in the descending order are those of sedimentary rock, quartz porphyry and rhyolite lava.

Table III-4-3 Statistic Values of Elastic Wave Velocity

(Unit Km/sec)

Rocks	Average Value	Maximum Value	Minimum Value	Standard Deviation
Quartz Porophyry	4.00	4.33	3.76	0.24
Sandstone	4.66	5.38	3.83	0.57
Rhyolite Lava	2.44	3.62	1.81	0.84
Sedimentary Rocks	4.70	5.38	3.83	0.56

From the fact that the elastic wave velocity of rhyolite lava in the shallow part is far lower than the elastic wave velocities of sedimentary rocks and quartz porphyry below the rhyolite and the deviation of measured values is small, the state of distribution of rhyolite lava can be made clear by seismic prospection. The difference between the average value of the elastic wave velocity of quartz porphyry and that of sedimentary rocks is 0.70 km/sec, and the elastic wave velocity of sedimentary rock is larger, but the deviations are large and the minimum values of both rocks are almost the same. According to the investigation data last year, the average value of the elastic wave velocity of the quartz porphyry of La Salvadora stock of lightly altered is 5.03 km/sec and a little higher than that of sedimentary rocks, i.e., the relation of velocity difference is inverted. From the above, it is difficult to estimate the distribution of quartz porphyry rock by seismic prospection. However, heavily altered quartz porphyry of La Salvadora Stock shows a value as low as 3.36 km/sec, so that it will be comparatively easy to detect the mineralized zone altered heavily.

(3) Resistivity

Resistivity was measured for one sample except sedimentary rocks, ores were not measured this time and the values from the measurement made during the investigation last year were employed for comparison.

Table III–4–1 Measured Value of Physical Property of Rocks

No.	Sample No.	Rock name	Sampled location	Density (gr/cm^3)	Elastic Wave velocity (km/sec)	Resistivity (Ω-m)	I.P. (%)	Magnetic susceptibility (10^{-6} emu/cc)	Observation
1	2	S.S	San Florencio mine	2.59	4.67	116	2.3	366	Average value of density of rock
2	3	Rhy-lava	San Florencio mine	2.16	1.88	24	2.4	305	(gr/cm^3)
3	4	S.S	Huanuni mine	2.69	5.31	597	1.8	318	Quartz porphyry 2.40
4	5	QP	Huanuni mine	2.38	4.33				Sandstone (except No. 14) 2.60
5	6	Sandy sl	Huanuni mine	2.58	5.06	394	2.5	348	Rhyolite-lava 2.29
6	7	Rhy-lava	Huanumi mine	2.40					Sandy slate 2.58
7	12	QP	Catavi mine	2.36	3.76				
8	13	SS	Andernivelque	2.55	4.29	110	2.1	201	
9	14	SS	Andernivelque	2.58	4.95	672	2.1	432	
10	15	SS	Road to Morococala	2.62	5.38	1528	0.7	800	Average value of elastic wave – velocity
11	16	Rhy-lava	Road to Morococala	2.18	1.81				
12	17	SS	Road to Morococala	2.57	4.09	558	2.6	198	(km/sec)
13	18	SS	Road to Morococala	2.60	5.34	1803	0.4	1556	Quartz porphyry 4.00
14	26	SS	Morococala mine	2.97	6.37	584	14.5	3618	Sandstone (except No. 14) 4.66
15	28	Rhy-lava	Santa Fé mine	2.40	3.62				Rhyolite-lava 2.44
16	30	QP	Japo mine	2.46	3.91				Sandy slate 5.06
17	31	SS	Japo mine	2.60	4.10	408	0.5	322	
18	40	SS	Agua Caliente	2.62	3.83	102	3.0	103	

Q.P : Quartz porphyry
S.S : Sandstone
Rhy-lava: Rhyolite-lava
Sandy sl: Sandy slate

Table III-4-4 Statistic Value of Resistivity

(Unit Ω – m)

Rocks	Average Value	Maximum Value	Minimum Value	Standard Deviation
Sedimentary Rocks	654	1,803	102	582
Rhyolite Lava	24			
Altered Sandstone	584	Sampled in Morococala Mine		
Ore	4	from last year's data		

Although the measured values of sedimentary rocks deviate widely, these values ore far larger than the resistivity values of ores, so that the difference between the average value of sedimentary rocks and that of ores is very large and distinct. However, other rocks usually have high resistivity values even when altered, so that the classification of veins and other rocks will be possible.

