Figure 4-2-9.1 A sample of Canton District Map
(La Paz Dept., Gualberto Villarroel Prov., San Pedro de Curahuara Canton, M2180001.BMP)

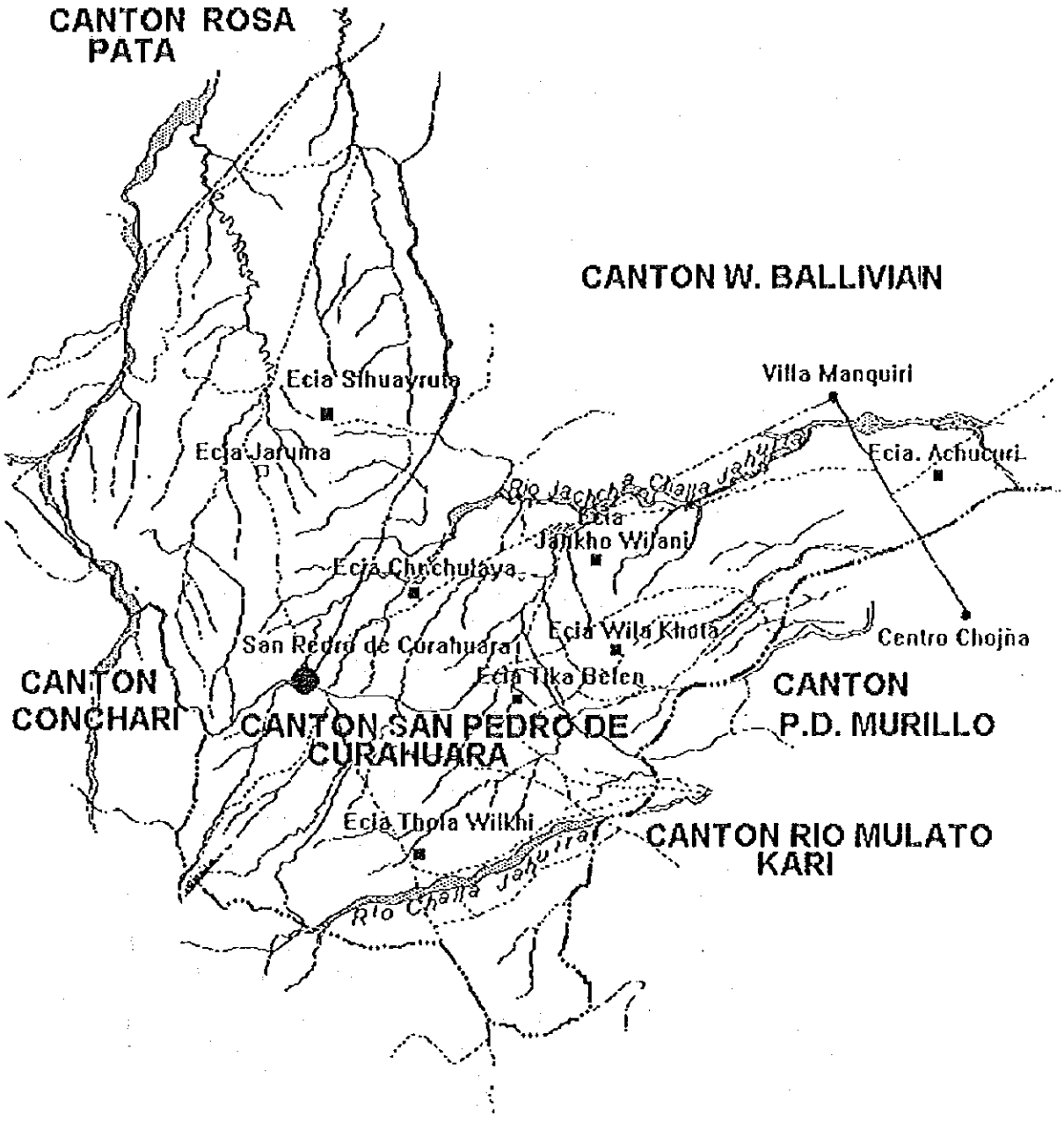
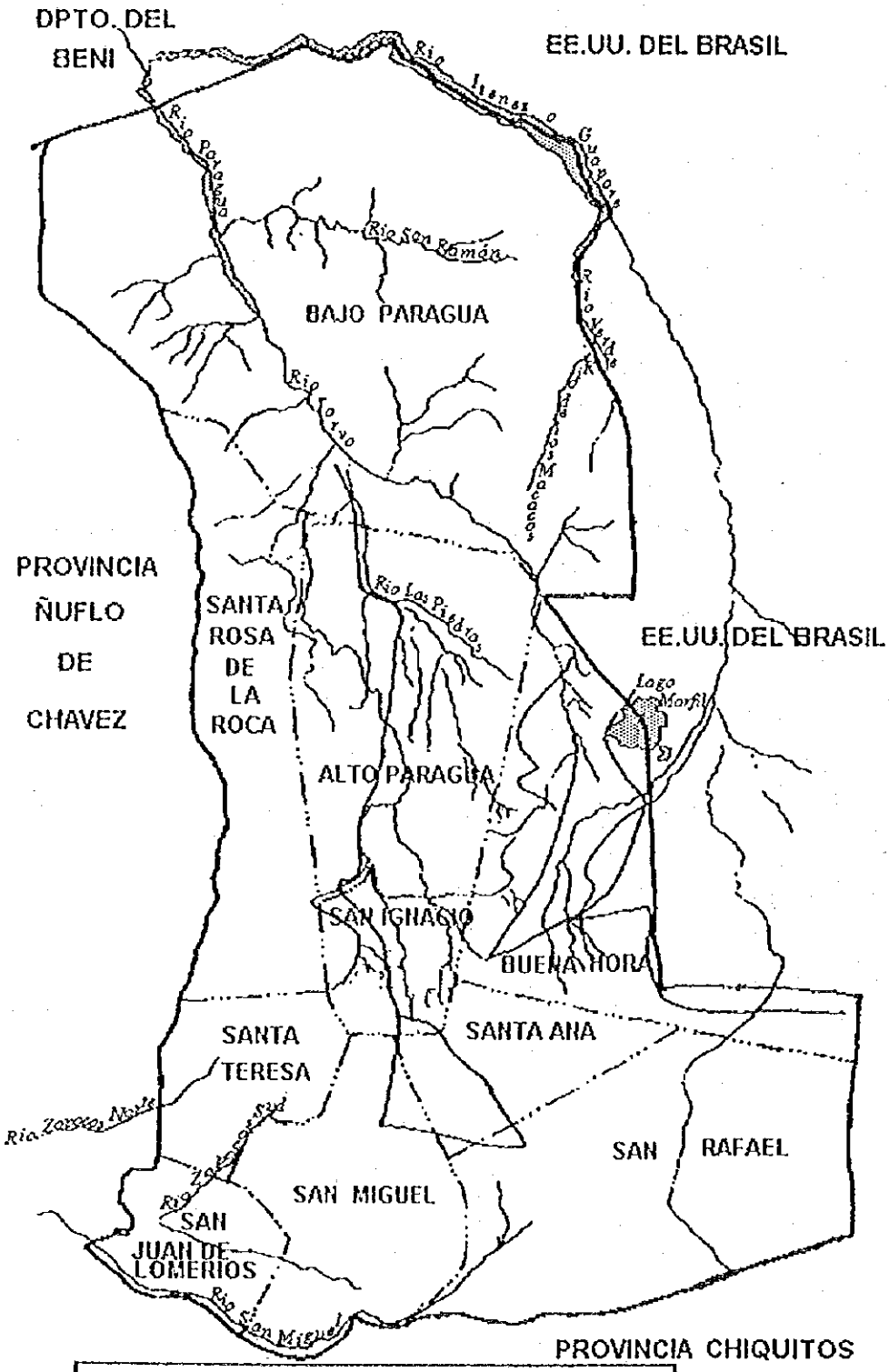


Figure 4-2-9.2 A sample of Provincia Administrative Map
(Santa Cruz Dept.,Velasco Prov., P703ADMI.BMP)



P703-Provincia VELASCO (Santa Cruz)

Figure 4-2-9.3 A sample of Department Administrative Map
(D7-ADMI.BMP-Santa Cruz)

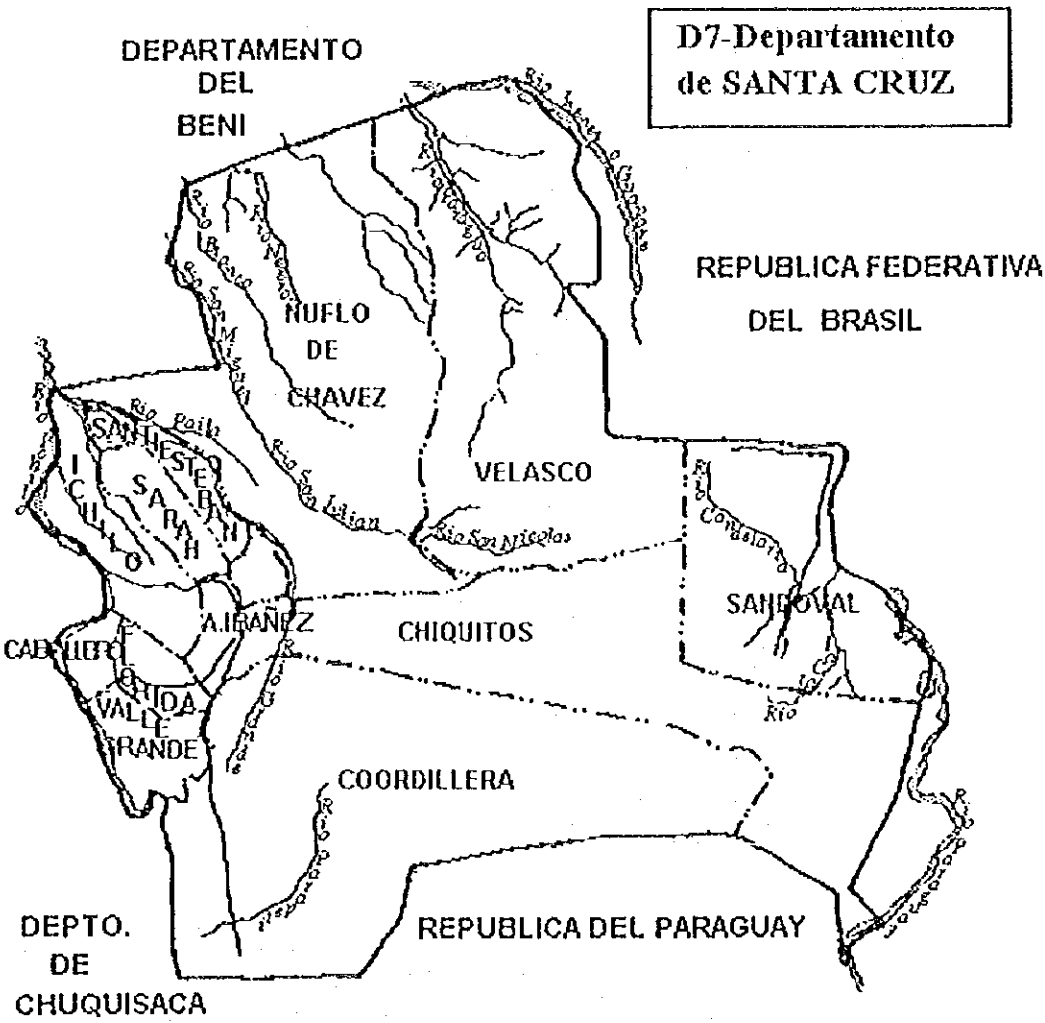


Figure 4-2-9.4 A sample of Well Geographic Column Map (W6030301A.BMP)

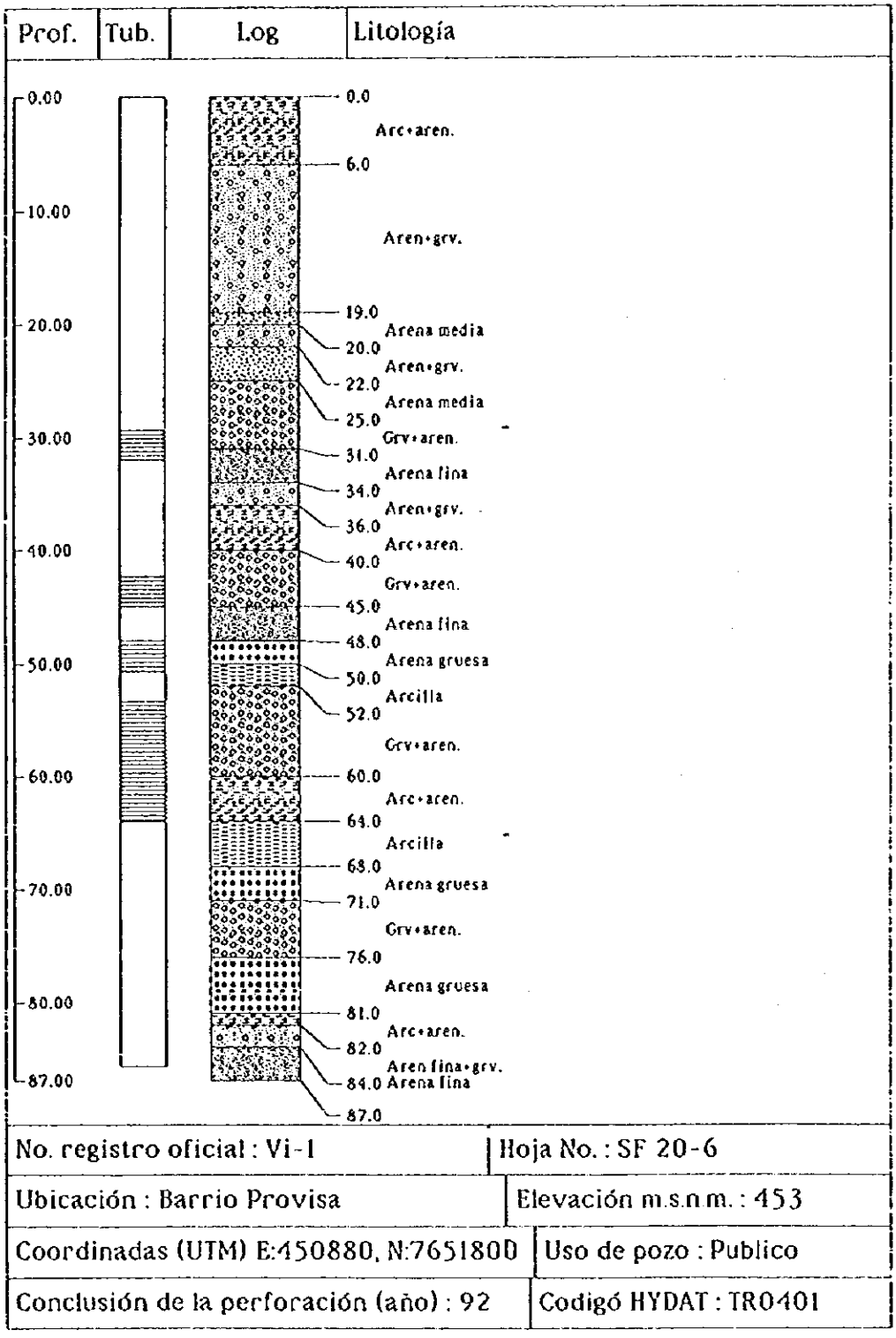


Figure 4-2-9.5 A sample of Road Network Map (ROAD05-La Paz)

Figure 4-2-9.6 A sample of Hydrological Map (HILO05-La Paz)

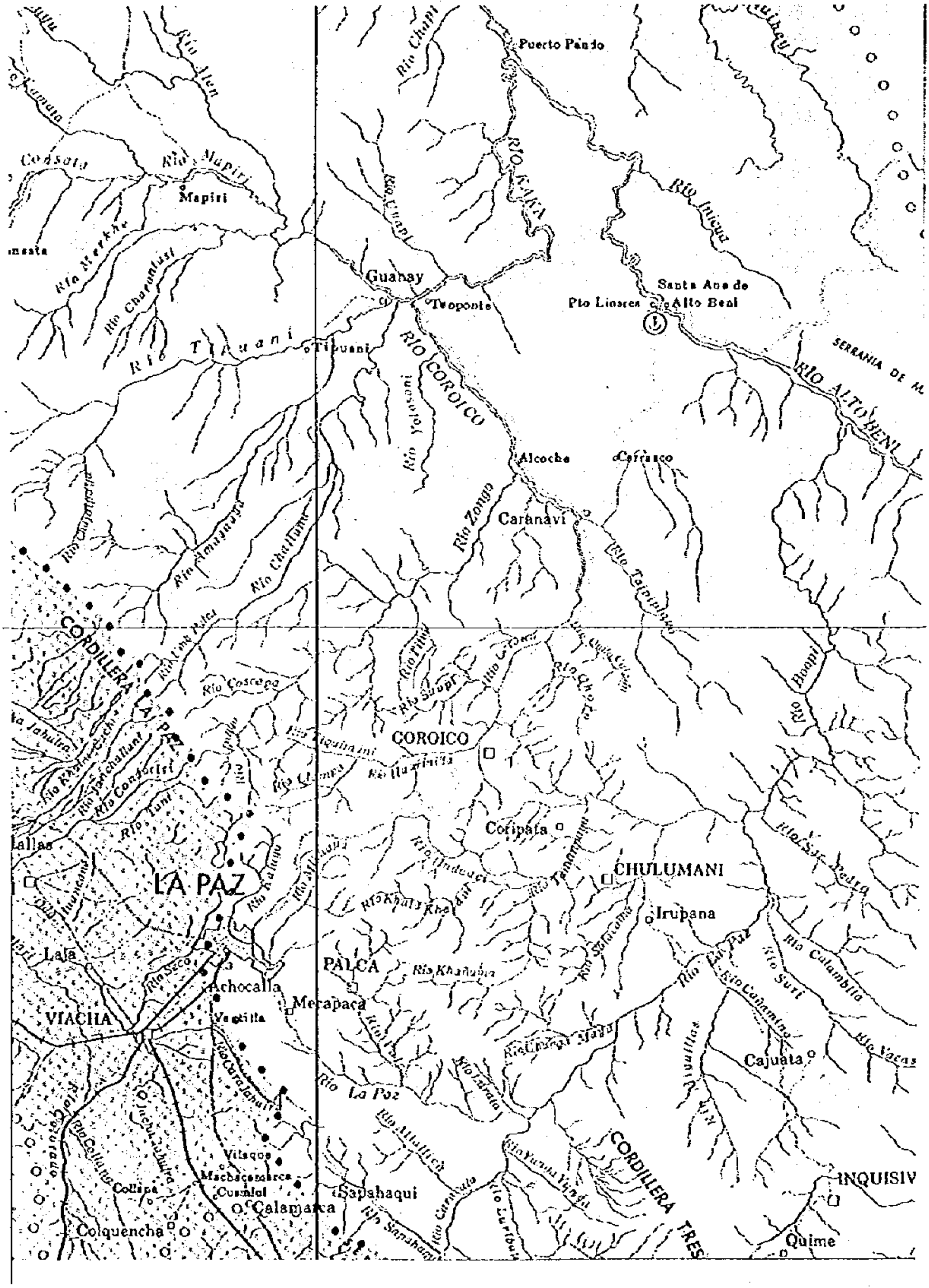


Figure 4-2-9.7 A sample of Geological Map (GEOL05-La Paz)

