Appendix

Appendix

A.1 Measurement of Sonic Velocity

A.1.1 Instrument

New Sonic Viewer, Model-5217, OYO corporation.

A.1.2 Method of Measuring Sonic Velocity

A piece is held between a pair of vibrators and a travelling time of wave from one end of vibrator to another through a piece of sample is recorded (see Fig. A-1-1). Travelling time read from CRT is divided by a length of sample to obtain the velocity. A piece of sample is one which is used for measurement of apparent resistivity. Samples are dried in a room condition.

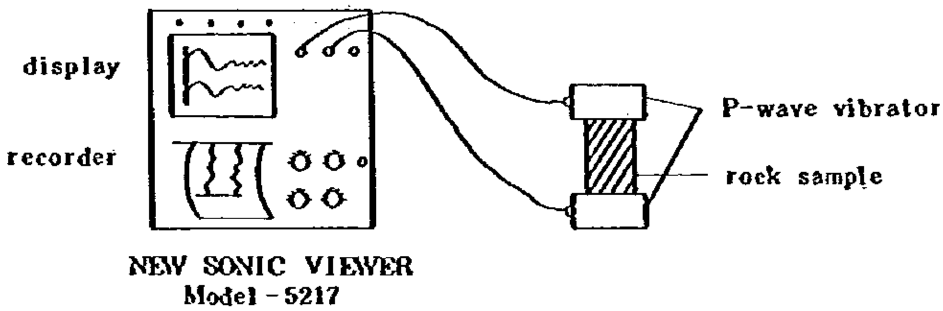


Fig. A-1-1 Schematic diagram for measuring sonic velocity

The results are shown in Table A-1-1 and compiled in Table A-1-2 with respect to lithological units.

A.2 Heat Flow Survey

A.2.1 Methods of Temperature Measurement

(1) Multi-sensor logging

The system consists of multiple thermistors mounted on cables at 10 m intervals.

The cables are inserted into a hole and after waiting more than 30 minutes when the effect of disturbance due to insertion ceased, the readings are taken from every 10 m spaced thermistor. Then the cables are pulled up by 5 meters and, after more than 20 minutes, the readings are made. Thus the system gives the readings of every five meters.