(4) IP Values

IP values wave measured for only one sample except sedimentary rocks. The average IP value of sedimentary rocks is 3.0% and that of rhyolite lava is as low as 2.4% The IP values of altered sandstone and ores are all higher than those of these rocks.

Table III-4-5 Statistic Value of IP

Rocks	Average Value	Maximum Value	Minimum Value	Standard Deviation	Electrod Blank test
Sedimentary Rocks	1.7	3.0	0.4	0.90	3.0
Phyolite Lava	2.5				
Altered Sandstone	14.5	Sampled in Morococala Mine			
Ore	39.5	from last year's data			

As the deviation of the IP values of sedimentary rocks is small, it is clear that all the sedimentary rocks have low IP values, and from these measurement results, the application of IP method to this area is very effective in deposit exploration, and altered zones and mineralized zones can be found.

(5) Magnetic Susceptibility

Magnetic susceptibility values were measured for one sample of each kind of rock except sedimentary rocks. The measured values of sedimentary rocks have large deviation, and even when referring to the values measured last year each rock showed a low value, and it seems that each rock does not have a definite susceptibility value.

Table III-4-6 Statistic Value of Magnetic Susceptivility

Rocks	Average Value	Maximum Value	Minimum Value	Standard Deviation
Sedimentary Rocks	464	1,556	103	405
Rhyolite Lava	305			
Altered Sandstone	3,618			

(6) Residual Magnetism

The measured values of residual magnetism are all very small except that of altered sandstone collected in No. 10 Morococala mine (Sample No. 26), and both declination and inclination deviate greatly and no regularity can be recognized. When seen therefore from this measurement results, magnetic prospection is not suitable for this area.

From the measured values of various physical properties of rocks mentioned above, the applicability of geophysical prospecting methods can be concluded as follows;

(1) There is a clear difference between the density of sedimentary rocks and that of quartz porphyry which may embed or be closely related with ore deposits and this difference can effectively be used to discover hidden quartz porphyry. Accordingly, it is necessary to carry out gravity exploration first widely over an area where the latency of quartz porphhry is expected to investigate the possibility of the existence of quartz porphyry stocks.

(2) If the possibility of the existence of quartz porphyry is found, it will be most effective to carry out electrical exploration by means of IP Method to explore ore deposits themselves with those places having possibility as centers.

Table III–4–7 Measured Value of Residual Magnetization

No.	Sample No.	Rock name	Sampled location	Jo (C.G.S. e.m.u.)	Jd (C.G.S. e.m.u.)	Declination	Inclination
1	2	Sandstone	San Florencio mine	8.17×10^{-7}	3.45×10^{-7}	S 11° E	–47°
2	3	Rhyolite lava	San Florencio mine	7.64×10^{-6}	4.03×10^{-6}	S 6° W	45°
3	4	Sandstone	Huanuni mine	8.71×10^{-6}	3.56×10^{-6}	N 25° E	–52°
4	6	Sandy slate	Huanuni mine	4.58×10^{-7}	1.85×10^{-7}	N 19° W	22°
5	13	Sandstone	Andernivelque	8.67×10^{-6}	3.68×10^{-6}	N 27° E	2°
6	14	Sandstone	Andernivelque	1.66×10^{-6}	6.69×10^{-7}	N 18° E	–23°
7	15	Sandstone	Road to Morococala	4.25×10^{-6}	1.75×10^{-6}	N 19° E	–23°
8	17	Sandstone	Road to Morococala	4.80×10^{-6}	2.06×10^{-6}	S 64° E	16°
9	18	Sandstone	Road to Morococala	1.74×10^{-6}	7.26×10^{-7}	N 58° E	– 9°
10	26	Sandstone	Morococala mine	1.47×10^{-4}	5.55×10^{-5}	N 35° W	–20°
11	31	Sandstone	Japo mine	7.37×10^{-5}	3.14×10^{-5}	N 46° E	–20°
12	40	Sandstone	Agua caliente	7.37×10^{-5}	3.29×10^{-5}	N 28° E	–89°