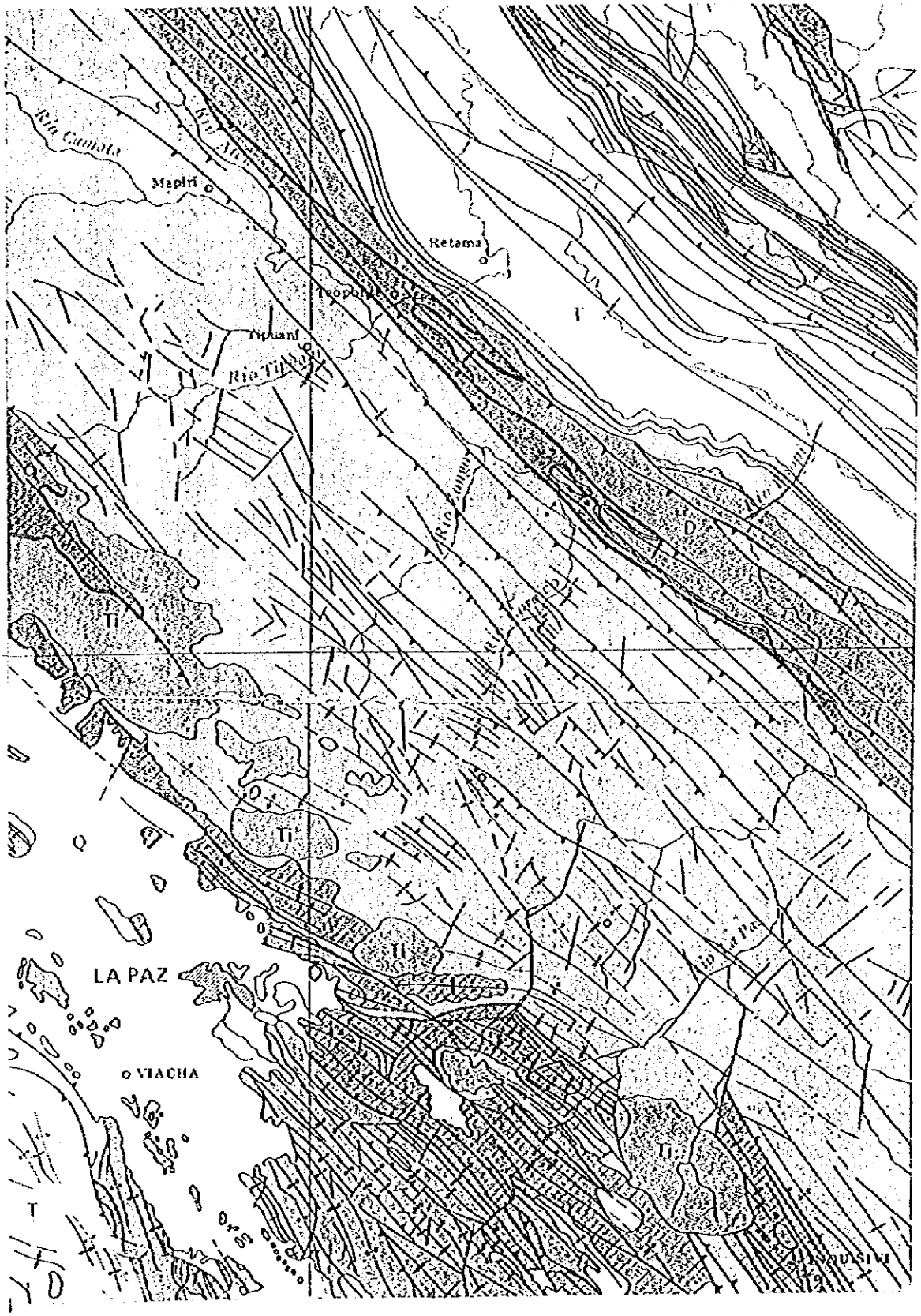


Figure 4-2-9.8 A sample of Topographic Map (TOPO05-La Paz)

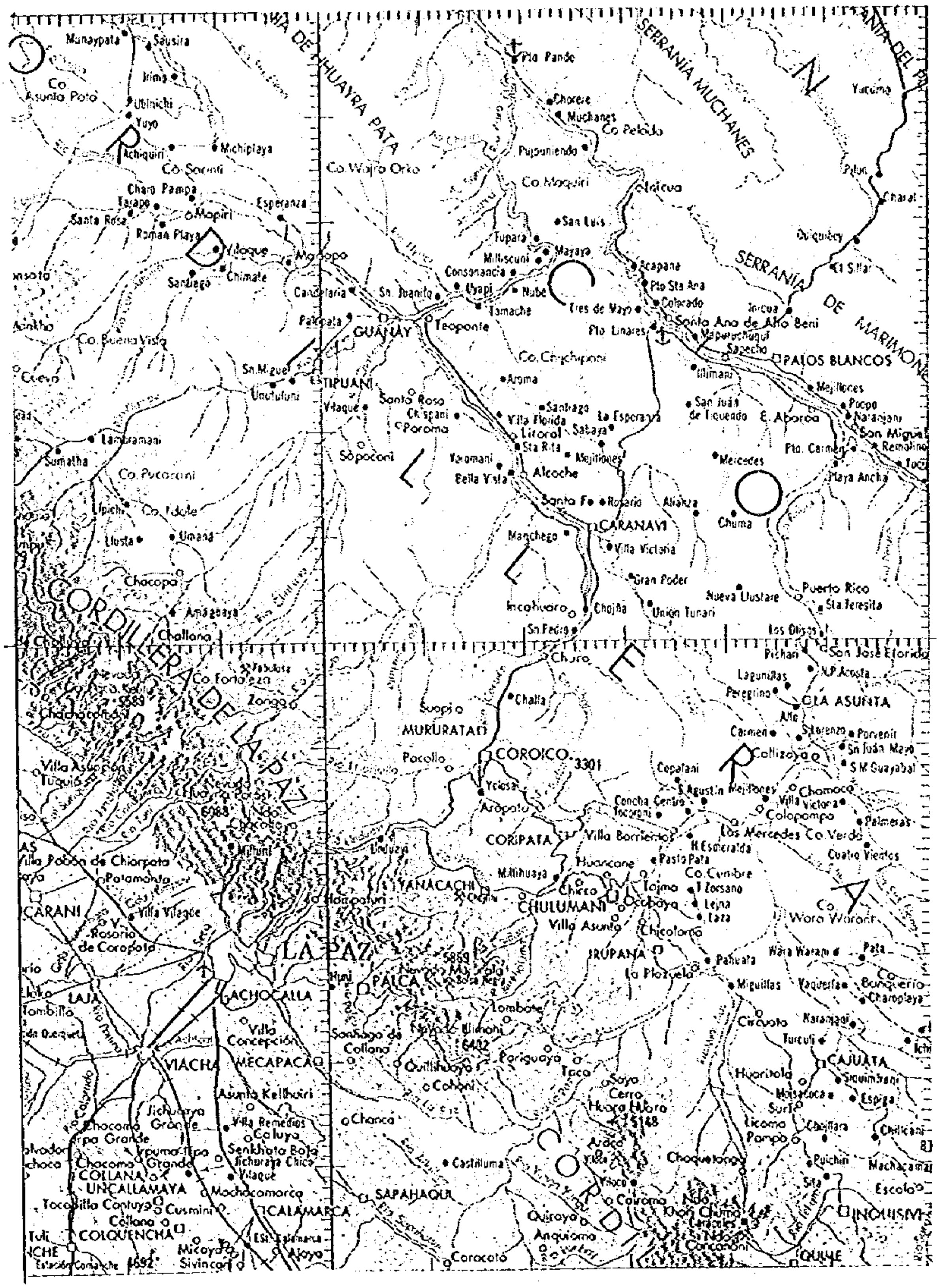


Figure 4-2-9.8 A sample of Topographic Map (TOPO05-La Paz)

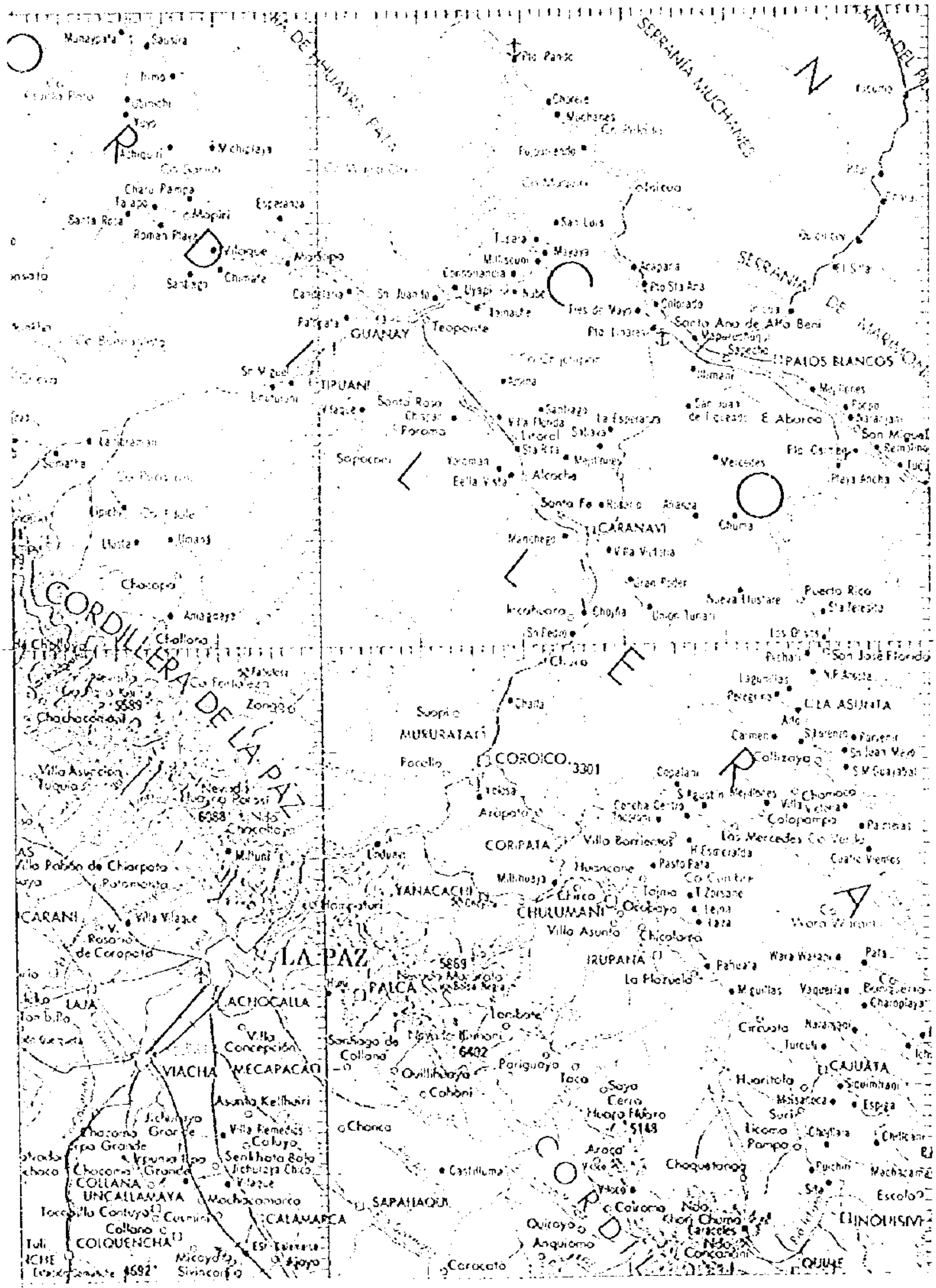


Figure 4-2-9.9 A sample of Land Use Map (LAND05-La Paz)

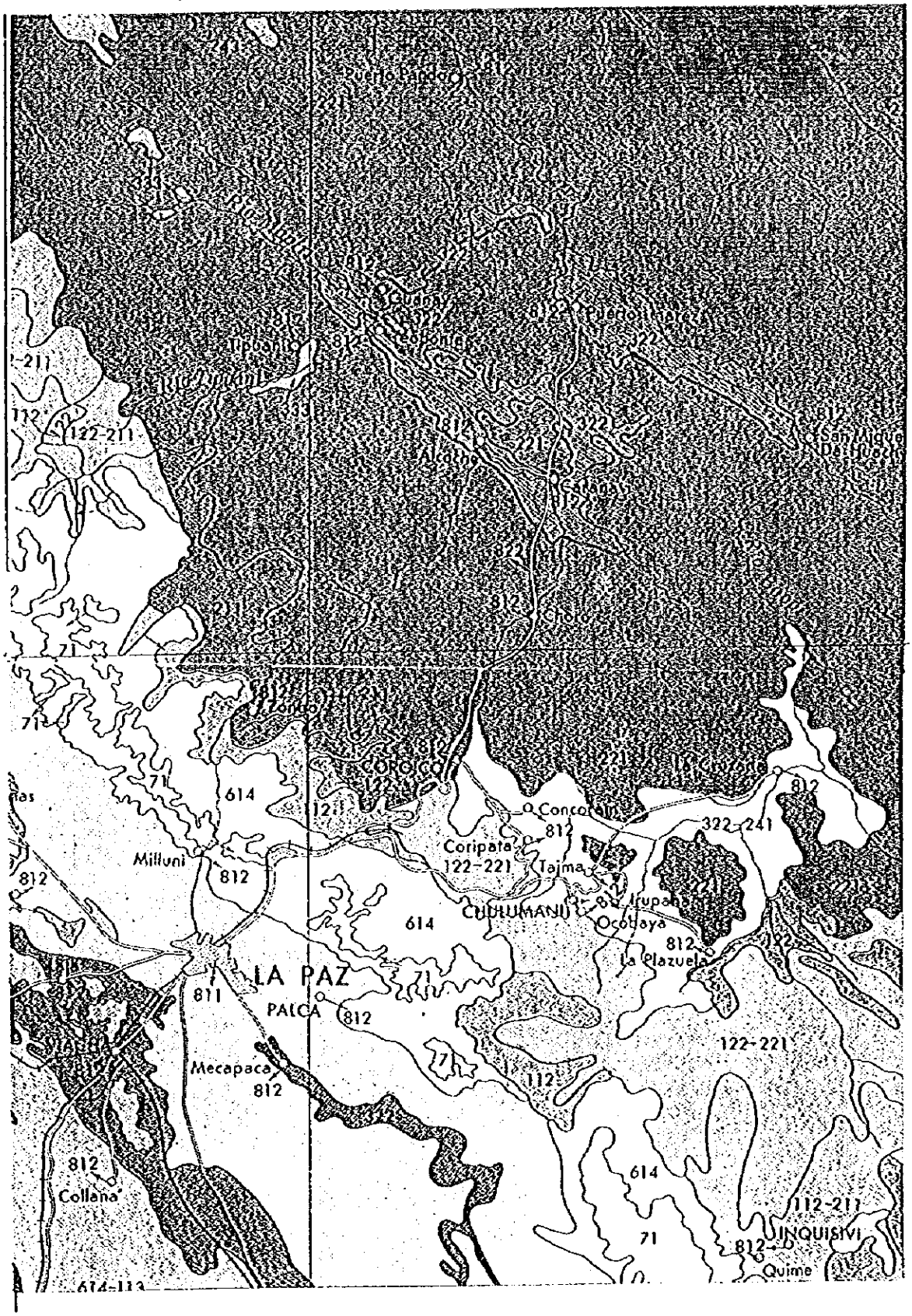


Figure 4-2-9.9 **A sample of Land Use Map** (LAND05-La Paz)