(2) Normal logging

A standardized method of temperature logging is to move a thermal electrode at a

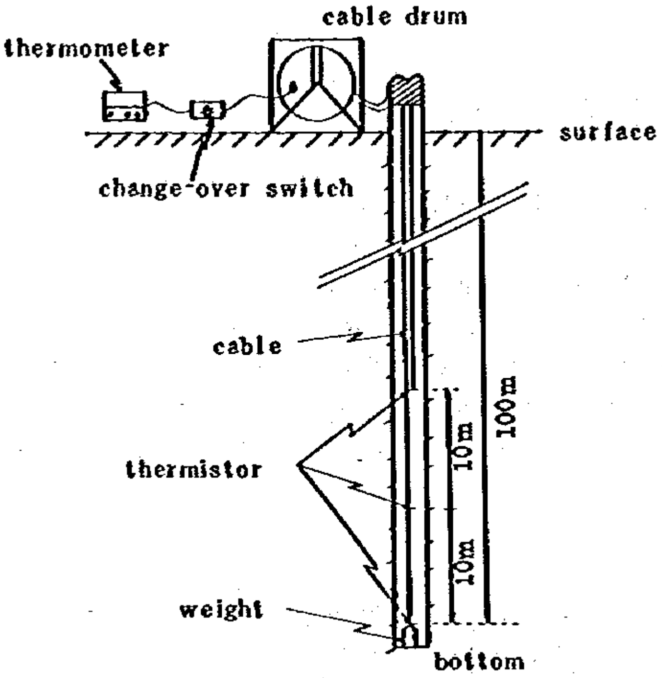


Fig. A-2-1 Schematic diagram of measuring ground temperature by multi sensor

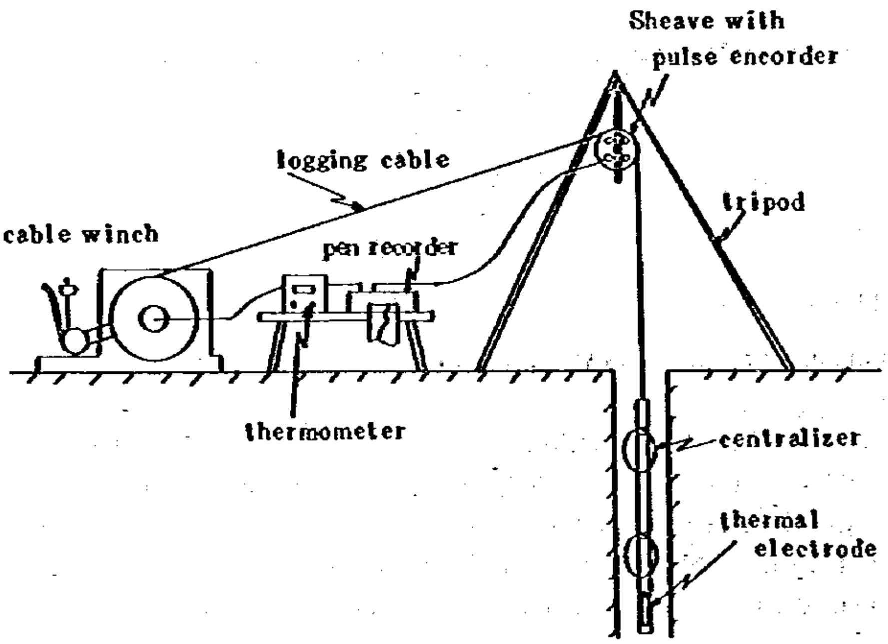


Fig. A-2-2 Schematic diagram of measuring ground temperature by normal logging

Table A－1－1 Results of measurement of sonic velocity (m/sec)

Sample No.	Rock name	P-wave velocity	Sample No.	Rock name	P-wave velocity
F-1	Granodiorite	5,160	TM-27	Granodiorite	5,050
F-3	Dacitic welded tuff	4,180	TM-31	Andesite	6,140
F-5	Andesitic vitric tuff	2,450	TM-35	Andesitic tuff	2,650
F-8	Basaltic tuff breccia	2,250	TM-40	Dacite	2,170
F-9	Aplite	5,640	TM-44	Andesitic tuff	3,260
F-14	Quartz diorite porphyry	4,500	TM-45	Pyroxene andesite	4,270
F-21	Dacite	4,290	TM-46	Sandstone	4,710
F-23	Rhyolite	3,810	TM-47	Dacitic tuff	2,190
F-25	Dacite	3,320	TM-48	Granodiorite porphyry	4,770
F-26	Granodiorite	4,580	TM-50	Rhyolite	2,500
F-27	Aplite	4,840	TM-52	Andesite	5,080
F-28	Hornfels	6,730	TM-53	Rhyolite	3,360
F-31	Dacitic lapilli tuff	6,290	TM-55	Dacitic tuff	6,060
F-32	Andesite	4,820	TM-57	Dacite	6,450
F-33	Andesitic tuffaceous Sandstone	6,320	TM-59	Sandstone	5,420
F-40	Andesitic sandy tuff	5,680	TM-64	Pyroxene andesite	4,740
F-41	Andesite	2,970	TM-66	Hornfels	6,030
F-41-2	Andesitic tuff breccia	2,140	TM-68	Andesite	6,330
F-43	Pyroxen andesite	4,630	TM-69	Pyroxene andesite	5,830
F-44-2	Dacite	3,400	TM-71	Augite andesite	6,390
F-45	Andesitic tuff breccia	1,890	TM-74	Dacitic tuff breccia	3,410
F-48	Dacitic sandy tuff	2,440	TM-80	Andesite	4,630
F-60	Dacitic vitric tuff	1,740	TM-86	Dacite	3,070
F-160	Andesite	4,880	TM-87	Dacite	2,430
TM-6	Dacitic tuff	5,330	TM-89	Pyroxene andesite	6,030
TM-11	Granodiorite	4,760	TM-92	Pyroxene andesite	4,000
TM-13	Rhyolitic tuff breccia	2,640	TM-94	Pyroxene andesite	4,810
TM-15	Dacite (Perlite)	2,480	TM-106	Tuffaceous sandstone	6,260
TM-16	Granodiorite	6,810	TM-110	Sandstone	3,720
TM-23	Dacite	2,600	TM-114	Sandstone	5,110

Table A－1－2 Results of measurement of sonic velocity (m／sec)
(the mean value of rock facies & geological unit)