Note: Upward inclination from horizontal (–)
Downward " " (+)

CHAPTER 5. EXPLORATION PLAN

5–1 Base of Planning Exploration

The characteristic of mineral exploration is that mineralized zones are included in Altiplano and form a deposit region extending from south to north, but as the region is a high land, few trees grow and altered outcrops can easily be found, so that most of the outcrops whose scales show promising mineralization have already been explored or developed, accordingly, it is no exaggeration to say that it is impossible to discover new ore deposits in future without discovering blind deposits. From this standpoint, the investigated area is as stated before:

① The investigated area is in the ore deposit area of tin or the complex sulfide ores accompanying tin.

② As shown by the possibility of the latency of quartz porphyry of Hunani type deposit in the area investigated this time, there is the possibility of latency of quartz porphyry, which is accompanied by the possibility of discovering blind deposits.

③ Although there is a high possibility of embedded ore deposits in about half of the investigated area, the area is covered with rhyolite lava far newer than the deposit formation age, so that the geological structure of this area and the state of embedding porphyry which is related with deposit formation are unclear and plenty of scope for exploration is left.

From these viewpoints, the area is sufficiently worthy of exploration and the process of exploration is :

① First, in order to clarify the distribution of quartz porphyry and geological structure related with ore deposits, gravity exploration whose applicability has been confirmed by the results of the measurement of physical properties of rocks should be carried out.

② Next, about the areas which were recognized to be abnormal by the gravity exploration, more detailed investigation and IP exploration method should be carried out to directly examine the existence of ore deposits.

③ COMIBOL has already carried out gravity exploration in this area, but the examination of COMIBOL's maps showed that the method of representation is inappropriate, and it is necessary to analyze the area by modern advanced analyzing methods and to make clear the relations of gravity exploration results with geological structure, etc.

Based on the above-mentioned idea, the following plan was made.

5-2 Gravity Exploration

5-2-1 Reason for Selecting Region

If economic conditions could be set aside, it is desirable to explore the whole area covered with rhyolite lava in the investigated area, but enormous expenses would be incurred. According to the geological investigation results this time, in the part from Llallagua Deposit to Japo Deposit exist deposits on the anticlinal axis, San Florencio, San Luis, Morococala, Santa Fé and Japo in succession at comparatively small intervals. Near San Flurencia Deposit, there is high possibility of the latency of quartz porphyry or ore deposits. From this viewpoint, we want to carry out exploration in a 15 km x 10 km area near San Florencia.

5-2-2 Exploration Work

(1) Working Area : N60E 10 km x N30W 15 km = 150 km^2

(2) Survey Lines : Thirty-one survey lines each 10 km long in the direction of N60E will be set at the interval of 500 m towards the direction of N30W. The total extent of the survey lines would be 310 km.

(3) Survey Points : 21 points will be set at the interval of 500 m on each survey line. The number of survey points would be 651 (21 points/line x 31 survey lines).

(4) Instrument Used : La-Coste gravimeter

(5) Density Measurement

Taking 15 samples/100 km^2 as standard, the values of density of over 23 samples will be measured and their sampled points will be marked clearly on 1/20,000 topographical maps.

(6) Survey : Levelling will be carried out about all the survey points.