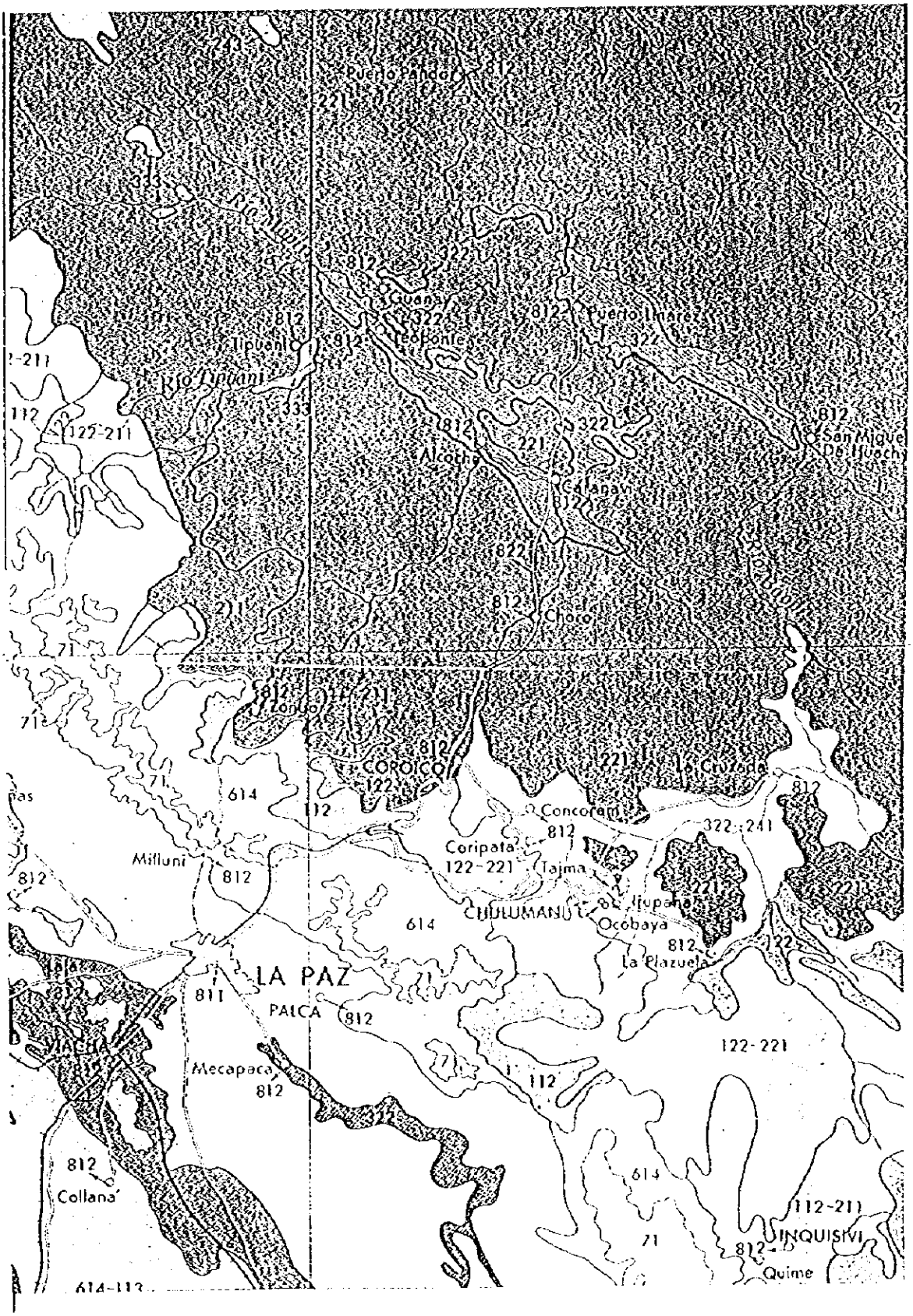


Figure 4-2-9.10 A sample of Administrative Map (ADMI05-La Paz)

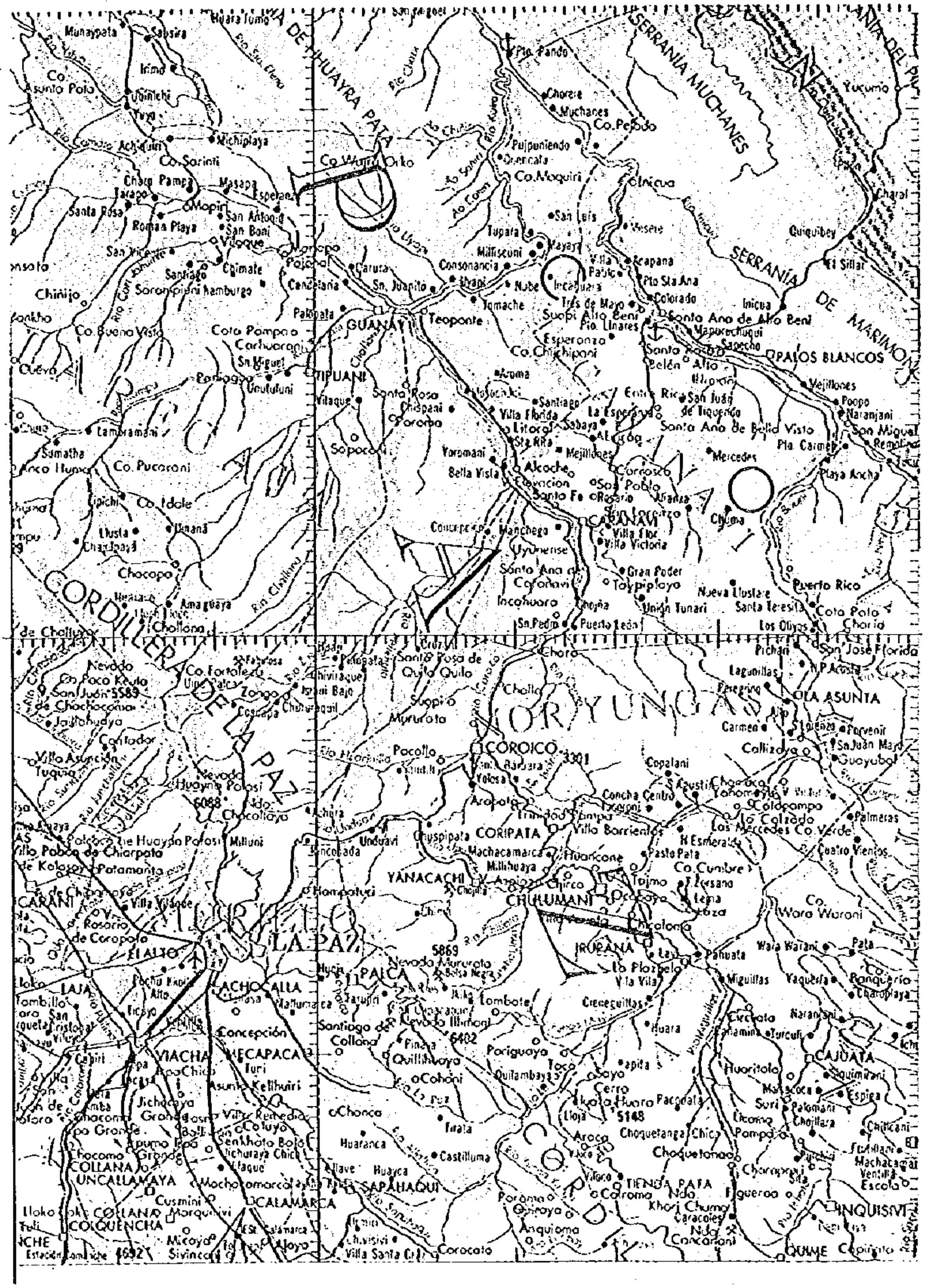
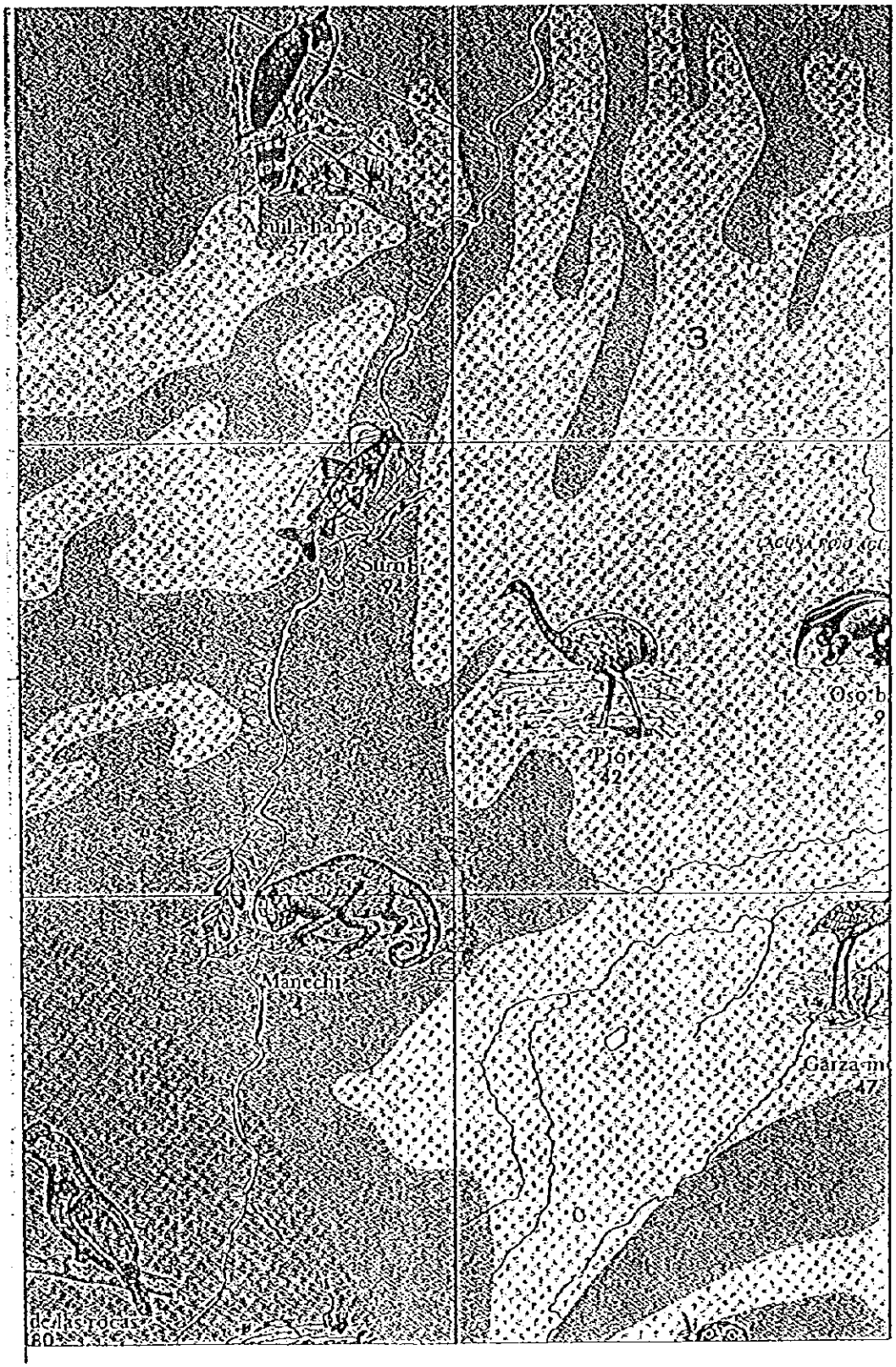


Figure 4-2-6.11 Hydrogeological Map

Figure 4-2-6.12 Natural Environmental Map



C. HYDROGEOLOGICAL INVESTIGATION

1. Geophysical Prospecting
2. Regional Groundwater Development Conditions in the Study Area

CHAPTER 4 HYDROGEOLOGICAL INVESTIGATION

4.1 Geophysical Prospecting

Two types of geophysical prospecting, such as vertical electric sounding of electrical resistivity and electromagnetic sounding, have been implemented in this study.

Vertical electric sounding (VES, Schlumberger method) was carried out to cover most parts of the Project Area (Altiplano, Valle and Llano), while electromagnetic sounding (transient electromagnetic method,TEM method) to cover the Chaco area.

The tools used by the current work are listed in the Table 4-1-1.

1) Principle and Method of Geophysical Prospectin

(1) Vertical Electric Sounding

Vertical electric sounding (VES) on the current work was implemented with electrodes allocation of the Schlumberger type as shown in following Figure 4-1-1. Electrical current I was run into then earth through a couple of the current electrodes A and B to measure the potential difference, generated between the two potential electrodes M and N by the current I. Two potential electrodes were symmetrically allocated on a traverse line as to substantially uphold such a relationship between the spacings of AB and MN as to being that AB/2 > 3 x MN/2, while. station O is on the center of traverse line to being that OA = OB = AB/2 and OM = ON = MN/2.

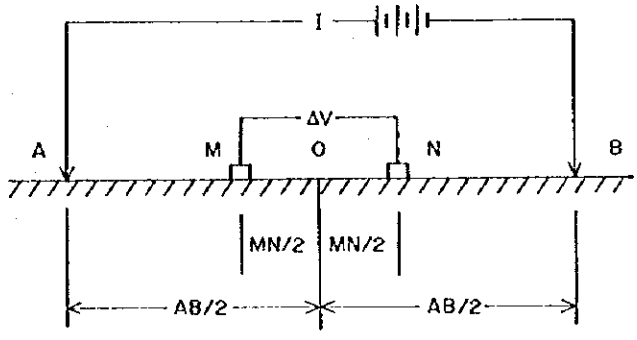


Figura 4-1-1 Configuracion de Schlumberger de Sondeo Electrico Vertical (SEV)
Figure 4-1-1 Schlumberger array of Vertical Electric Sounding (VES)

The apparent resistivity value in the occasion of the above is shown below:

$$Pa = K\ V/I$$

where Pa : apparent resistivity

V : potential difference between the electrodes, M and N

I : intensity of current

K : electrode configuration coefficient, $2\ \pi\ [(AB/2)^2 - (MN/2)^2]/MN$

The smaller spacing value of MN of two potencial electrodes, as small as possible, against the spacing value of AB of two current electrodes, should provide more effective geophysical achievements, since smaller V value is prone to be hardly measured if AB value get larger, as shown in the following equation:

$$V = Pa\ I\ MN/2\ \pi\ /[(AB/2)^2 - (MN/2)^2]$$

Based on the above relationship, the current vertical electrical sounding has been substantially operated under a conditional combination of AB/2 and MN/2 as shown in the Table 4-1-2 .

(2) Electromagnetic Sounding (TEM)

When a steady current in a cable loop on the Earth's surface is rapidly terminated, a time varying (primary) magnetic field is generated. The magnetic field induces eddy currents in underground conductivie materrials (such as mineral deposits), and the manner in which these currents decay is characteristic of the properties of the conductive material (mainly their conductivity, shape and size).

The (secondary) magnetic field associated with these decaying currents is detected by a suitable coil known as the receiver (Rx). This Rx is a small multi-turn coil placed at the centre of the transmitting (Tx) loop. This loop configuration is known as In Loop and in this study this configuration is used. The transmitting (Tx) loop has a size of 100m x 100m as follow:

Tabla 4-1-1 Especificacion de los equipos geofisicos
Table 4-1-1 Specification of tools

Method	Tools	Form	
Vertical Electric Sounding	McOhom 2115	OYO Corp.	
	Tramsmitter	Output Voltage	100V. P-P
		Range of current	1, 2, 5, 10, 50. 100. 200mA
	Receiver	Input Impedance	1M.
		Range of Measurment	0. 001mV-0. 6V
		Resolution	0. 001
	Power	Internal battery or	
		External battery of 12V	
	PowerBooster	350mA/200V	
		500mA/200V	
		650mA/200V	
		800mA/200V	
Electromagnetic Sounding (TEM)	SIROTEM 3	Geo Instruments Pty. Ltd., Australia	
	Tramsmitter	Waveform	Bipolar, Rectangular
		Rocetition	25Hz to 0. 12Hz with 50Hz rejection or 30Hz to o. 12Hz with 60Hz
		Current output	10 Amp max
		Voltage output	24 Volts DC max
	Receiver	Measurment range	8 micro-sec to 2 secs
		No. of measurment windows	53 total
		Window width	50 micro-seconds
		Band width	10KHz
		Voltage resolution	1 microvolt(gain=0. 1)
		Signalaveraging	1-9999
		Gain	0. 1, 1, 10, 100times
		Instrument noise	12 nV max

Tabla 4-1-2 Hoja de calculo de Sondeo Electrico Vertical (SEV)
Table 4-1-2 Vertical Electric Sounding (VES) sheet

No.	AB/2	MN/2	K	dV(mV)	I(mA)	R	ρa (Ω-m)
1	3	0.5	27.5				
2	4	0.5	49.5				
3	5	0.5	77.8				
4	5	1	37.7				
5	6.5	0.5	131.9				
6	6.5	1	64.8				
7	8	1	99.0				
8	10	1	155.5				
9	13	1	263.9				
10	16	1	400.6				
11	20	1	626.7				
12	24	1	903.2				
13	24	5	173.1				
14	30	1	1,412.1				
15	30	5	274.9				
16	35	5	377.0				
17	40	5	494.8				
18	50	5	777.5				
19	65	5	1,319.5				
20	65	10	648.0				
21	80	5	2,002.8				
22	80	10	989.6				
23	100	10	1,555.1				
24	130	10	2,638.9				
25	160	10	4,005.5				
26	200	10	6,267.5				
27	240	10	9,032.1				
28	240	50	1,731.0				
29	300	10	14,121.4				
30	300	50	2,748.9				
31	350	50	3,769.9				
32	400	50	4,948.0				
33	500	50	7,775.4				

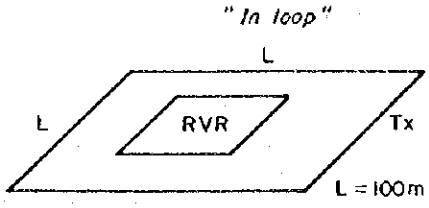


Figura 4-1-2 Configuracion de Loop de TEM
Figure 4-1-2 Loop array of TEM

The transmitter current waveform consists of positive going and negative going pulses. Between the pulses is an off-time, during which the signal is measured.