Rock facies	Geological unit		No. of samples	Arerage R.f.	Arerage O.u.		Maximum R.f.	Maximum O.u.	Minimum R.f.	Minimum O.u.
Rhyolite			4	3,011			3,810		2,372	
Dacite		V-2	11	2,883	2,900		4,290	4,290	2,169	2,169
Dacitic tuff breccia(1)			–	–			–		–	
Dacitic tuff breccia(2)			1	2,640			–		–	
Pumice tuff	V		–	–			–		–	
Welded tuff			2	4,755			5,330		4,180	
Andesitic tuff breccia		V-1	2	2,195	4,129		2,250	6,390	2,140	1,740
Scoria tuff			4	2,525			3,260		1,740	
Andesite			7	5,420			6,390		4,000	
Andesite	T		5	4,316	4,164		5,080	5,680	2,970	1,890
Andesitic tuff breccia			2	3,785			5,680		1,890	
Sandstone, Mudstone		J-3	2	4,910		3,572	5,110		4,710	
Tuff			3	2,680			3,410		2,190	
Sandstone		J-2	1	3,720		–	–	–	–	–
Limestone	J		–	–	4,863	–	–		–	
Sandstone, Mudstone (Basalt)			3	6,000			6,320		5,420	
Andesite, Basalt		J-1	2	4,850		5,813	4,880	6,450	4,820	4,820
Pyroclastic rocks			3	6,267			6,450		6,060	
Granodiorite			5	5,272			6,810		4,580	
Metamorphic rocks	B		2	6,380	5,511		6,730	6,810	6,030	4,580
Aplite			2	5,240			5,640		4,840	
Andesite dyke			1	6,330			–		–	
Basalt dyke	D		–	–	5,200		–	4,770	–	4,500
Granodiorite porphyry			2	4,635			4,770		4,500	
Total			64							

R.f. : Rock facies

O.u. : Geological unit

rate of 5 to 10 m/min by means of an electric winch.

The time intervals of measurement are set logarithmically after the completion of drilling.

A.2.2 Instruments

(1) Multi-sensor logging

Thermometer:	Thermistor Thermometer D-221 Range 0–99.9°C Sensitivity 0.1°C TAKARA INDUSTRY Co., Ltd.
Sensor-Cable:	PXA-64, 210 m, with 10 m spacing sensors Operating Temperature 80°C, max. TAKARA INDUSTRY Co., Ltd.

(2) Normal logging

Thermometer:	Thermistor Thermometer D-111 Range 0–199.9°C Sensitivity 0.1°C with a compensating circuit of cable resistivity TAKARA INDUSTRY Co., Ltd.
Recorder:	Automatic three-pen-recorder KER-4 KAIHATSU KOGYO Co., Ltd.
Thermistor:	ϕ45 mm-thermistor KAIHATSU KOGYO Co., Ltd.
Winch:	Electric Winch KEW-1,000 KAIHATSU KOGYO Co., Ltd.
Cable:	ϕ11 mm-heatproof Cable, 600 m Operating Temperature: below 150°C Temperature Limitation: 200°C an instant KAIHATSU KOGYO Co., Ltd.

A.2.3 Results of Temperature Measurement

Temperature of 5 m-sections; See Table A-2-1

Temperature Log: See Fig. A-2-3

A.2.4 Estimation of Equilibrium Temperature

$$T = To - \frac{q}{4\pi K} \cdot \ell n \frac{dt}{t + dt}$$

Where: To : temperature before drilling
q : loss or gain of heat per unit time and unit length
K : the thermal conductivity
dt : a time difference between completion of drilling and measurement
t : the time elapsed between passing a depth and completion of drilling

A.2.5 Estimated Equilibrium Temperature (by Argentine team)

The Table A-2-2 shows the estimation of equilibrium temperature over a ten-meter section of each holes by Argentine team.

Table A-2-2 Estimated equilibrium temperature (by Argentine)

(Unit: °C)

Depth (m) \ Hole No.	1	9	10	11	12	14
10		14.5	9.2	9.5		9.0
20		13.5	10.8	15.2	11.0	15.0
30	28.0	13.4	10.8	13.8	11.3	16.8
40	34.2	13.0	11.7	12.8	11.1	19.0
50	43.3	13.5	11.3	13.0	11.2	20.2
60	49.5	18.5	10.9	11.8	11.4	22.5
70	50.0	18.8	10.9	11.1	12.4	25.2
80	36.0	36.1	10.8	11.8	13.1	29.8
90	48.0	41.2	10.8	11.6	14.3	30.8
100	59.0	62.0	11.3	9.5	14.8	37.0
110		69.0				
120		77.0				

Argentine partners conducted a method applicable with repetitions of measurement in a short time using a graph especially prepared through their experiences.

A.2.6 Geothermal Gradient

The Table A-2-3 shows the geothermal gradients obtained by the calculations from the equilibrium temperature over a 5-m section. Calculation was made

1) in the ranges where the gradients remain rather stable in the depths, and
2) over a total length drilled by the least squares method.

In the test, the former was adopted.