For the accuracy of survey, the equation $\epsilon \leqq 20$ D would be used, where : ϵ = tolerence (unit : cm) D = block distance (unit : km)

When determining altitudes by other methods than levelling, precision barometers will be used to obtain the utmost accuracy possible.

(7) Error of Gravity Measurement : The closure of measurement should be once a day and a closure error shall be within 0.2 m gal.

(8) Correction : As correction, tidal correction, drift correction, altitude correction (Free Air and Bouger correction), latitude correction and topographical correction will be carried out.

(9) Analysis : By preparing two kinds of isogravitational force maps (1/20,000) classified by density, two kinds of filter maps, normal structure filter maps and double structure filter maps, plane qualitative analysis maps, two-dimensional quantitative analysis profiles (1/20,000, three crosssection) and g-H correlation maps, and combining with geological investigation results,

Table III-5-1 Cost of Gravity Prospection

Article		Class of Work	Base of Calculation			Amount
Labor Cost	Geophysicist	Preparation	10 days x 2 per	20 per	25US$/day	500 US$
	"	Field work	50 x 2 x 2 groups	200	25	5,000
	"	Laboratory work	51 x 2 x 2	204	25	5,100
	Laborer	Field work	50 x 2 x 2	200	5	1,000
	Laboratory Assistant	Lab. work	51 x 1 x 2	102	12	1,224
	Driver	Field work	50 x 1 x 2	100	15	1,500
	Sub total					14,324
	Surveyer	Preparation	5 days x 2 per	10 per	25 US$/day	250
	"	Field work	60 x 3 x 3 groups	540	25	13,500
	"	Lab. work	11 x 3 x 2	99	25	2,450
	Laborer	Field work	60 x 2 x 3	360	5	1,800
	Driver	"	60 x 1 x 3	180	15	2,700
	Sub total					20,725
	Geologist	Field work	30 x 1	30	25	750
	"	Lab. work	10 x 1	10	25	250
	Laborer	Field work	30 x 1	30	5	150
	Driver	"	30 x 1	30	15	450
	Sub total					1,600
	Draftman	Lab. work	30 x 2	60	12	720
	Sub total					720
	Total					37,369
Traveling Allowance	Geophysicist	Field work	50 x 2 x 2	200	10	2,000
	Surveyer	"	60 x 3 x 3	540	10	5,400
	Geologist	"	30 x 1	30	10	300
	Total					7,700
Material cost			651 stations		2 US$/sta.	1,302
Depreciation Expense	Gravimetry Inst.		38,500 US$x0.369 ÷ 180 x 50 days x 2			7,893
	Leveliny Inst.		700US$ x 0.369 ÷ 180 x 60 x 3			258
	Jeep		23,000 x 0.9 ÷ 1,800 x 50 x 2			1,150
	Jeep		23,000 x 0.9 ÷ 1,800 x 60 x 3			2,070
	Jeep		23,000 x 0.9 ÷ 1,800 x 30 x 1			345
	Total					11,716
Computer cost						7,000
Total amount						65,087

Note : 15 US$/day of driver includes traveling allowance.