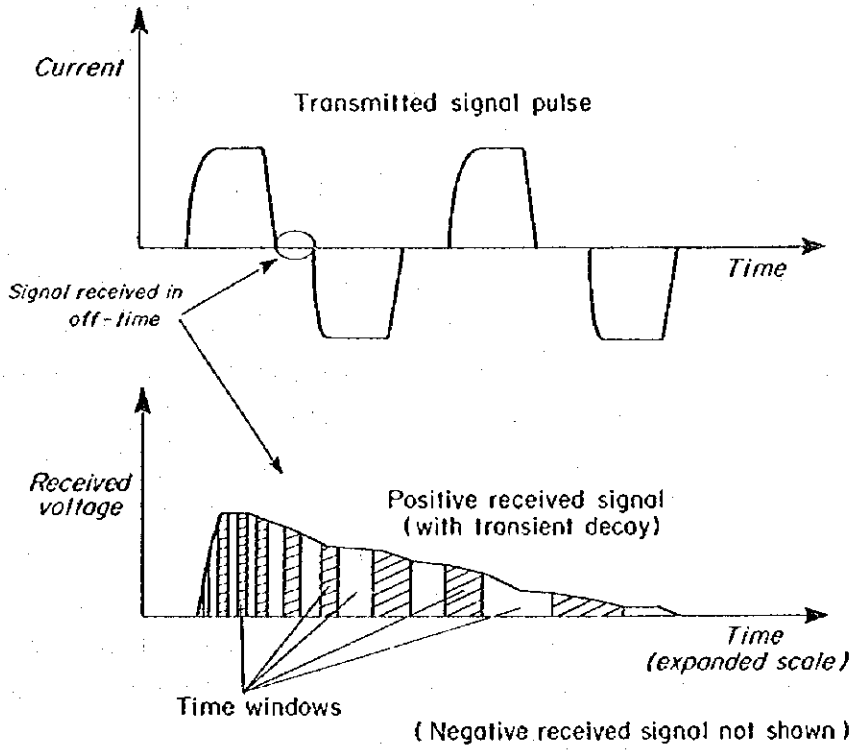


Figura 4-1-3 Senales transmitidos y recividos
Figure 4-1-3 Transmitted and received signals

2) Results of Geophysical Prospecting

Groundwater prospecting is to detect an aquifer. A layer found by geophysical prospecting is judged to be an aquifer or not by the results of drilling and well logging. In geophysical prospecting, here, a word an "aquifer-resistivity layer" is used for a layer which has possibility to be an aquifer by analyzing it's resistivity structure.

According to the results of geophysical prospecting, it is known that a depth of an "aquifer-resistivity layer" is affected by local geological condition. The depth and specific resistivity of an "aquifer-resistivity layer" of each geophysical station including it's coordinate and elevation is shown in the Table 4-1-3. And the depth and specific resistivity of an "aquifer-resistivity layer" of each area is shown as follows:

Area	"aquifer- resistyvity layer"	specific resistivity
Altiplano :	10m~250m	30~80 Ω-m
Valle :	20m~250m	40~60 Ω-m
		(30~50 Ω-m in lacustrine layer)
Llanura :	30m~250m	40~60 Ω-m
Chaco :	100m~450m	25~80 Ω-m

(Main Report *afterhere written as MR*: See MR Figure 4-1-2, Table 4-1-3)

In Altiplano, the old age lake occupies widely and has thick lacustrine deposits. In this zone in which lacustrine sediment formation is thick, an "aquifer-resistivity layer" lies in deeper or is not find (e.g. Toledo). But, in the foot of the mountains or around the outcrops of the basement of the area an "aquifer-resistivity layer" lies relatively on shallow place. In island zone in the old lake, the depth of an "aquifer- resistivity layer" is about 10m in depth in very closed area around an island. And salt water exits under this "aquifer- resistivity layer". As going away from the island the thickness of an "aquifer- resistivity layer" reduces and on the contrary the upper surface of salt water rises (MR Figure 4-1-3).

The Valle is extended from the Department of Tarija to the department Santa Cruz through Chuquisaca. In the Valle an "aquifer-resistivity layer" of each Department lies on closed depth affected by topography and geology with differences.

In the Department of Chuquisaca, the tendency is toward deeper the depth of the "aquifer-resistivity layer" from the west to the east.

In the Department of Santa Cruz, there is a Quaternary wide valley and in the center of there (Cochabambita) an "aquifer-resistivity layer" lies on deep place and rises to surrounding.

In the Department of Tarija, like Chuquisaca, the tendency is toward deeper the depth of the "aquifer-resistivity layer" from the west (Iscayachi) to the east. But no "aquifer-resistivity layer" was detected at least 200m in depth in the north of Entre Rios (in Saladito, Lajitas) because the formations of there contain salt.

In the Llano, it is known that the tendency is toward shallower the depth of the "aquifer-resistivity layer" from Costa, where morphological condition is changed, to the east.

In the Chaco, the tendency is toward shallower the depth of the "aquifer-resistivity layer" from the west to the east.

Tabla 4-1-3 Datos de las estaciones geofisicas
Table 4-1-3 Geophysical station's data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
1	LP1	Patacamaya	LP	3795	17 19 09	67 54 18	27-70, 102-	35	A1	behind Railleway Station
2	LP2	Patacamaya	LP	3820	17 13 53	67 54 29	40-70	30	A1	E side of the Community
3	LP3	Patacamaya	LP	3845	17 13 57	67 53 55			A1	site of new watertank
4	LP4	Patacamaya	LP	3785	17 14 52	67 54 13	20-50, 150-	60	A1	Cablebol's property
5	LP5	Patacamaya	LP	3790	17 14 38	67 54 00	35-65, 95-	60	A1	400m E of LP5
6	LP6	Patacamaya	LP	3800	17 13 40	67 55 24	70-110	30	A1	near to the Wicuma River
7	LP7	Joco Pampa	LP	3810	17 13 16	67 55 17	16-150	85	A1	Patacamaya
8	LP8(2)	Collana Tholar	LP	3980	16 58 59	68 05 01	60-	28	A1	behind the Community
9	LP9(2)	Collana Tholar	LP	3940	17 00 57	68 03 59	10-40, 56-	22	A1	W side of the Community
10	LP10	Topohoco	LP	4170	17 10 09	68 14 45	15-50	30	A1	1km W of the Community
11	LP11	Topohoco	LP	4160	17 09 57	68 14 44	120-	30	A1	300m N of LP10
12	LP12	Caquingora	LP	3870	17 14 47	68 29 33	35-70, 150-	80	A1	behind the church
13	LP13	Caquingora	LP	3870	17 14 08	68 29 51	70-110		A1	lake side
14	LP14	Caquingora	LP	3890	17 14 47	68 29 52			A1	well side
15	LP15	Caquingora	LP	3930	17 14 44	68 29 28	10-45, 150-	55	A1	north side of the church
16	LP16(2)	Umala	LP	3860	17 22 21	68 01 27	25-55, 100-	35	A1	entrance of the Community
17	LP17(2)	Umala	LP	3870	17 22 03	68 01 19	36-55	33	A1	behind the Community
18	LP18(3)	Canaviri	LP	3840	17 20 13	68 01 55	30-45, 100-	25	A1	behind the Community
19	LP19(3)	Copani	LP	3860	17 19 52	68 03 31	20-40, 55-130	40	A1	Center of the Community
20	OR1	Penas	OR	3810	18 41 09	66 46 00	100-	50	A1	near to the cemetery
21	OR2	Ichu Kkollu	OR	3805	18 41 12	66 49 40	50-	40	A1	Penas
22	OR3	Huacuyo	OR	3790	18 41 59	66 44 26	117-	47	A1	Penas
23	OR4	Penas	OR	3865	18 38 33	66 44 50	30-	35	A1	Qda. Chillihuani
24	OR5	Penas	OR	3880	18 38 44	66 44 49	30-105	38	A1	cemetery
25	OR6	Penas	OR	3895	18 37 14	66 45 30			A1	1km N from Wila Jakke
26	OR7	Tutuni	OR	4005	18 34 51	66 44 15	8-50	80	A1	Penas
27	OR8	Penas	OR	3915	18 35 45	66 45 09			A1	near to Ecia. Quebrada
28	OR9	Pena Vinto	OR	3840	18 40 41	66 45 29	16-	24	A1	Penas
29	OR10	Corque	OR	3730	18 20 35	67 40 42	40-	40	A1	500m N from Runway road
30	OR11	Huerta Mayu	OR	3745	18 20 03	67 40 47	25-200	45	A1	Corque
31	OR12	Corque	OR	3745	18 19 27	67 40 46	40-	45	A1	1.5km N from H. Mayu
32	OR13	Collun Chullpa	OR	3750	18 18 48	67 40 49	10-	55	A1	Corque
33	OR14	Corque	OR	3725	18 21 30	67 40 29	20-200	48	A1	SW corner of the runway
34	OR15	Corque	OR	3730	18 20 21	67 40 26	75-170	80	A1	500m E of OR10
35	OR16	Corque	OR	3745	18 20 14	67 40 45	22-	75	A1	between OR10 and OR11
36	OR17	Corque	OR	3740	18 19 48	67 40 46	25-	46	A1	between OR11 and OR12
37	OR18	Corque	OR	3755	18 17 08	67 40 55	28-150	55	A1	near to Choachilla Rvr

Tabla 4-1-3 Datos de las estaciones geofisicas
Table 4-1-3 Geophysical station's data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
38	OR19	Corque	OR	3740	18 19 20	67 40 32	40-	38	Al	Qda Tankhami
39	OR20	Toledo	OR	3710	18 11 25	67 24 30			Al	South of Toledo/roadside
40	OR21	Toledo	OR	3710	18 11 30	67 25 00	(1-13)		Al	SW
41	OR22(3)	Toledo	OR	3705	18 13 30	67 27 08			Al	500m W of the bridge
42	OR23(2)	Sillota Belen	OR	3725	17 48 33	67 20 40	12-80	120	Al	behind Community
43	OR24(2)	Sillota Belen	OR	3715	17 48 14	67 20 54	8-60	70	Al	in front of Community
44	OR25(2)	Janconuno	OR	3760	17 46 01	67 14 19	15-80	73	Al	behind the school
45	OR26(2)	Janconuno	OR	3765	17 46 04	67 14 17	8-160	50	Al	in front of the school
46	OR27(2)	Cantu Sta. Ana	OR	3715	17 50 13	67 02 49	13-130	36	Al	200m E of the school
47	OR28(2)	Cantu Sta. Ana	OR	3710	17 49 47	67 02 50	16-95	26	Al	200m N of OR26
48	OR29(2)	San Juan Pampa	OR	3730	17 52 16	67 04 19	12-40	32	Al	in front of the school
49	OR30(2)	San Juan Pampa	OR	3730	17 52 48	67 04 31	10-60, 150-	45	Al	700m S of OR29
50	OR31(3)	Sillota Witu	OR	3710	17 53 07	67 19 48	9-20	60	Al	school
51	OR32(3)	Wallchapi	OR	3740	17 51 35	67 21 00	7-45	56	Al	church
52	OR33(3)	Anacasi	OR	3745	17 50 59	67 23 08	4-55	66	Al	behind school
53	OR34(3)	Kochiraya	OR	3710	17 55 32	67 07 42			Al	behind Community
54	OR35(3)	Aeropuerto	OR	3710	17 58 12	67 04 44	20-75	68	Al	W side of Runway
55	OR36(2)	Rosa Pata	OR	3720	18 39 58	67 32 58	55-	45	Al	behind the school
56	OR37(2)	Rosa Pata	OR	3720	18 40 03	67 33 02	19-	30	Al	200m W of OR36
57	OR38(3)	Rosa Pata	OR	3720	18 40 13	67 32 49	18-50, 80-	40	Al	300m S of OR37
58	OR39(3)	Quimsa Chata	OR	3710	17 47 38	67 36 35			Al	behind the school
59	OR40	Nva. Llallagua	OR	3710	17 47 57	67 39 27	(5-17)		Al	W side of the Ground
60	OR41	Nva. Llallagua	OR	3710	17 47 44	67 39 15			Al	N side of the Community
61	OR42(3)	Nva. Llallagua	OR	3710	17 47 58	67 39 19			Al	S side of the Community
62	OR43(3)	Calacoto Huari	OR	4105	19 06 47	66 26 59	7-32, 62-	55	Al	50m S of the guide plate
63	CH1-20	Campo Leon	CH	800	20 31 39	63 08 35	320-450	50	Ch	school
64	CH21-40	El Simbolar	CH	570	20 31 19	62 56 48	220-300	40	Ch	school
65	CH41(20)	El Paraiso	CH	620	20 45 54	62 53 41	200-	14	Ch	ranch
66	CH42(20)	Cuatro Vientos	CH	570	20 51 48	62 41 15	170-	9	Ch	crossroads
67	CH43(20)	Carandayti	CH	810	20 40 17	63 05 48	165-	19	Ch	farm field
68	CH44	El Salvador	CH	850	20 37 15	63 10 40	325-	23	Ch	pasture
69	CH52	Ipati de Ivo	CH	1220	20 32 32	63 24 32	100-	50	Ch	school
70	CH53	Ipati de Ivo	CH	1220	20 33 05	63 24 54	100-	60	Ch	crossroads
71	CH54	Cuahuyuqui	CH	1030	20 24 46	63 24 36	16-	32	Ch	school
72	SC1	San Carlos	SC	560	17 58 39	63 19 00	150-225	37	Ll	in front of the School
73	SC2	San Carlos	SC	580	17 58 33	63 18 33	150-200	45	Ll	750m E from the school
74	SC3	San Carlos	SC	550	17 58 31	63 19 04	120-200	40	Ll	500m W from the school
75	SC4(3)	San Carlos	SC	540	17 58 15	63 19 38	135-	23	Ll	400m NW from the crossr.
76	SC5	San Juan	SC	565	17 58 40	63 19 25			Ll	500m from Cemetery
77	SC6	San Juan	SC	555	17 58 53	63 19 18	150-	20	Ll	north side of Community
78	SC7	San Juan	SC	560	17 59 14	63 19 10	140-	23	Ll	near to the Church

Tabla 4-1-3 Datos de las estaciones geofisicas
Table 4-1-3 Geophysical station's data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
79	SC8	San Juan	SC	565	17 59 24	63 19 03	100-	20	L1	near to the creek
80	SC9(3)	San Carlos	SC	545	17 58 08	63 19 15	30-200	20	L1	north creek
81	SC10(3)	San Juan	SC	590	17 59 52	63 19 02	135-	20	L1	San Juan
82	SC11	San Carlos	SC	555	17 58 33	63 19 02	140-	40	L1	between SC1 and SC3
83	SC12	Quituquina	SC	290	17 39 05	60 41 58	130-	60	L1	150m from the school
84	SC13	Quituquina	SC	290	17 39 05	60 42 05	100-	50	L1	roadside
85	SC14	Quituquina	SC	290	17 39 05	60 42 03	110-	35	L1	school
86	SC15(4)	Quituquina	SC	290	17 39 15	60 41 41	120-	60	L1	800m from the school
87	SC16	Quituquina	SC	290	17 38 50	60 42 06	100-	65	L1	roadside
88	SC17	Quituquina	SC	290	17 39 20	60 42 14	100-	60	L1	roadside
89	SC18(4)	Candelaria	SC	310	17 38 05	60 35 46	100-	45	L1	centre of the Community
90	SC19(3)	La Fortuna	SC	350	17 27 11	60 40 44	5-23	23	L1	in front of the school
91	SC20(4)	Okinawa I	SC	285	17 12 52	62 53 55	70-	40	L1	behind the Culture Cent.
92	SC21(4)	Abapo	SC	640	18 53 53	63 23 39			L1	side of the highway
93	SC32(4)	Yapacani	SC	330	17 24 27	63 53 16	50-	60	L1	behind the square
94	SC33(4)	Curva	SC	280	17 49 30	60 46 05	20-40	44	L1	roadside
95	CH45	Parque Monumental	CH	2800	19 01 25	65 15 17	20-45, 80-	40	Va	park
96	CH46	Tarabuco	CH	3230	19 09 09	64 53 54	60-	160	Va	farm field
97	CH47	Tarabuco	CH	3200	19 09 42	64 54 10	80-	100	Va	farm field
98	CH48	Lupiara Pampa	CH	3210	19 15 33	64 46 59	60-80	50	Va	behind the school
99	CH49	Lupiara Pampa	CH	3200	19 15 37	64 47 11	60-100	42	Va	other side of the creek
100	CH50	Redencion Pampa	CH	2490	18 49 29	64 36 41			Va	under the watertank
101	CH51	Padilla	CH	2140	19 18 22	64 17 42	100-	50	Va	farm field
102	CH55	Yamparaez	CH	3105	19 10 50	65 07 58	50-70	50	Va	500m W from the Station
103	CH56	Yamparaez	CH	3105	19 10 52	65 07 48			Va	150m SE
104	CH57	Lavadero	CH	3010	19 10 41	65 02 58			Va	50m N from the well
105	SC22	Sanjon	SC	1415	18 01 52	64 14 58	18-80	38	Va	400m N from the well
106	SC23	Lagunillas	SC	1565	18 16 07	64 09 29			Va	Cemetery
107	SC24	Cochabambita	SC	1505	18 14 25	64 10 07	200-	60	Va	farm filed
108	SC25	Tucumancillo	SC	1580	18 22 20	64 08 54	35-50	35	Va	farm field
109	SC26	El Trigal	SC	1560	18 18 23	64 09 00	120-	35	Va	Plaza
110	SC27	Comarapa	SC	1730	17 55 02	64 31 07	35-	50	Va	near to The Runway
111	SC28	San Isidro	SC	1485	18 02 45	64 25 59	30-50, 100-	50	Va	near to the school
112	SC29	El Tambo	SC	1490	18 01 30	64 26 54	150-	30	Va	peach yard
113	SC30	Pampa Grande	SC	1250	18 04 57	64 06 58	65-	55	Va	500m to the bridge
114	SC31	Samaipata	SC	1610	18 10 33	63 52 56	40-	25	Va	The cemetery
115	TA1	Calamuchita	TA	1690	21 42 05	64 37 17	80-130	40	Va	in the Community
116	TA2	La Choza	TA	1725	21 40 14	64 36 42			Va	along the highway
117	TA3	San Isidro	TA	1750	21 39 45	64 37 28	65-130	40	Va	on the roadside to S. I.
118	TA4	San Isidro	TA	1700	21 39 52	64 37 52	9-40	45	Va	San Isidro
119	TA5	San Isidro	TA	1710	21 40 15	64 37 35	10-18	34	Va	near to the cemetery

Tabla 4-1-3 Datos de las estaciones geofisicas
Table 4-1-3 Geophysical station's data