A.3 Electrical Prospecting

A.3.1 Theory of Electrical Prospecting

The Schlumberger array is an layout of electrodes to detemine the subsurface distribution of resistivity and comprises one pair of electrodes to introduce current into the earth,

Table A-2-1(i) Records of temperature logging

Hole No. 1

Coordinates ; X 5939.935 , Y 1629.353		Elevation ; m
Date ; from 5/Dec./83 , to 13/Dec./83		Depth, drilled 101.00 m
Drilling Method ; Rotary	Bit size ;	
Casing ;	Casing diameter ;	

Measurement	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
Date	13.Dec	13.Dec	14.Dec	14.Dec	15.Dec	16.Dec	18.Dec	19.Dec	21.Dec	27.Dec	8.Jan
Hour	13°00', 15°00'	15°40'	8°15', 8°35'	13°15', 13°35'	21°00'	19°30', 20°10'	14°25', 15°00'	13°20', 13°45'	20°05', 20°25'	13°50', 13°25'	15°00', 14°20'
Weather	fine	fine	fine	fine	cloudy	cloudy	fine	fine	fine	fine	fine
Depth (m)	Temperature (℃)										
0	21.3	20.4	12.5	19.9	14.4	14.6	23.0	16.2	17.3	18.0	21.6
5	13.8		13.1	13.0		12.5	12.4	12.1	12.1	12.1	12.0
10	17.1	16.9	16.4	16.2	16.2	16.0	16.1	15.8	15.8	15.8	15.8
15	19.0		19.0	19.0		18.8	18.9	18.7	18.8	18.7	18.6
20	21.2	21.7	21.6	21.6	21.7	21.7	21.7	21.6	21.4	21.6	21.6
25	23.9		24.5	24.5		24.7	24.7	24.7	24.7	24.6	24.7
30	26.2	27.1	27.4	27.4	27.7	27.8	27.9	27.9	27.8	28.0	28.1
35	29.2		30.6	30.7		31.1	31.2	31.2	31.3	31.3	31.5
40	31.4	33.2	34.0	34.1	34.6	34.7	34.8	34.9	35.0	35.2	35.3
45	35.7		37.6	37.9		38.7	38.9	39.1	39.3	39.5	39.7
50	38.7	41.3	42.6	42.8	43.4	43.6	43.8	44.0	44.1	44.5	44.6
55	41.8		45.6	45.9		47.2	47.6	47.8	48.2	48.6	49.1
60	41.1	45.6	47.9	48.8	50.0	50.6	51.2	51.5	51.9	52.4	52.7
65	43.0		48.2	48.8		50.6	51.2	51.4	51.6	52.1	52.4
70	34.4	44.2	47.7	48.7	49.6	49.8	50.2	50.4	50.7	51.0	51.2
75	35.8		46.6	47.4		49.1	49.3	49.4	49.5	49.5	49.5
80	23.6	28.9	31.4		38.0	39.0	40.7	41.6	43.3	44.8	46.4
85	27.0		39.7	41.7		44.6	45.3	45.5	45.9	46.3	46.8
90	29.7	38.4	44.5		46.5	46.7	46.9	47.1	47.2	47.3	47.4
95	36.6		46.0	46.6		47.8	48.1	48.1	48.3	48.3	48.4
100	40.3	49.2	55.0		56.7	57.0	57.1	57.2	57.2	57.8	57.6

Note ; Water Level : 20°00' 14. Dec. 75~80m
17°00' 24. Jan. 58m

Table A−2−1(i) Records of temperature logging

Hole № 2

Coordinates ; X 5940899 , Y 1627.966		Elevation ;	m
Date ; from 5/Dec/83 , to 20/Dec/83		Depth, drilled 103.00	m
Drilling Method ; Rotary	Bit size ;		
Casing ;	Casing diameter ;		

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th		
Date	20.Dec.	21.Dec.	21.Dec.	22.Dec.	24.Dec.	27.Dec.	1 Jan.	8 Jan.		
Hour	21°00′	8°35′, 9°06′	21°15′, 20°53′	18°05′, 18°25′	20°15′, 20°35′	16°00′, 15°47′	18°20′, 18°40′	11°18′, 11°40′		
Weather	fine	fine	fine	fine	fine	fine	cloudy	fine		
Depth (m)	Temperature (℃)									
0	120	145	146		163	197	208	185		
5		156	117	98	8.9(4)	8.0(4)	9.4(4)	8.5(4)		
10	210	150	131(8.2)	11.4(8.2)	110	106	105	102		
15		156	144	134	121(14)	124(14)	11.8(14)	11.3(14)		
20	221	166	150(18.2)	143(18.2)	143	146	138	140		
25		175	167	156	150(24)	150(24)	145(24)	155(24)		
30	232	188	175(23.2)	168(28.2)	185	17.6	17.5	181		
35		199	19.4	19.0	20.1(34)	20.1(34)	20.0(34)	19.6(34)		
40	250	216	20.4(38.2)	199(38.2)	214	220	221	226		
45		231	227	228	229(44)	229(44)	234(44)	239(44)		
50	268	249	236(48.2)	238(48.2)	241	247	259	264		
55		267	268	27.2	266(54)	266(54)	28.2(54)	28.9(54)		
60	293	295	283(58.2)	29.1(58.2)	295	299	31.4	330		
65		319	326	323	323(64)	323(64)	332(64)	359(64)		
70	351	381	35.4(68.2)	359(68.2)	381	39.4	370	411		
75		405	416	425	434(74)	43.4(74)	438(74)	449(74)		
80	377	420	440(78.2)	452(78.2)	487	500	512	519		
85		449	47.9	506	544(84)	544(84)	556(84)	563(84)		
90	441	510	521(88.2)	547(88.2)	576	59.8	623	626		
95		573	605	634	?61.6(94)	?61.6(94)	65.8(94)	67.2(94)		
100	480	660	657(98.2)	67.9(98.2)						