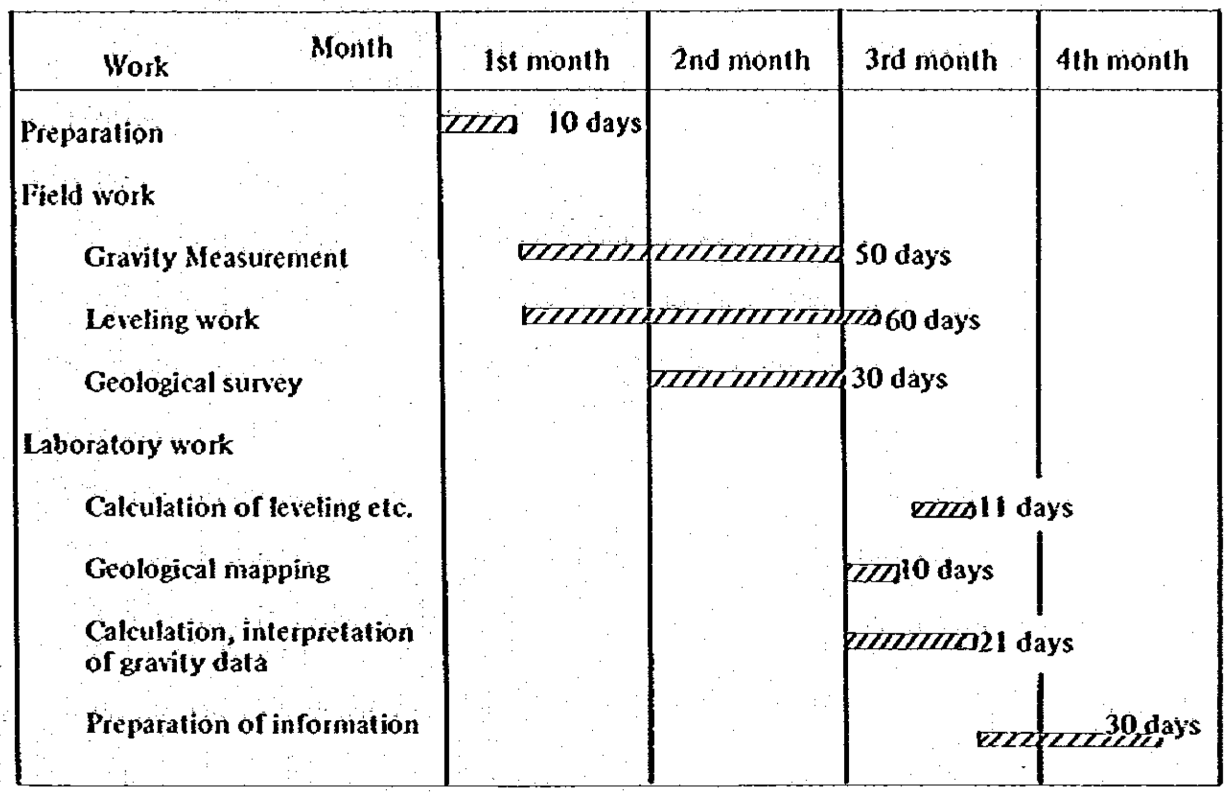


Fig. III–5–1 Process of Gravity Exploration

models will be corrected and accurate geological structures and the distribution of quartz porphyry will be estimated.

(10) Working Process and Members

Although the interval of survey points is 500 m and the density of survey points is 4.3 points/km², as there is no need to cut trees there, efficiency was estimated as follows.

Gravity Measurement Efficiency 10 points/day/group (actual working days, 23 days/month)

Levelling Efficiency : 5 points/day/group (actual working days, 23 days/month)

The organization of investigators is as follows. For gravity measurement, two groups will be organized, each group of which consisting of two engineers, two laborers and a driver, in total five members; and for levelling, three groups will be organized, each group of which consisting of three engineers, two laborers and a driver in total six members. In addition, for the purpose of surface geological survey, one geophysicist and one laborer will be added to prepare geological maps. The process of gravity prospection the organization of members are shown in Table III−5−1, the period of field work is six months and that of desk work is three months. However, the report will not be printed and bound.

(11) Approximate Costs

At present, COMIBOL does not have La Coste gravimeters, so it is necessary to purchase them, but these new investment amounts have not been counted in, only depreciation costs have been summed up. Total costs amount to about US$ 65,000 and the itemized costs are as follows.