No.	Station No	Location	Depto	Eleva.	Latitude	Longitude	Depth of Aquifer	Res.	Zone	Note
120	TA6	San Isidro	TA	1710	21 39 40	64 38 08	30-50	30	Va	soccer ground
121	TA7	San Isidro	TA	1710	21 40 10	64 37 08			Va	W of the old mine
122	TA8	San Isidro	TA	1730	21 40 00	64 36 55			Va	entrance to an old mine
123	TA9	San Isidro	TA	1730	21 40 44	64 36 31	30-90	30	Va	along the highway
124	TA10	Col. Linares	TA	400	22 40 17	64 16 16	45-85	43	Va	Col. Linares
125	TA11	Campo Grande	TA	365	22 48 31	64 18 23	40-60, 110-	100	Va	near to Campo Grande
126	TA12	Bermejo	TA	360	22 49 26	64 18 20	60-110, 200-	90	Va	sugar cane field
127	TA13	Bermejo	TA	350	22 49 30	64 19 16	23-40	120	Va	near to Bermejo River
128	TA14	Bermejo	TA	352	22 49 49	64 19 23	70-100, 180-	70	Va	sugar cane field
129	TA15	Bermejo	TA	379	22 46 19	64 18 06	55-	130	Va	Vda. Patrocina's house
130	TA16	Porcelana	TA	379	22 46 16	64 17 25	75-	130	Va	near to the School
131	TA17	Com. Talita	TA	378	22 46 40	64 19 08	45-	140	Va	behind the runway, Berm.
132	TA18	Naranjita	TA	339	22 50 56	64 19 20	150-	80	Va	Bermejo
133	TA19	San Antonio	TA	3440	21 26 30	64 57 59	7-45, 90-	30	Va	Iscayachi
134	TA20	Chorcoya Aviles	TA	3810	21 37 34	65 03 01	6-30	75	Va	Iscayachi
135	TA21	Chorcoya Lago	TA	3710	21 43 02	65 05 13	50-90, 160-	80	Va	Iscayachi
136	TA22	Sama	TA	3465	21 29 09	64 57 27	18-80	90	Va	Iscayachi
137	TA23	Lulcayo	TA	3460	21 29 59	64 57 21	18-30	27	Va	Iscayachi
138	TA24	Pueblo nuevo	TA	3550	21 32 33	64 58 35	2-52	57	Va	Iscayachi
139	TA25	Junacas	TA	2300	21 25 52	64 27 48	20-85	30	Va	school
140	TA26	Junacas Norte	TA	2350	21 24 58	64 26 57	35-	70	Va	behind the school
141	TA27	Polla	TA	2430	21 23 17	64 26 39			Va	farm filed
142	TA28	Polla	TA	2400	21 22 49	64 27 18			Va	near to the school
143	TA29	Naranjos	TA	1230	21 35 21	64 08 57	20-45	25	Va	pasture
144	TA30	Naranjos	TA	1250	21 34 15	64 08 36	8-40, 100-	27	Va	school
145	TA31	El Puesto	TA	1210	21 39 00	64 09 10	8-20	32	Va	pasture
146	TA32	La Cueva	TA	1130	21 40 55	64 12 24	20-38, 52-	35	Va	pasture
147	TA33	Lajitas	TA	990	21 22 32	64 07 28			Va	behind the school
148	TA34	Saladito	TA	890	21 17 04	64 06 19			Va	farm

LP :La Paz OR :Oruro CH :Chuquisaca SC :Santa Cruz TA :Tarija
LPS(2) : two points as LPS
Eleva. : elevation (m)
Depth of Aquifer : -depth of "aquifer-resistivity layer"- depth from the surface of the ground in meter(m)
Al :Altiplano Ch :Chaco Ll :Llano Va :Valle
Res. : resistivity of possible aquifer (Ω-m)

(1) Department of Chuquisaca

In the Valle of this Department there are widely outcrops of Paleozoic basement and topographically the Valle forms a watershed between Amazon basin and Pilcomayo basin. Meteorologically this area is dry and annual precipitation is very small. Therefore there is no good condition for existing of groundwater.

The resistivity columns of all geophysical stations in thie Valle are shown in the Figure 4-1-4-a~b.

In the Sucre zone we can comfirm the existing of two "aquifer-resistivity layers" with resistivities 30 Ω-m、 40 Ω-m respectively. The upper layer is 20m in depth and the lower 80m. The upper layer is no expect because of it's thickness (20m) and low specific resistivity. It seems that the "aquifer-resistivity layer" correspods to a part of the much fissured part inside the basement.

In Yamparaez zone, under the station CH55 an "aquifer-resistivity layer" lies under 50m in depth with it's 50 Ω-m specific resistivity and 20m thickness. It has small dimension.

In Lavadero (CH57) no "aquifer-resistivity layer" was detected.

In Tarabuco zone (CH46,CH47), "aquifer-resistivity layers" lie under 60m~ 70m in depth with 160~100 Ω-m specific resistivity. It seems that groundwater is in the fissure of the basement.

In Lupiara Pampa zone (CH48,CH49) an "aquifer-resistivity layer" lies under 60m depth with 40~50 Ω-m specific resistivity. It seems that this "aquifer-resistivity layer" is not thick because the basement lies under surface 80~100m in depth.

In Redencion Pampa the basement was detected under surface 40m in depth but no "aquifer-resistivity layer".

In Padilla the vertical electric sounding (VES) is realized at a distance of about 500m from the shore of the old lake. An "aquifer-resistivity layer" lies under the surface more 100m in depth with 50 Ω-m resistivity.

In the area from Sucre to Tarabuco the basement is widely exposured. It seems that "aquifer-resistivity layers" of this area correspond to parts of fissured zone inside the basement and a part with specific resistivity under 40 Ω-m is a fissured zone filled clay of shale or slate by weathering. It seems that Lavadero is under this geological condition.

In the Chaco, Ipati de Ivo is located in the west of the area and near to the Valle. Here an "aquifer-resistivity layer" lies under surface more than 100m with 50~60 Ω-m. Generally the "aquifer-resistivity layer" lies under 350m deep with 30~80 Ω-m in Campo Leon and under 250m deep with 25~70 Ω-m in El Simbolar. Therefore the tendency is toward shallower the depth of "aquifer-resistivity layer" fron the west to the east. (MR Figure 4-1-18~20, Figure 4-1-4-c~d).

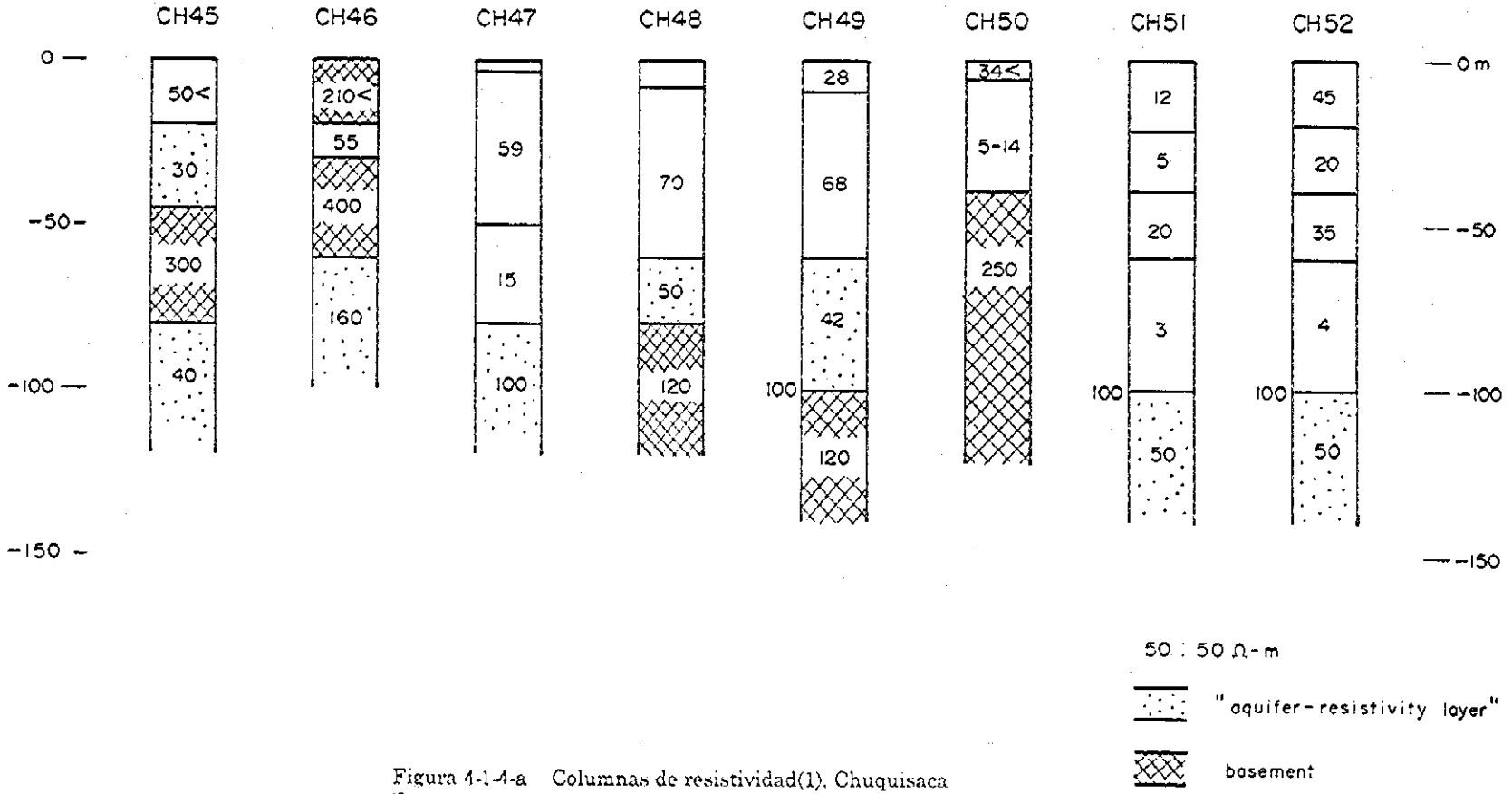


Figura 4-1-4-a Columnas de resistividad(1), Chuquisaca
Figure 4-1-4-a Resistivity columns(1), Chuquisaca

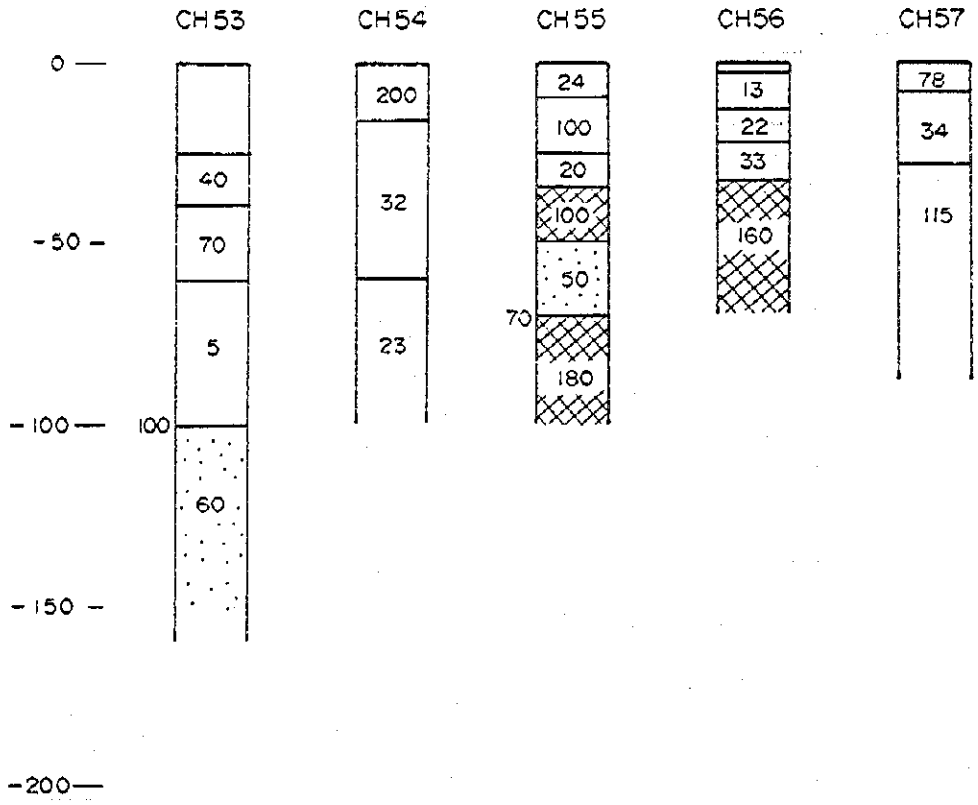
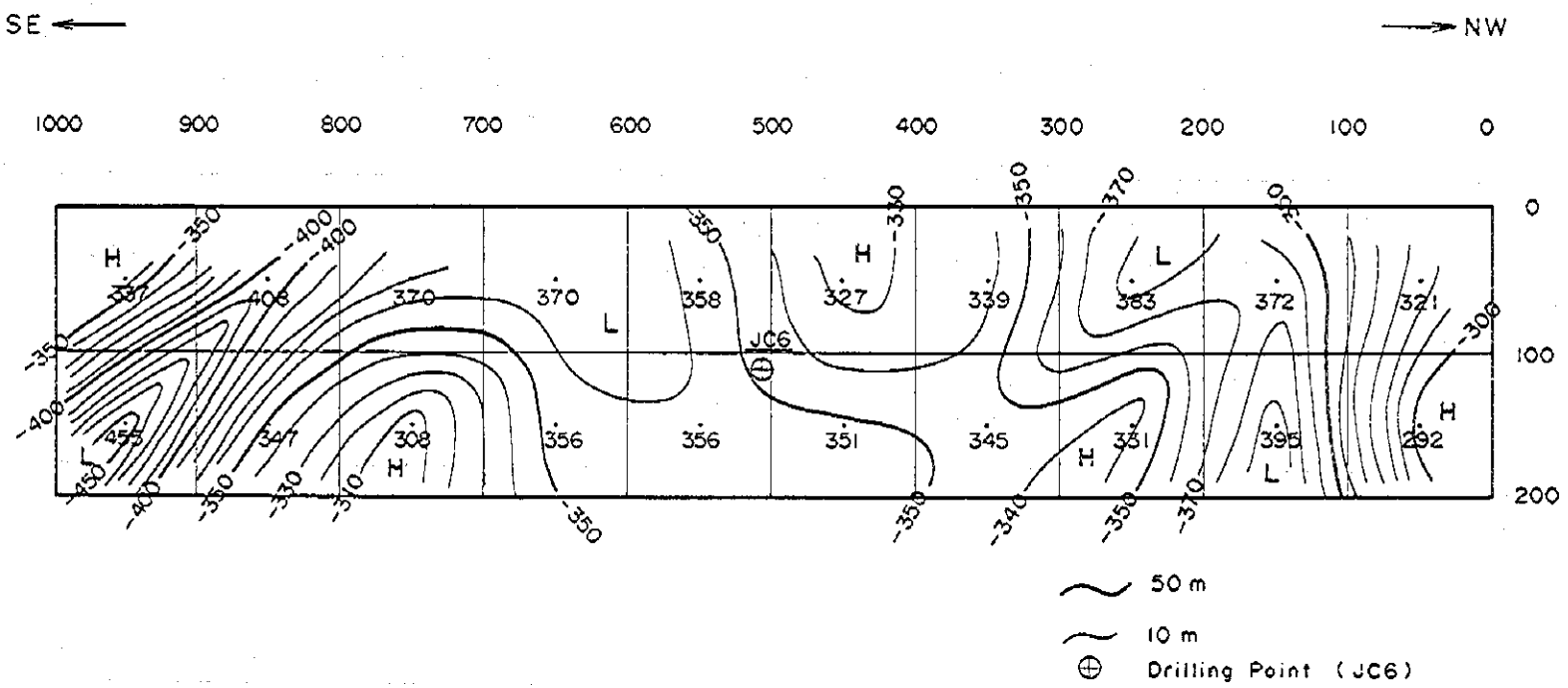
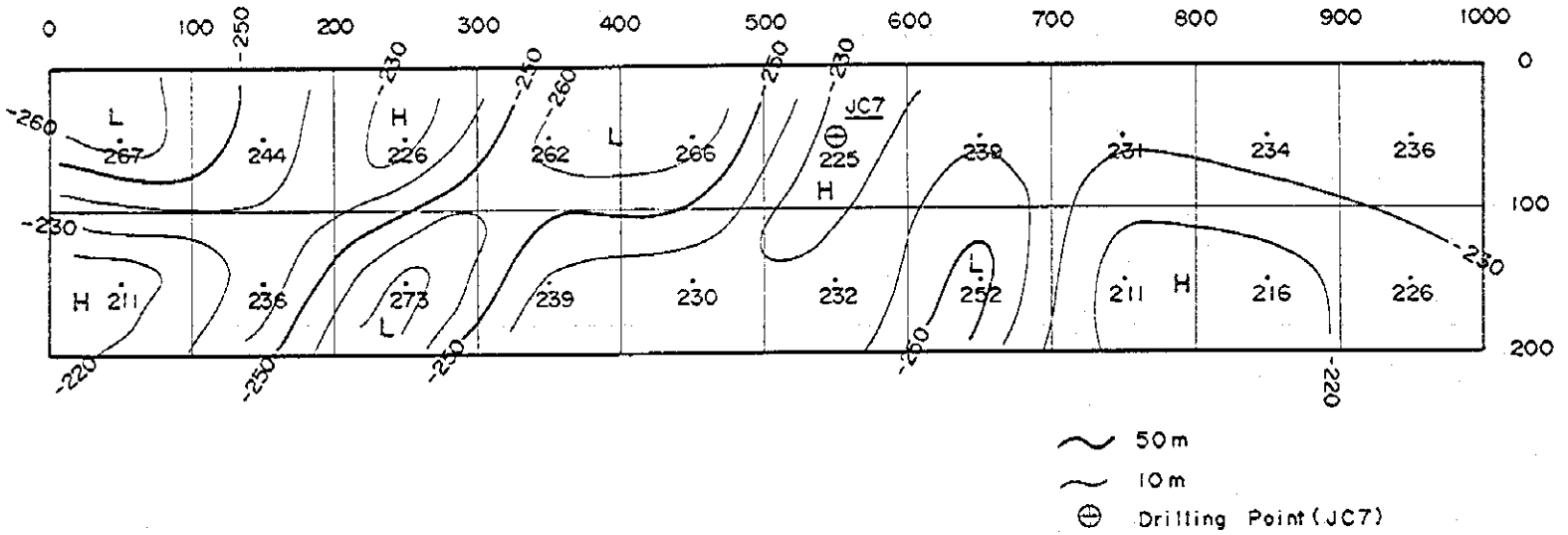


Figura 4-1-4-b Columnas de resistividad(2), Chuquisaca
Figure 4-1-4-b Resistivity columns(2), Chuquisaca



CH10	CH9	CH8	CH7	CH6	CH5	CH4	CH3	CH2	CH1
CH20	CH19	CH18	CH17	CH16	CH15	CH14	CH13	CH12	CH11

Figura 4-1-4-c Mapa de iso-profundidad de "capa de resistividad-acuifera" de Campo Leon, Chuquisaca
Figure 4-1-4-c Iso-depth map "aquifer-resistivity layer" of Campo Leon, Chuquisaca



CH21	CH22	CH23	CH24	CH25	CH26	CH27	CH28	CH29	CH30
CH31	CH32	CH33	CH34	CH35	CH36	CH37	CH38	CH39	CH40

Figura 4-1-4-d Mapa de iso-profundidad de "capa de resistividad-acuifera" de El Simbolar, Chuquisaca
Figure 4-1-4-d Iso-Depth Map "Aquifer-Resistivity Layer" of El Simbolar, Chuquisaca

(2) South of the Department of La Paz

In this Department "aquifer-resistivity layers" lie under surface less than 50m. But these "aquifer-resistivity layers" generally have thin thickness. (MR Figure 4-1-6, MR Figure 4-1-7, Figure 4-1-5-a~b).