Note ; Water Level : 10°20′ 26. Jan. 56m

Table A-2-1(6) Records of temperature logging

Hole No. 3

Coordinates ; X 5942314 , Y 1629497	Elevation ; m
Date ; from 14/Dec./83 , to 20/Dec./83	Depth, drilled 10100 m
Drilling Method ; Rotary	Bit size ;
Casing ;	Casing diameter ;

Measurement	1st	2nd	3rd	4th	5th	6th	7th	8th		
Date	20. Dec.	21. Dec.	21. Dec.	22. Dec.	24. Dec.	27. Dec.	1. Jan.	8. Jan.		
Hour	1725, 1745	1015, 1110	1906, 1830	1935, 1915	1903, 1920	1705, 1725	1950, 1930	935, 1000		
Weather	fine	fine	fine	fine	fine	fine	cloudy	fine		
Depth (m)	Temperature (℃)									
0	161	134	152	164	204	209	153	118		
5	153	117	110	101	93	85	81	82		
10	176	135	131	121	114	108	101	98		
15	176	136	132	122	116	110	106	104		
20	180	144	139	131	125	119	115	113		
25	180	151	148	140	134	129	126	124		
30	186	159	154	148	142	141	137	136		
35	186	164	161	156	152	152	149	146		
40	194	182	178	169	166	165	163	162		
45	195	185	182	177	175	176	175	173		
50	199	192	190	186	185	188	188	189		
55	201	201	200	197	198	199	199	198		
60	201	211	210	210	210	210	213	213		
65	206	221	222	223	225	226	226	221		
70	206	232	234	237	239	242	243	242		
75	212	244	246	251	255	259	258	260		
80	213	257	260	266	271	275	276	275		
85	232	273	276	281	284			288		
90	226		286	291	294			298		
95	228	291	294	300	302			306		
100	248		307	310	312					

Note ; Water Level : 9°20' 26. Jan. 48m

Table A-2-1 (iV) Records of temperature logging

Hole No. 4

Coordinates ; X 5943331 , Y 1630918	Elevation ; m
Date ; from 21/Dec./83 , to	Depth, drilled 2450 m
Drilling Method ; Rotary	Bit size ;
Casing ;	Casing diameter ;

Measurement	1 st	2 nd	3 rd	4 th						
Date	12 Jan.	13 Jan.	16 Jan.	1 Feb.						
Hour	18 55	9 16, 8 55	16 45, 17 01	12 25						
Weather	fine	fine	fine	fine						
Depth (m)	Temperature (℃)									
0	118	123	257	150						
5	438(4	534(4	534(33	624(33						
10	692	821	900	903(75						
15	586(14)	771(14)	837(133	924(100						
20	690	814	869	926(133						
25	713(24)	826(24)	857							
30										
35										
40										
45										
50										
55										
60										
65										
70										
75										
80										
85										
90										
95										
100										

Note ;

Table A-2-1(V) Records of temperature logging

Hole No. 5

Coordinates ; X 5941677 , Y 1625898		Elevation ; m
Date ; from 9/Jan./81 , to 23/Jan./81		Depth, drilled 10200 m
Drilling Method ; Rotary	Bit size ;	
Casing ;	Casing diameter ;	