Labor Cost	US$ 37,369
Traveling Allowance	US$ 7,700
Material Cost	US$ 1,302
Depreciation Expense	US$ 11,716
Computer Cost	US$ 7,000
Total	US$ 65,087

5−3 Electrical Exploration (IP Method)

5−3−1 Reason for Selecting Area

The reason for selecting the area is as follows. The anticlinal structure of Llallagua Deposit is cut by a fault near San Florencia Deposit and the north-western part of the area is covered with rhyolite lava, so it is unclear, but the disturbance of geological structure is expected and the latency of igneous rock is expected. In addition, although its scale is small, San Florencia Deposit exists near here and this altered quality zone extends to north-west, so that there is high possibility that altered zones also exist under the rhyolite lava and mineralization is expected. Based on these conditions, this area was selected to detect ore deposits directly or altered quartz porphyry rock by the IP method more precise than the gravity exploration.

5-3-2 Exploration Work

(1) Working Area : N60E 3 km x N30W 6 km = 18 km^2

(2) Measuring Instruments : IP Mod. IPR-8 or IPC-7 2.5 kw
(SCINTEREX) 1 set
IP YOKOHAMA ELECTRONIC Mod.
1-5202-D (1040) 1 set
Small Compass

(3) Measuring Method

By employing Frequency Domain Method and the disposition of electrodes of gradient method, measurement will be carried out as follows in principle. Each survey line will be divided at every 500 m intervals, and at two positions on the extensions of both ends 500 m apart from the ends, etrodes C_1 and C_2 will be earthed and a current will be passed. In a measuring section, the measurement distance is taken as P_1, P_2 = 50 m and potentials will be measured. Measuring positions will be moved ten times by moving 50 m each time. When the measurement

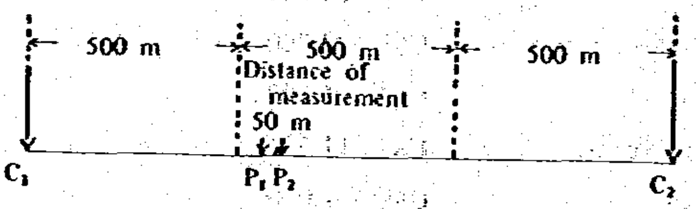


Fig. III-5-2 Schlumberger Array Disposition

of one survey line is completed in such a way, measurement will be moved to the adjacent survey line, and the two remaining lines will be measured in the same way. Next, C_1 and C_2 electrodes will be moved and the following measuring section will be measured in the same manner.

The reason why the Frequency Domain Method and gradient method are employed is : Frequency Domain Method is easier than Time Domain Method in measurement and as the machines used are not complicated, measurement is easy; and by the gradient method, the position of ore deposits or stocks can be represented on a plane comparatively accurately, so that there is an advantage that the level positions of deep mineralized zones can be grasped accurately; accordingly, when used in site these two methods are regarded to be appropriate.

(4) Survey Line Arrangement and Survey Point Interval

Thirty-one survey lines each 3 km long in the direction of N60E will be set at 200 m intervals and total plofil line will be 93 km. Then the number of total measurement point will be 1,860.

(5) Method of Analysis

As the geological structure there is not so complicated, there are few elements which may become electrical noise sources, and there is a possibility that IP irregularities caused by ore deposits can be interpreted comparatively clearly, but recently, a method to analyze IP investigation results quantitatively by means of two-dimensional analysis of finite elements and boundary elements has been used. By employing this method of analysis for the simulated analysis of two-dimensional crosssections, mineralized positions on the positions of quartz porphyry will be clarified. As analysis results, maps of survey line positions, plans by depths, sections per survey lines, quantitative analysis maps and the maps of relations between ore deposits and measurement results will be prepared.

(6) Working Process and Members

Considering that there are no trees in the area and measurement can be carried out rather easily, efficiency was estimated as follows.

0.7 km/day (actual working days 23 days/month)

The members will include one engineer for the IP transmitter, one engineer each for two IP receivers, ten laborers and two drivers.

The process in this case is shown in Table III–5–3.

The period of field measurement work is about six months, that of desk analysis work is two months, report writing time is about 20 days, so that the total period becomes nine months. For help in the interpretation of IP investigation, geological survey will be carried out to prepare geological maps.