In Patacamaya zone, specific resistivity of the "aquifer-resistivity layers" vary with 30~80 Ω-m and it's depth with 200~100m depending to place. The tendency is toward shallower depth of the "aquifer-resistivity layer" from the north (LP7,100) to the south (LP4,20m).

In Collana Tholar, an "aquifer-resistivity layer" lies under surface 60m in depth with 30 Ω -m.

In Topohoco an "aquifer-resistivity layer" lies under surface 20m in depth with 30 Ω-m~100 Ω-m.

In Caquingora an "aquifer-resistivity layer" lies under surface 40m~70m in depth with 45~80 Ω-m resistivity. It seems it is possibile to get water under the foofball ground (LP12) behind the Church or near to the pond (LP13). Unfortunately, near to the real well (LP14) no "aquifer-resistivity layer" was detected.

In Umala an "aquifer-resistivity layer" lies under surface 20~30m in depth with about 30 Ω -m resistivity.

In Canaviri an "aquifer-resistivity layer" lies under surface 30m with 25 Ω-m. But it is not much expected "aquifer-resistivity layer" by reason of it's low specific resistivity and thin thickness (15m).

In Copani two "aquifer-resistivity layers" were detected under surface 20m and 60m with 40 Ω-m resistivity. The upper layer has thin thickness (20m) and the lower 70m in thickness.

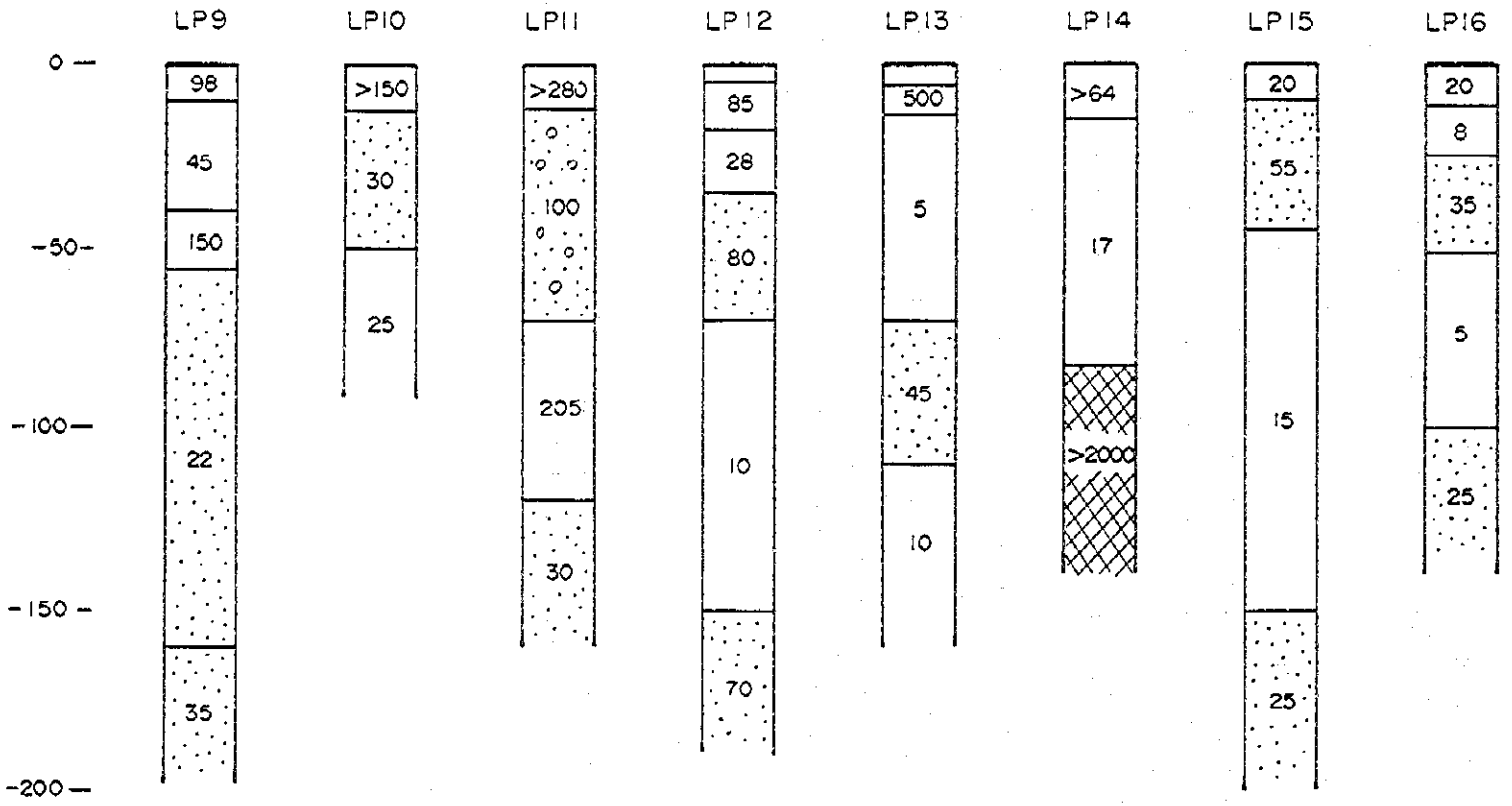


Figura 4-1-5-a Columnas de resistividad(2), La Paz
Figure 4-1-5-a Resistivity columns(2), La Paz

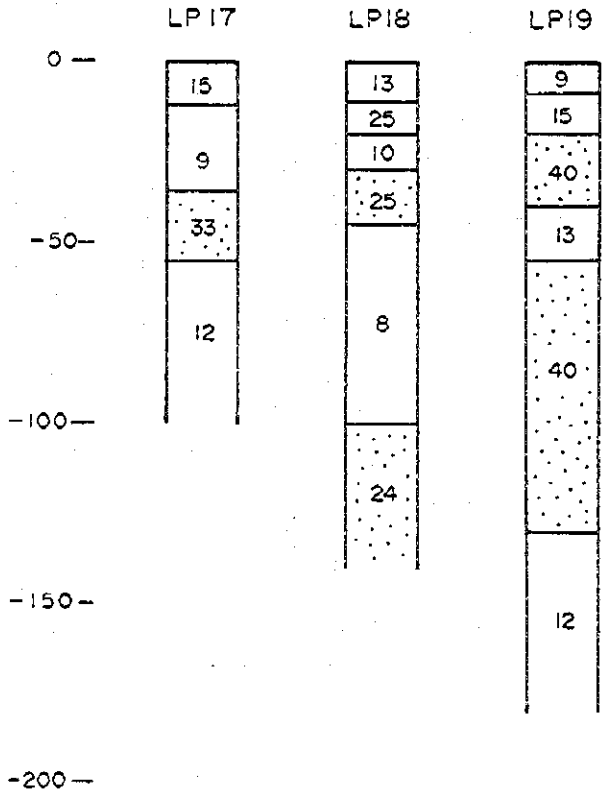


Figura 4-1-5-b Columnas de resistividad(3), La Paz
Figure 4-1-5-b Resistivity columns(3), La Paz

(3) Department of Oruro

The old age lake occupies most part of this Department and has thick lacustrine deposits in some places. These lacustrine formations contain high salinity water. It's difficult to get groundwater to drink from these formations. But in the foot of the eastern mountain range and around the outcrops of the basement it is possible to detect an aquifer at shallow place under surface and around islands in the old lake,too. It becomes clear that an "aquifer-resistivity layer" lies under surface about 10m in closed area around the old islands. Under this "aquifer-resistivity layer" saline is detected. What saline exits under "aquifer-resistivity layer" is common characteristic in all islands area.

Corque zone is in a valley which is extended from south to north in Tertiary formations. An "aquifer-resistivity layer" lies under surface 20~30m with 40~55 Ω-m in this zone (MR Figure 4-1-8, MR Figure 4-3-9). It seems that the water in the "aquifer-resistivity layer" is contaminated by a little saline because of existence of salt near to the current.

Penas zone is located in a valley like Corque. An "aquifer-resistivity layer" lies under surface 20~30m with 25~40 Ω-m in the north of Penas, which is an important village of the Zone, and in the south of it 50~120m with 40~60 Ω-m (MR Figure 4-1-10, MR Figure 4-1-11).

Cantu Santa Ana- San Juan Pampa zone is plane near to the foot of mountains and an "aquifer-resistivity layer" lies under surface about 15m with 25~45 Ω-m there. It's necessary to consider quality of groundwater by contamination by surface water. The depth of the basement is shallow under surface about 130m here.

Sillota Bellen zone includes Sillota Witu, Wallchapi and Anacasi. These villages are situated on a shore of a same old island and there an "aquifer-resistivity layer" lie under surface shallow in depth (about 10m). It became clear that salt water was under the "aquifer-resistivity layer" in every village. As going away from the island the "aquifer-resistivity layer" becomes thin and upper front of salt water rises. It seems that the "aquifer-resistivity layer"'s structure is as the Fig. 4.3.4, therefore it's necessary to search upper front of saline before to drill up for a well.

Janconuno is located in a shore of an old lake no like Sillota Belen. An "aquifer-resistivity layer" lie under surface about 15m with resistivity 50~70 Ω-m. A condition of this "aquifer-resistivity layer" is like it of Sillota Belen.

In Rosa Pata an "aquifer-resistivity layer" lies under surface 20m~50m with resistivity 30~45 Ω-m. Around Rosa Pata there is salt educed, then it's necessary to analize groundwater before to use it. This village is located from Corque to south. Same rocks of Corque lie in a place with a distance of few kilometers from this village, then it seems that the basement lies shallow under this village.

Toledo and Nuva Llagua are situated in the old lake where lacustrine deposits are thick. No "aquifer-resistivity layer" is detected there. (Figure 4-1-6-a~c).

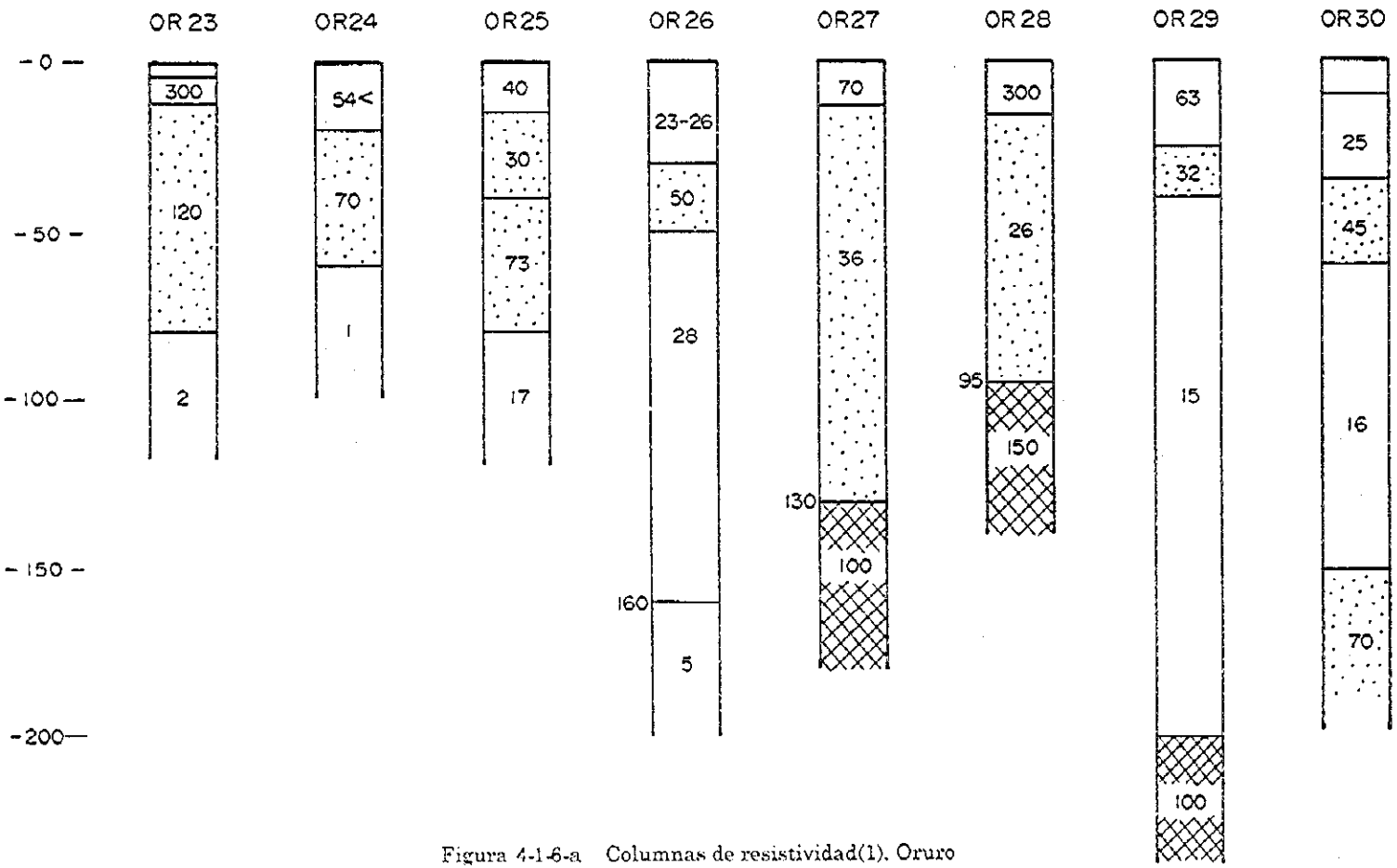


Figura 4-1-6-a Columnas de resistividad(1). Oruro
Figure 4-1-6-a Resistivity columns(1). Oruro

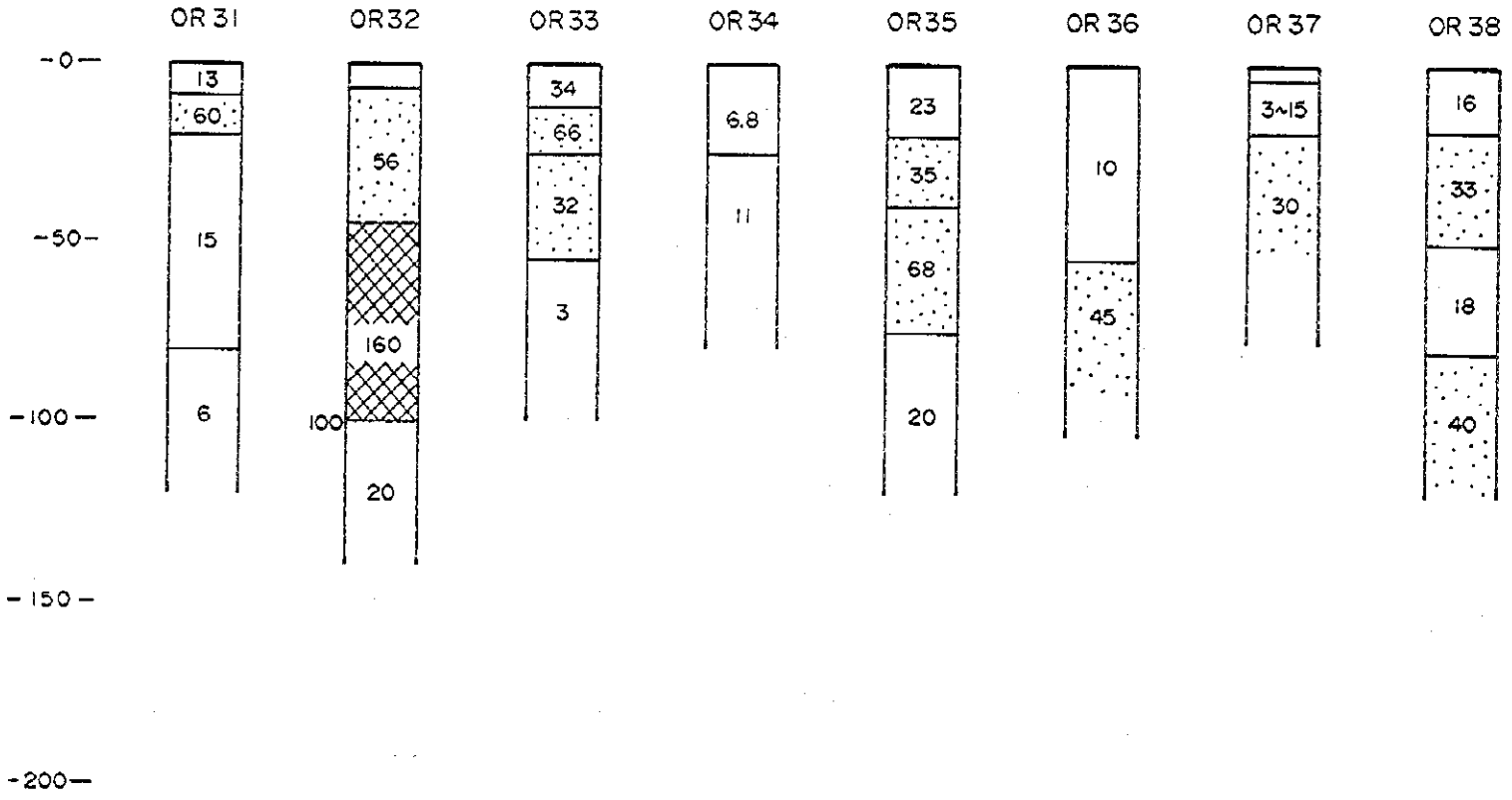


Figura 4-1-6-b Columnas de resistividad(2), Oruro
Figure 4-1-6-b Resistivity columns(2), Oruro