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th				
Date	23. Jan.	24. Jan.	28. Jan.	1. Feb.	3. Mar.	7. Mar.				
Hour	18°40'	8°55', 9°15'	10°10', 10°20'	9°15', 9°30'	13°40'					
Weather	fine	fine	fine	fine	fine	fine				
Depth (m)	Temperature (℃)									
0	232	131	152	123		153				
5		155	128	122	114					
10	251	177	146	135		120 m (75)				
15		151	115	108	103					
20	252	160	119	112		104 (125)				
25		161	119	112	105					
30	242	163	120	111		105 (275)				
35		162	120	112	105					
40	237	161	120	113		105 (375)				
45		164	120	113	105					
50	233	160	122	116		105 (475)				
55		164	145	131	123					
60	246	178	153	148		131 (575)				
65		205	166	162	159					
70	272	194	176	176		164 (675)				
75		206	196	196	197					
80	270	226	219			209 (775)				
85		243								
90	284	260								
95		282								
100	311	303								

Note ;

Table A-2-1 (vi) Records of temperature logging

Hole No. 6

Coordinates ; X 5910901 , Y 1621149		Elevation ; m
Date ; from 18/Jan./81 , to 21/Jan./81		Depth, drilled 100.00 m
Drilling Method ; Rotary	Bit size ;	
Casing ;	Casing diameter ;	

Measurement	1 st	2 nd	3 rd	4 th	5 th					
Date	22 Jan.	23 Jan.	28 Jan.	1 Feb.	3 Mar.					
Hour	9°15′, 9°00′	9°10′, 8°50′	9°05′, 9°20′	10°30′, 10°15′	11°21′					
Weather	fine	fine	fine	fine	fine					
Depth (m)	Temperature (℃)									
0	133	110	167	171						
5	149	131	116	112						
10	166	151	130	126	115 (9.0 m)					
15	17.5	160	142	140						
20	201	18.5	161	158	111 (19.0)					
25	20.7	19.1	178	171						
30	211	20.0	188	181	17.7 (29.0)					
35	216	211	203	201						
40	227	223	218	214	20.9 (39.0)					
45	237	237	237	236						
50	253	251	253	215 (49.0 m)	252 (49.0)					
55	263	267								
60	278	278								
65	283	287								
70	289	293								
75	291	30.1								
80	300	305								
85	306	312								
90	312	318								
95	313	323								
100										

Note ; Water Level : 10°25′ 25. Jan. 165 m

Table A-2-1 (VII) Records of temperature logging

Hole No. 7

Coordinates ; X 5939650 , Y 1626326		Elevation ; m
Date ; from 12/Jan./81 , to 16/Jan./81		Depth, drilled 10500 m
Drilling Method ; Rotary	Bit size ;	
Casing ;	Casing diameter ;	

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th		
Date	16. Jan.	17. Jan.	18. Jan.	20. Jan.	23. Jan.	1. Feb.	3. Mar.	9. Mar.		
Hour	18°15′	9°20′, 9°50′	9°15′, 9°25′	10°30′, 10°10′	10°35′, 10°15′	11°30′, 11°45′	17°30′	12°00′, 12°30′		
Weather	fine	fine	fine	cloudy	fine	fine	fine	fine		
Depth (m)	**Temperature (℃)**									
0	145	121	150	173	156	202	237	126		
5		114	105	101	90	86		83		
10	167	119	107	97	92	88	83	83		
15		122	109	104	94	88		83		
20	165	112	102	100	95	92	87	83		
25		114	101	92	89	84		79		
30	181	121	100	90	86	83	79	78		
35		115	96	88	85	81		80		
40	182	116	98	90	85	82	80	80		
45		115	99	88	85	82		80		
50	171	113	97	87	90	82	80	80		
55		113	97	88	88	86		81		
60	179	113	96	87	88	84	81	82		
65		113	98	88	88	83		83		
70	170	114	98	89	86	83	82	83		
75		113	98	90	86	84				
80	163	112	98	90	91	85(79.0m)				
85		114	98	90	89					
90	165	122	98	91						
95		125	102	91						
100	178	122	102	94						

Note ; Water Level : 15°00′ 25. Jan. 30.0 m

Table A-2-1 (Ⅷ) Records of temperature logging

Hole № 9

Coordinates ; X 5910039 , Y 1632632		Elevation ; m
Date ; from 26/Jan./84 , to 27/Feb./84		Depth, drilled 120.00 m
Drilling Method ; Rotary	Bit size ;	
Casing ;	Casing diameter ;	