(6) Approximate Costs

At present, COMIBOL has two sets of IP exploration instruments, it is therefore not necessary to purchase them, accordingly, new investment has not been counted in, but only depreciation costs have been summed up. The costs are shown in Table III–5–2. Total costs amount to about US$ 87,000 and itemized costs are as follows.

Labor Cost	US$	34,935
Traveling Allowance	US$	5,340
Material Cost	US$	8,000
Depreciation Expense	US$	20,111
Computer Cost	US$	19,000
Total	US$	87,386

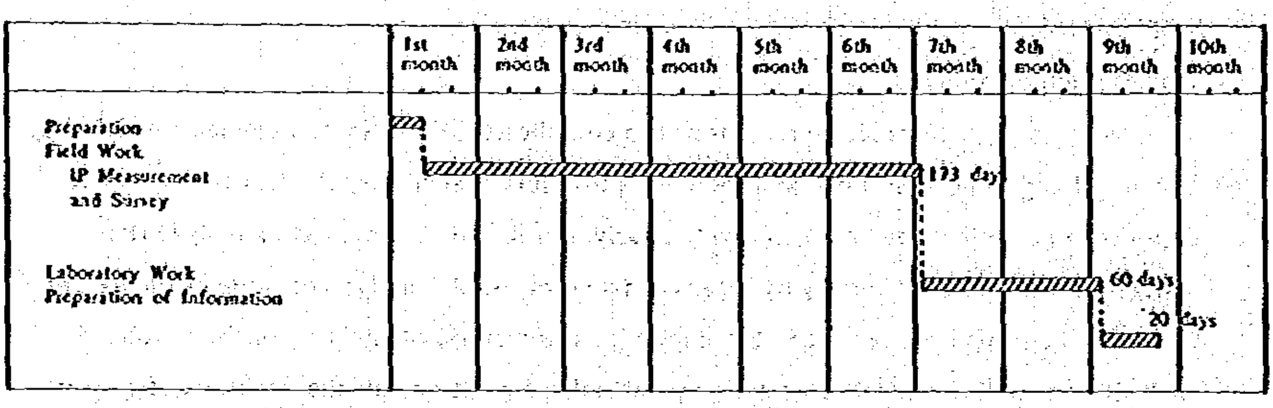


Fig. III-5-3 Process of IP Electrical Exploration

Table III-5-2 Cost of IP Electrical Exploration

Article		Class of Work	Base of Calculation			Amount
Laborer Cost	Geophysicist	Preparation	10 days x 3 per	30 per	25 US$/day	750 US$
	"	Field Work	173 days x 3 per	519	25	12,975
	"	Laboratory Work	80 days x 3 per	240	25	6,000
	Laborer	Field Work	73 days x 10 per	1,730	5	8,650
	Driver	"	173 days x 2 per	346	15	5,190
	Sub total			2,865		
	Geologist	Field Work	15 days x 1 per	15	25	375
	Laborer	"	15 days x 1	15	5	75
	Geologist	Laboratory Work	20 days x 1	10	25	200
	Sub total			40		
	Draftman	Laboratory Work		60	12	720
	Sub total			60		
	Total			2,965		
Traveling Allowance	Geophysicist	Field Work	173 days x 3 per	519 per	10	5,190
	Geologist	"	15 days x 1	15	10	150
	Total					5,340
Material Cost						8,000
Depreciation Expense	IP Equipment		30,000 US$ x 0.369 ÷ 180 x 173 days x 1.5 set			15,959
	Jeep		23,000 x 0.9 ÷ 1,800 x 173 x 2			3,979
	Jeep		23,000 x 0.9 ÷ 1,800 x 15 x 1			173
	Total					20,111
Computer Cost						19,000
Total Amount						87,386

Note: The 1.5 in calculation of Depreciation expense means one transmiter and two receivers

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