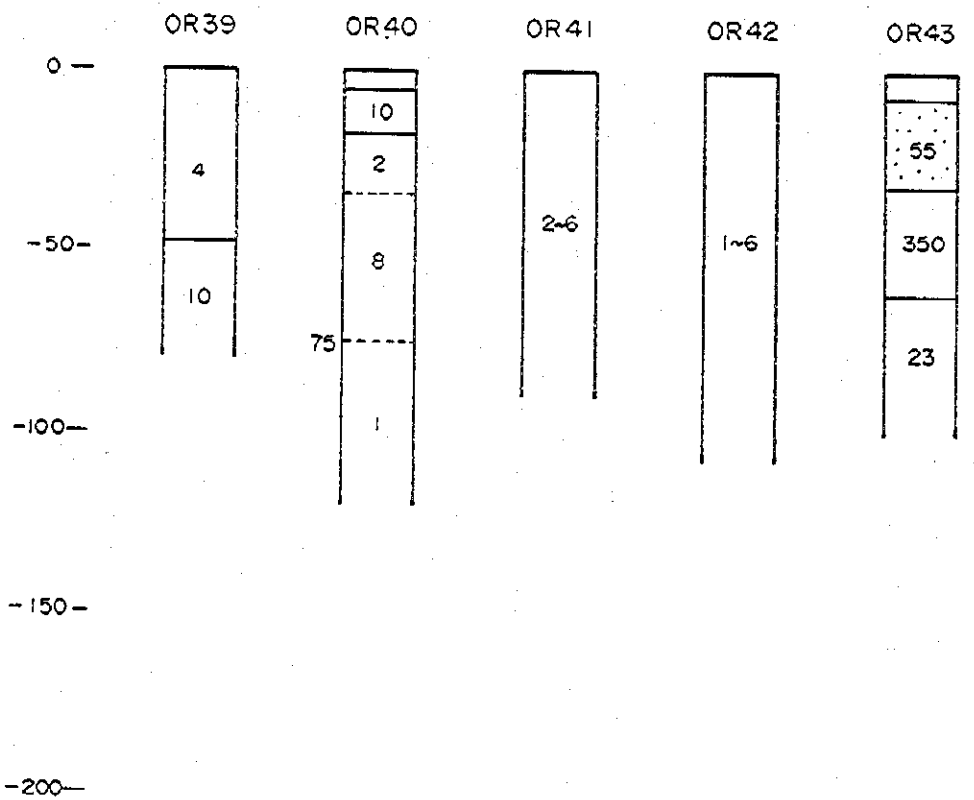


Figura 4-1-6-c Columnas de resistividad(3), Oruro
Figure 4-1-6-c Resistivity columns(3), Oruro

(4) Department of Tarija

An "aquifer-resistivity layer" lies shallow in depth of 20m~50m in the valley of Iscayachi, which is located in the west of the Department, and 40~100m in La Choza, Junacas in the Center. In Entre Rios in the east an "aquifer-resistivity layer" lies under 100m but in some stations no "aquifer-resistivity layer" was detected. In Bermejo zone, in the south an "aquifer-resistivity layer" was detected under 50~100m. Generally the tendency is toward deeper depth of "aquifer-resistivity layer" from the west to the east. Figure 4-1-7-a~d

In the valley of Iscayachi in the west an "aquifer-resistivity layer" lies under surface 20~50m with 30~90 Ω-m and overlies besement. But the depth of the basement is shallow. In Chorcoya Lago (TA21) the depth of the "aquifer-resistivity layer" is lower (50m).

In San Isidro zone in the center an "aquifer-resistivity layer" generally lies under surface 30~70m with resistivity of 30~45 Ω-m but in the center of this zone no "aquifer-resistivity layer" was detected (MR Figure 4-1-21~4-1-23). This zone has an important condition to be an aquifer, of which two muddy beds are as putting an "aquifer-resistivity layer" between them. Lower muddy bed overlies basement. In Junacas zone an "aquifer-resistivity layer" lies under surface 40~50m with 30~70 Ω-m and has a thickness of about 30m. In Polla which is located in the north of Junacas zone, unfortunately, no "aquifer-resistivity layer" was detected. (MR Figure 4-3-24, Figure 4-1-8-a).

In Entre Rios zone in the north of the Department an "aquifer-resistivity layer" lies under surface 50~100m. But in La Cueva(TA32) in the north of the zone an "aquifer-resistivity layer" lies under surface about 20m with 35 Ω-m. In this zone sandy mud stones, silt stones and muddy sand stones lie widely and each of them is relatively homogeneous. If an inner variation of them was detected as an "aquifer-resistivity layer" with 25~35 Ω-m, then it's difficult that the variation is an "aquifer-resistivity layer" because of low specific resistivity.

In Lajitas and Saladito in the north of Entre Rios no "aquifer-resistivity layer" was detected. In this zone low resistivity layer (under 10 Ω-m) continues toawrd deeper and salt educed from rocks is observed there. It seems that almost formations of this zone contain salt.

In Bermejo zone an "aquifer-resistivity layer" lies under surface 50m with 45 Ω-m in Col. Linares in the north of the zone but 100m with 80 Ω-m in Naranjita in the south. It seems that a layer which lies under 30m with about 200 Ω-m corresponds to a gravel layer (Figure 4-1-7-b~d).

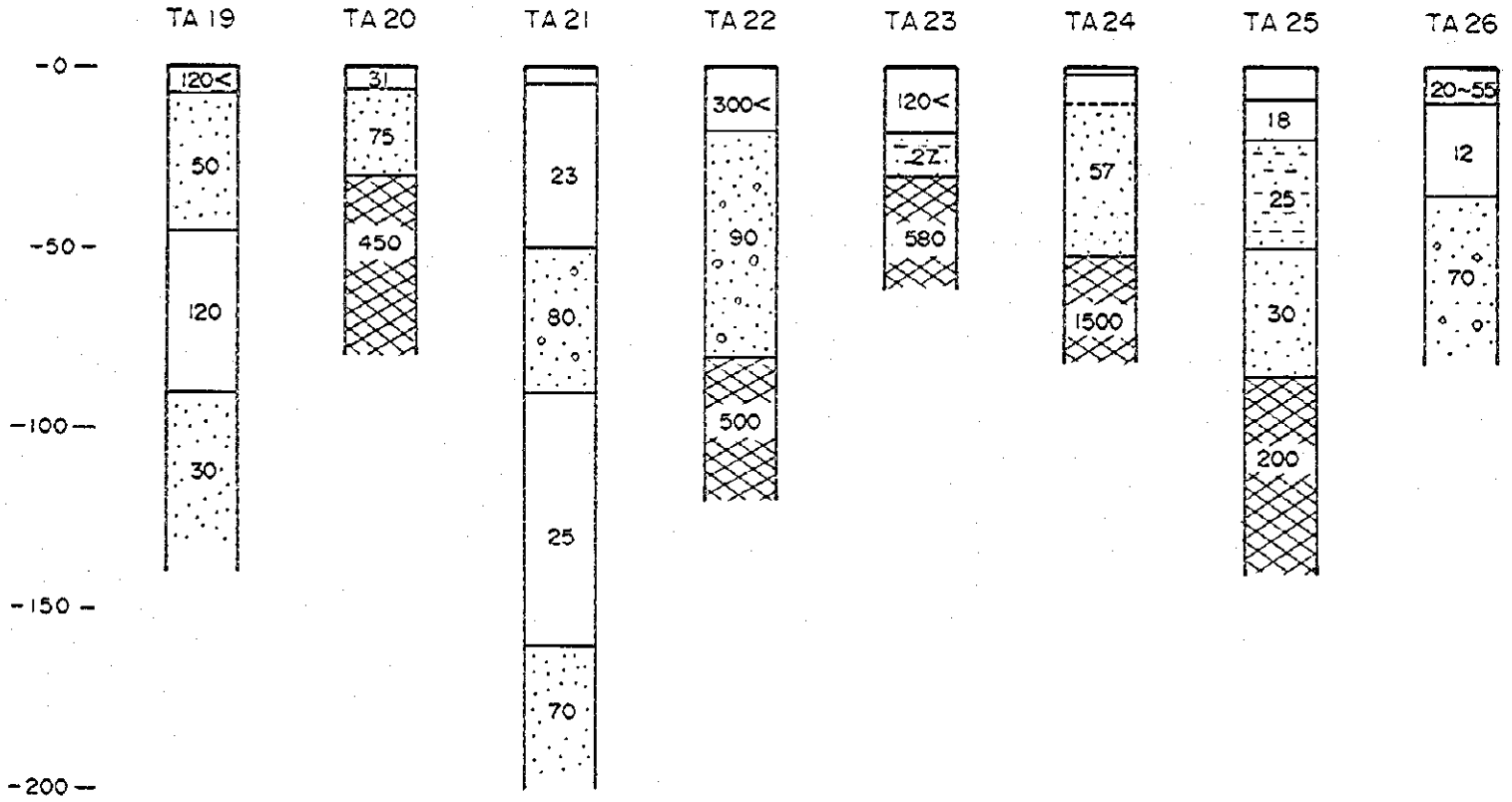


Figura 4-1-7-a Columnas de resistividad(1), Tarija
Figure 4-1-7-a Resistivity profile(1), Tarija

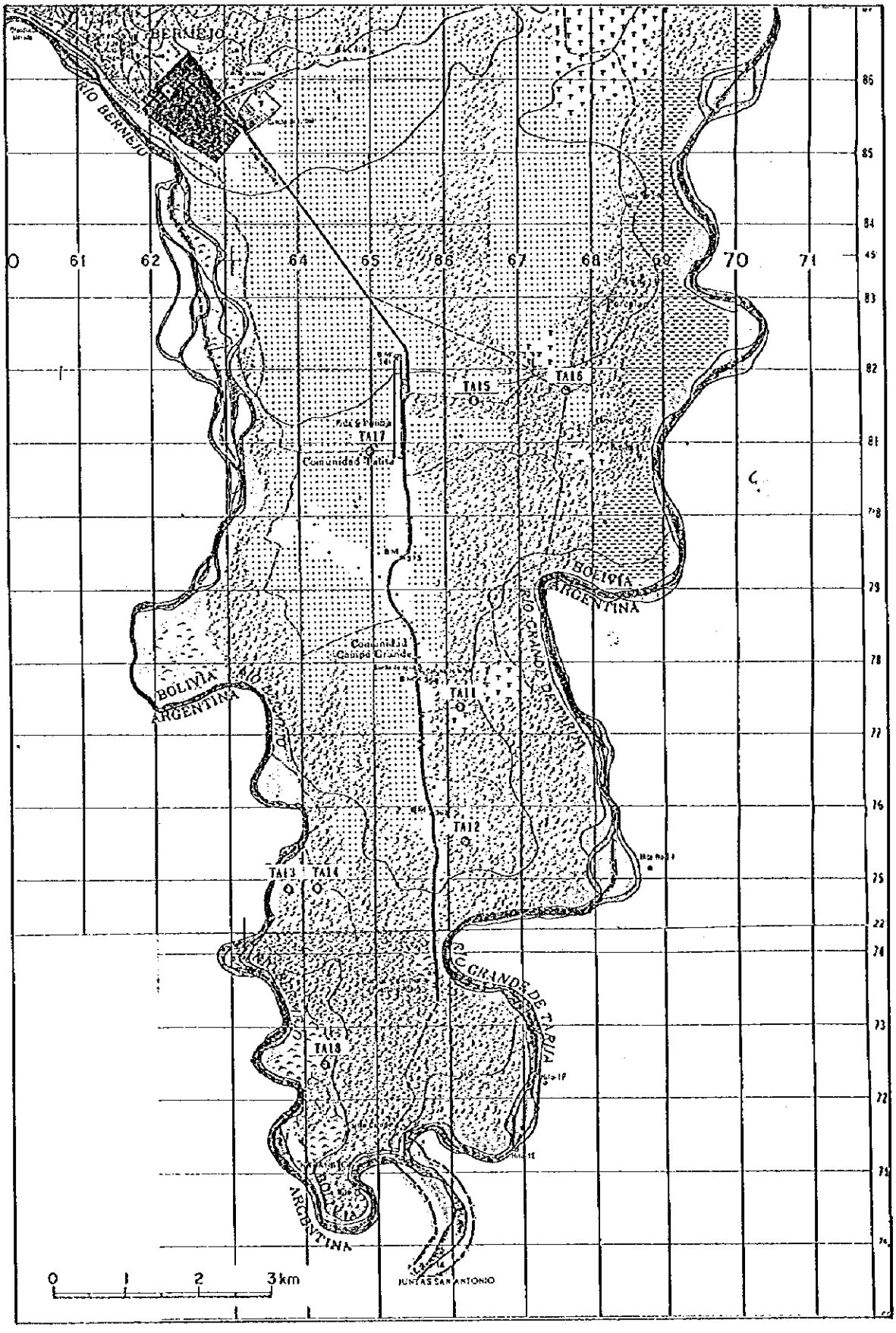
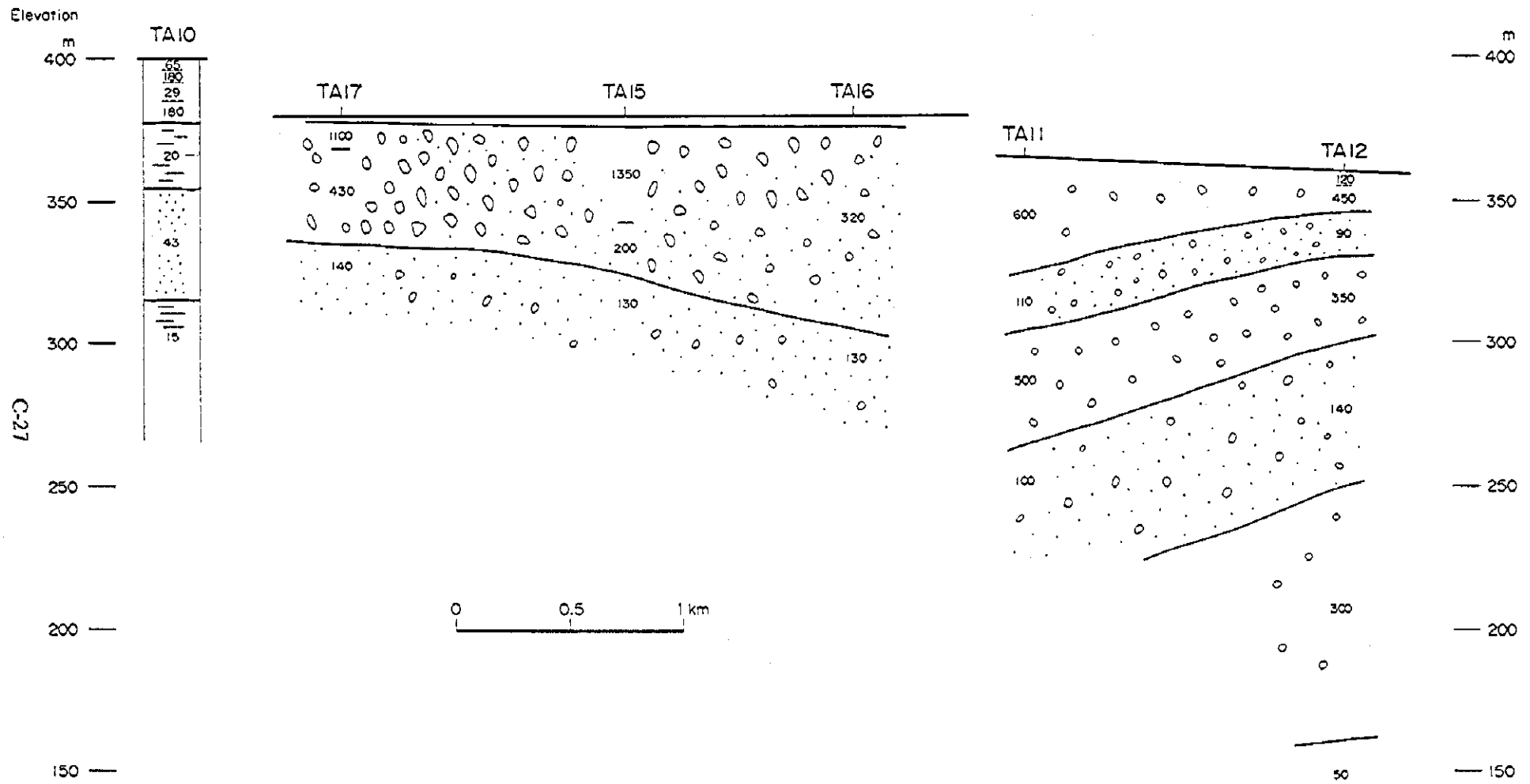


Figura 4-1-7-b Localizacion de las estaciones geofisicas en Bermejo, Tarija
Figura 4-1-7-b Location of geophysical points in Bermejo, Tarija