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th		
Date	4Feb.	6Mar.	6Mar.	7Mar.	9Mar.	12Mar.	15Mar.	20Mar.		
Hour	9°50′,10°10′	9°25′	13°25′,13°30′	11°00′,11°20′	10°30′,11°00′	15°40′	9°10′,9°30′	11°00′,11°30′		
Weather	cloudy	fine	fine	fine	fine	fine	fine	fine		
Depth (m)	**Temperature (℃)**									
0	-0.6	143	187	207	283	21.0	10.0			
5	145		153	116	103	17.0	9.2	8.9		
10	15.8	16.0	15.2	13.0	12.4(9.5)	15.2(9.5)	10.0(9.5)	9.5(9.5)		
15	17.5		15.1	129	123	110	105	101		
20	18.1	15.4	14.4	13.0	11.9(19.5)	13.2(19.5)	10.6(19.5)	10.0(19.5)		
25	18.1		13.8	122	112	128	10.1	9.7		
30	17.8	143	13.6	12.0	11.1(29.5)	12.2(29.5)	10.0(29.5)	9.7(29.5)		
35	17.7		133	121	11.1	120	98	105		
40	17.6	137	133	124	11.2(39.5)	11.8(39.5)	10.0(39.5)	10.3(39.5)		
45	17.4		13.5	132	113	11.4	102	9.9		
50	17.2	13.6	137	14.4	11.5(49.5)	11.4(49.5)	10.0(49.5)	9.7(49.5)		
55	17.5		145	163	128	11.4	107	10.4		
60	18.6	15.0	169	20.4	17.6(59.5)	13.5(59.5)	13.1(59.5)	13.2(59.5)		
65	21.5		20.0	212	211	19.0	21.5	202		
70	246	181	228	27.8	27.8(69.5)	26.4(69.5)	27.9(69.5)	28.4(69.5)		
75	287		27.1	30.6	29.9	31.0	313	318		
80	30.7	219	299	33.1	36.4(79.5)	34.0(79.5)	38.7(79.5)	40.3(79.5)		
85	33.4		321	35.4	37.1	385	445	45.9		
90	36.1	25.0	311	38.0	44.3(89.5)	43.0(89.5)	43.9(89.5)	51.2(89.5)		
95	433		44.1	51.5	50.5	545	56.5	57.0		
100	551	325	50.0	57.3	59.2(99.5)	60.0(99.5)	61.0(99.5)	61.1(99.5)		
105			538	61.7	622	64.0	65.1	658		
110		329	56.4	65.7	67.3(109.5)	68.3(109.5)	68.6(109.5)	69.0(109.5)		
115			61.3	70.8	70.1	725	730	732		
120		40.5	620	735	75.3(119.5)	76.0(119.5)	76.7(119.5)	76.8(119.5)		

Note ;

Table A−2−1 (IX) Records of temperature logging

Hole No. 10

Coordinates ; X 5937650 , Y 1628599	Elevation ; m
Date ; from 6/Apr./84 , to 9/Apr./84	Depth, drilled 102.00 m
Drilling Method ; Rotary	Bit size ; 5⅝ inches
Casing ;	Casing diameter ;

Measurement	1 st	2 nd	3 rd *	4 th	5 th	6 th	7 th **	8 th	9 th	
Date	9Apr.	9Apr.	9Apr.	9Apr.	10Apr.	11Apr.	12Apr.	14Apr.	17Apr.	
Hour	18°45	19°45	20°45	21°45, 22°10	10°35, 10°53	16°13, 17°05	16°00, 16°20	11°00, 11°20	16°20, 16°45	
Weather	fine				fine					
Depth (m)	**Temperature (℃)**									
0	12.6	14.1	13.0	10.2	9.2	10.6	17.3	8.3	9.0	
5				11.9	10.4	9.5	9.5	9.3	9.2	
10	15.3	13.2	12.5	12.0	10.1	9.4	9.3	8.5	8.7	
15				12.4	10.3	9.2	9.0	9.3	8.4	
20	15.4	14.9	14.5	13.9	10.4	9.4	9.4	9.4	8.4	
25				13.8	10.9	9.6	9.3	9.3	8.6	
30	15.4	14.8	14.3	13.9	11.0	9.8	9.4	9.4	8.7	
35				13.6	11.2	9.7	9.3	9.1	8.7	
40	15.1	14.4	14.0	13.7	11.3	9.8	9.4	9.2	8.7	
45				14.0	11.6	10.1	9.6	9.5	9.1	
50	15.3	14.7	14.3	14.0	11.6	10.2	9.8	9.6	9.2	
55				13.5	11.5	10.2	9.7	10.2	9.2	
60	15.5	14.9	14.4	14.0	11.6	10.4	9.9	10.5	9.4	
65				13.8	11.6	10.4	10.2	10.5	9.8	
70	15.5	14.9	14.4	13.9	11.6	10.5	10.3	10.7	9.9	
75				14.0	11.8	10.8	10.4	11.0	10.2	
80	15.6	14.9	14.5	14.0	11.8	10.8	10.5	11.1	10.3	
85				13.9	11.9	10.9	10.6	10.8	10.2	
90	15.9	15.4	14.7	14.2	11.8	10.9	10.6	11.0	10.3	
95				14.3	11.9	11.1	10.8	10.9	10.7	
100	16.0	15.5	14.8	14.3	11.8	11.1	10.9	10.9	10.7	