C-27

Figura 4-1-7-c Corte de resistividad de Bermejo(1), Tarija
Figure 4-1-7-c Resistivity profile of Bermejo(1), Tarija

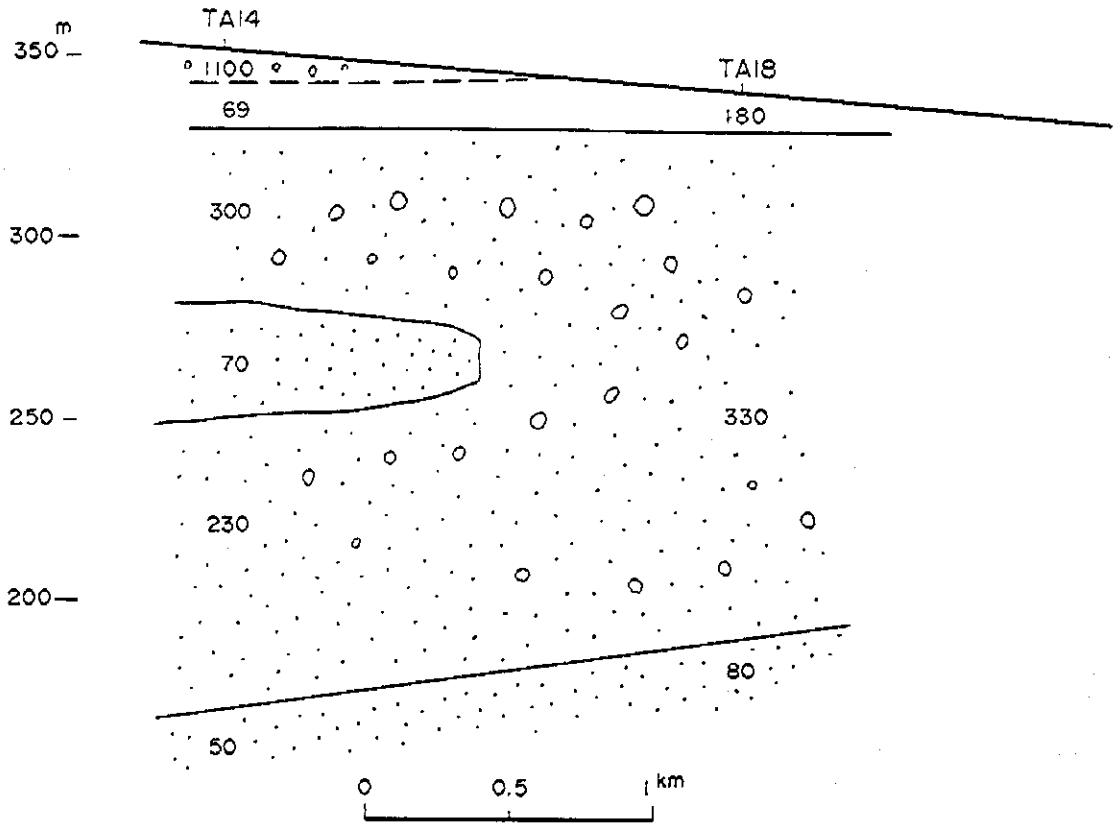


Figura 4-1-7-d Corte de resistividad de Bermejo(2), Tarija
Figure 4-1-7-d Resistivity profile of Bermejo(2), Tarija

(5) Department of Santa Cruz

The tendency is toward shallower a depth of a "aquifer-resistivity layer" from Cochabambita to north east. (Figure 4-1-8-a~b).

In Trigal zone, an "aquifer-resistivity layer" lies under 200m in depth in Cochabambita with 60 Ω-m, and under 120m in El Trigal (SC26) with 60 Ω-m and under 35m with 35 Ω-m in Tucumancillo. The tendency is toward shallower depth of "aquifer-resistivity layer" to the periphery. In Lagunilla (SC23) no "aquifer-resistivity layer" is detected.

In Sanjon (SC22) an effective "aquifer-resistivity layer" by consideration of topography lies under surface 60m with 38~45 Ω-m resistivity.

In Comarapa zone an "aquifer-resistivity layer" lies under surface 35m with 50 Ω-m in Comarapa (SC27), 150m with 30 Ω-m in El Tambo (SC29) and 30m with 50 Ω-m in San Isidro(SC28). In San Isidro another "aquifer-resistivity layer" is detected under surface 100m with 50 Ω-m.

In Pampa Grande (SC30) an "aquifer-resistivity layer" lies under surface 70m with 30~55 Ω-m.

In Samaipata an "aquifer-resistivity layer" lies under surface 40m. It seems that this layer consists of an alternated layer with muddy bed and sandy bed by judging low specific resistivity of the layer.

In the Llanura, the tendency is toward shallower depth of the "aquifer-resistivity layer" from the west, Costa zone, to the east.

In San Carlos zone, a well, which is in the court of the School of San Carlos, gave us an important information about underground condition of this zone, of which the well is dry at least 130m under surface even if an "aquifer-resistivity layer" is detected by geophysical prospecting. It seems that upper surface of "aquifer-resistivity layer" is under 130~150m and it's efective specific resistivity is between 35 Ω-m and 45 Ω(MR Figure 4-3-12~14).

Okinawa I has a good well which wells out from the depth of about 70m. Vertical Electric Sounding was carried out to confirm the aquifer in the north with an interval of 500m from the well. An "aquifer-resistivity layer" was detected under surface about 70m with 40 Ω-m and a muddy bed, too, with under 20 Ω-m, which presses the lower "aquifer-resistivity layer", was detected. Then it was certified that Vertical Electric Sounding Method was very effective method to detect an aquifer.

In Yapacani (SC32) an "aquifer-resistivity layer" is under surface 50m with 60 Ω-m.

In Quituquina it was interpreted that an "aquifer-resistivity layer" laid under 100~120m. But it became clear that there was no "aquifer-resistivity layer" by the results of the test drilling JC5 (MR Figure 4-3-15~17).

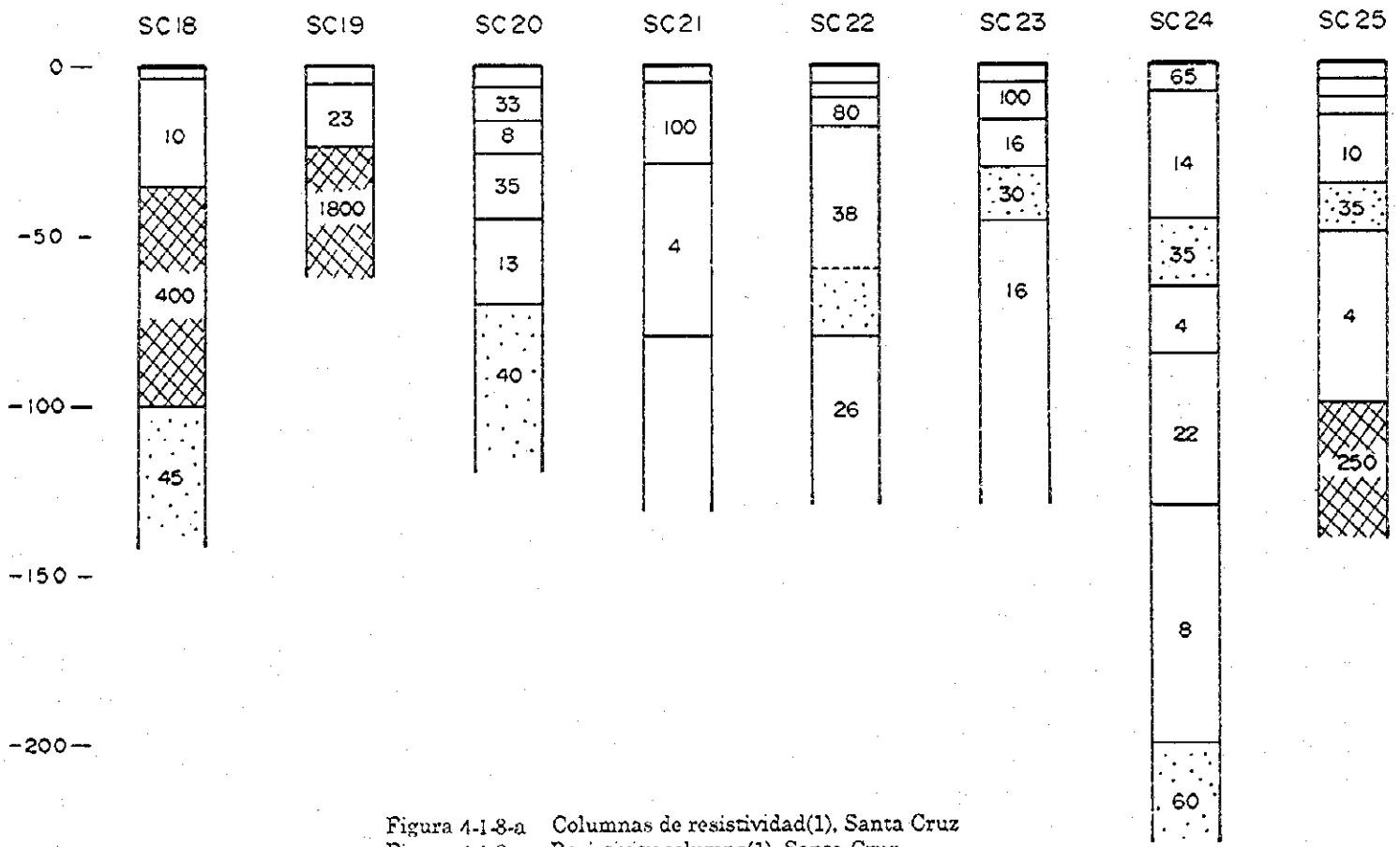


Figura 4-1-8-a Columnas de resistividad(1), Santa Cruz
Figure 4-1-8-a Resistivity columns(1), Santa Cruz

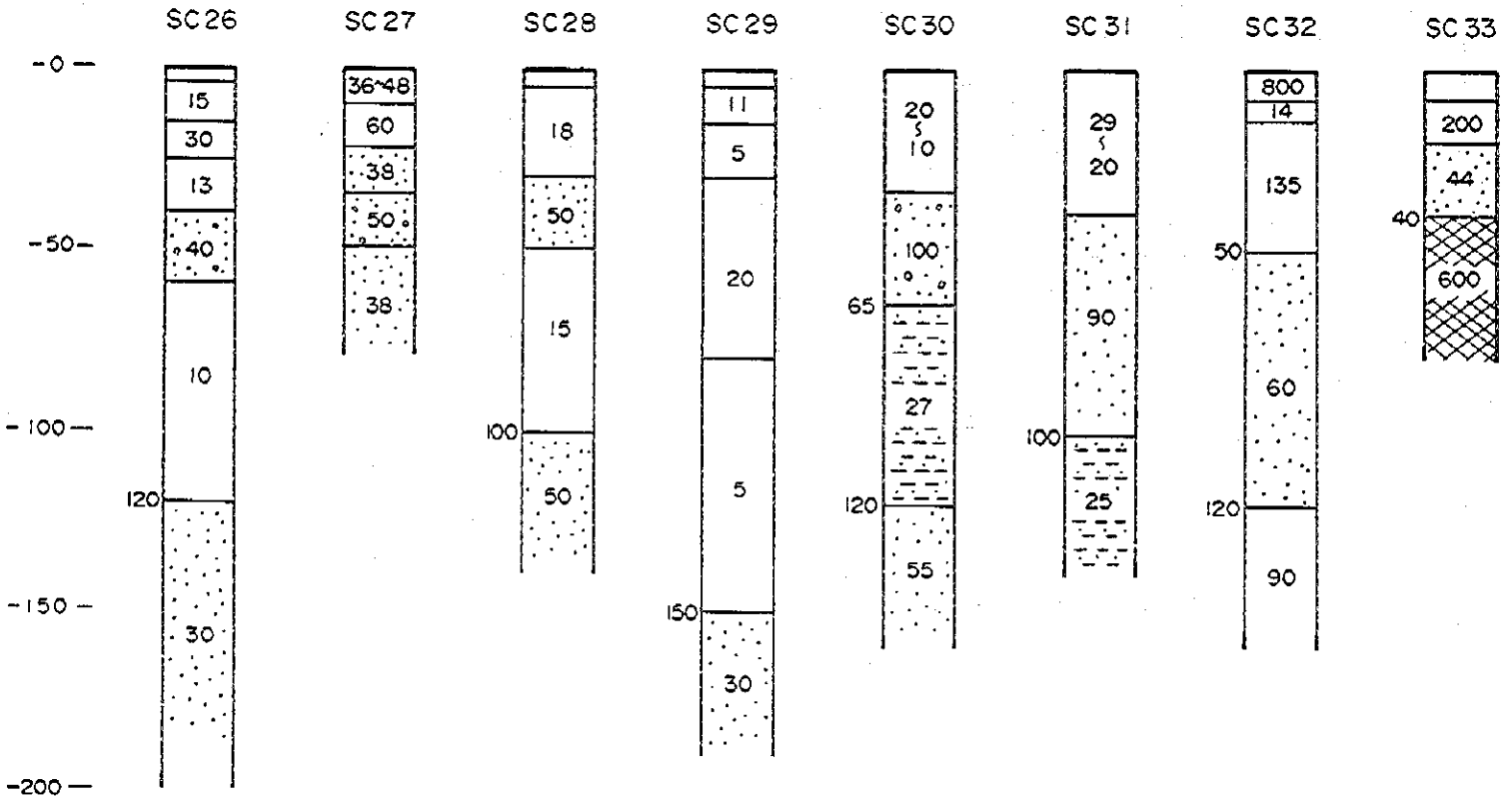


Figura 4-1-8-b Columnas de resistividad(2), Santa Cruz
Figure 4-1-8-b Resistivity columns(2), Santa Cruz

3) Results of Geophysical Prospecting, Test Drilling and Well Logging at Test Wells

Nine geophysical stations ware sellected for test drilling on geophysical results. They are as follows:

Area	Well No.	Geoph. No.	Location
Altiplano	JC1	LP5	Patacamaya-La Paz
	JC2	OR10	Corque-Oruro
	JC3	OR3	Penas-Oruro (substituted OR5)
Valle	JC8	TA9	La Choza-Tarija
	JC9	TA30	Naranjos-Tarija (TA10- TA11-)
Llanura	JC4	SC11	San Carlos-Santa Cruz
	JC5	SC14	Quituquina-Santa Cruz
Chaco	JC6	CH5	Campo Leon-Chuquisaca
	JC7	CH26	El Simbolar-Chuquisaca

The results of geophysical prospecting, test drilling and well logging and each other's relation are as follows.

(1) JC1 : Geophysical station LP5 in Patacamaya- La Paz

Geophysical results.

9~35m / 230 Ω-m	high resistivity layer consisting of much debris from back mountain range.
30~65m / 60 Ω-m	sandy layer - "aquifer-resistivity layer"
65~95m / 4 Ω-m	muddy layer
95m~ / 30 Ω-m	sandy layer - "aquifer-resistivity layer"

Drilling

support geophysical results.

Well logging

23~65m aquifer

Screen interval

23~65m

(2) JC2 : Geophysical station OR10 in Corque - Oruro

Geophysical results

9~40m /26 Ω-m	muddy layer

40m~ /40 Ω-m sandy layer - "aquifer-resistivity layer"

Drilling

support geophysical results.

Well logging

support geophysical results.

Screen interval

42~66m

(3) JC3 : Geophysical station OR3 in Huacuyo - Oruro

Geophysical results

4~ 33m / 63 Ω-m mixed current deposit with gravels, sand, mud

33~117m / 150 Ω-m consolidated sand stone or conglomerate

117m~ / 47 Ω-m sandy layer - "aquifer-resistivity layer"

Screen interval

29~60m

(4) JC4 : Geophysical station SC11 in San Carlos - Santa Cruz

Geophysical results

65~140m / 7 Ω-m muddy layer

140~ / 40 Ω-m sandy layer - "aquifer-resistivity layer"

Results of drilling and well logging

support geophysical results

Screen interval

146~248m

(5) JC5 : Geophysical station SC14 in Quituquina - Santa Cruz

Geophysical results

32~110m / 110 Ω-m shale, slate, sand stone with few cracks

110m~ /35 Ω-m shale, slate, sand stone with much cracks - "aquifer-resistivity layer"

Drilling results

0~40m mixed layer with grabel, mud

40m~ shale

110m~ more crack

Well logging

no support geophysical results

Screen interval

117~182m

(6) JC6 : Geophysical station CH5 in Campo Leon - Chuquisaca

Geophysical results

280~350m	/ 15 Ω-m	muddy layer
350m~	/ 60 Ω-m	sandy layer - "aquifer-resistivity layer"

Drilling

~300m	muddy layer
300m~	sandy layer

Well logging

support geophysical results

Screen interval

306~361m

(7) JC7 : Geophysical station CH26 in El Simbolar - Chuquisaca

Geophysical results

~225m	/ 6 Ω-m	muddy layer
225~	/23 Ω-m	muddy + sandy layer - "aquifer-resistivity layer"

Drilling

~240m	muddy layer
240m~	muddy + sandy layer

Well logging

75~150m	sandy layer

Screen interval

99~159m

(8) JC8 : Geophysical station TA9 in La Choza - Tarija

(Drilling point is located on the court of a chapel, 1km west from TA9)

Geophysical results

~31m	/ 12 Ω-m	muddy layer
31~90m	/ 30 Ω-m	sandy layer - "aquifer-resistivity layer"
90~105m	/ 2 Ω-m	muddy or silt layer
105m~	/ 120 Ω-m	basement

Drilling

support geophysical results.

Well logging

support geophysical results

Screen interval

46~119m welling out 7 l/s

(9) JC9 : Geophysical station TA30 in Naranjos - Tarija

Geophysical results

8~40m / 31 Ω-m sandy layer - "aquifer-resistivity layer"

40~100m / 16 Ω-m muddy layer

100m~ / 27 Ω-m sandy layer - "aquifer-resistivity layer"

Drilling

muddy layer dry well