Note ; * Water Level : 20°45′ 9. Apr. 20m
** 16°20′ 12. Apr. 40m

Table A-2-1 (X) Records of temperature logging

Hole № 11

Coordinates ; X 5938203 , Y 1630706		Elevation ; m
Date ; from 23/Mar./84 , to 27/Mar./84		Depth, drilled 1020 m
Drilling Method ; Rotary	Bit size ; 5⅝ inches	
Casing ;	Casing diameter ;	

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th *	9 th **	10 th
Date	27Mar.	27Mar.	27Mar.	27Mar.	27Mar.	27Mar.	28Mar.	30Mar.	31Mar.	12Mar.
Hour	19°55	20°25	20°55	22°00	22°55	23°53	17°34, 17°54	11°28, 11°59	11°50, 12°10	15°10, 15°30
Weather	fine									
Depth (m)	**Temperature (℃)**									
0	13.1	10.1	10.5	8.6	8.0	6.7	6.2	3.4	9.4	14.2
5							12.0	10.0	9.3	8.6
10	20.6	20.2	19.8	18.3	16.8	16.0	11.5	9.5	8.5	7.7
15							13.4	10.9	9.0	7.9
20	20.8	20.7	20.5	19.9	19.5	18.9	13.0	10.3	7.8	7.1
25							10.5	7.7	6.6	6.4
30	20.8	20.1	19.4	18.1	17.5	17.1	11.4	8.3	7.4	6.8
35							11.4	8.7	7.6	6.9
40	20.1	19.0	18.4	17.2	16.5	15.9	11.3	8.6	7.2	6.6
45							11.1	8.4	7.0	6.4
50	20.7	19.7	19.1	17.9	17.1	16.3	11.2	8.6	7.2	6.7
55							11.1	8.8	7.3	6.7
60	20.8	20.0	19.0	17.4	16.4	15.8	11.1	8.8	7.2	6.8
65							9.0	7.5	6.7	6.6
70	20.9	20.3	19.5	17.7	16.6	15.7	10.6	8.8	7.7	7.4
75							11.4	9.4	8.3	8.0
80	21.3	20.8	20.3	19.1	18.3	17.4	12.1	10.3	9.3	9.0
85							12.6	10.8	10.0	9.8
90	19.5	18.6	17.8	16.6	15.9	15.3	12.0	10.9		
95							12.2	11.3		
100	21.0	19.5	18.5	16.5	15.5	14.7	11.9	11.3		

Note ; * Water Level: 14°50′ 30. Mar. 70m
** 12°10′ 31. Mar. 15m

Table A−2−1 (XI) Records of temperature logging

Hole № 12

Coordinates ; X 5946265 , Y 1628081	Elevation ; 209691 m
Date ; from 25/Jan./84 , to 6/Mar./84	Depth, drilled 10100 m
Drilling Method ; Rotary	Bit size ; 5¾ inches
Casing ;	Casing diameter ;

Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th
Date	16Mar.	16Mar.	16Mar.	16Mar.	16Mar.	17Mar.	19Mar.	22Mar.	30Mar.	31Mar.
Hour	10 50	11 50	12 50	13 50	11 50, 15 00	10 40, 11 00	13 45, 13 55	16 50, 17 10	16 50, 17 10	10 11, 10 30
Weather	fine									
Depth (m)	Temperature (℃)									
0	7.9	67	7.3	9.1	128	102	227	19.5	60	6.0
5					10.5	9.6	9.4	9.3	3.8	86
10	109	10.6	10.6	10.5	10.4	10.0	9.7	93	102	8.7
15					10.8	10.6	10.1	10.7	9.2	9.3
20	11.1	11.1	11.1	11.1	11.0	10.9	10.3	10.0	9.4	9.7
25					112	10.9	105	10.2	9.9	9.8
30	11.3	11.3	11.3	11.3	11.3	11.0	10.6	10.6	10.0	10.3
35					11.3	11.0	107	109	105	105
40	112	112	11.1	11.1	11.1	119	10.7	10.5	10.7	
45					11.0	10.9	10.7	10.5		
50	11.3	11.3	11.2	112	112	11.0	10.8	10.8		
55					113	11.5	11.1	11.1		
60	11.4	11.4	11.4	11.4	11.4	11.7	11.3	11.6		
65					11.7	120	11.6	12.0		
70	11.7	11.9	120	120	120	123	12.0	122		
75					127	128	129	12.8		
80	125	128	128	128	129	132	133	132		
85					133	135	13.5	135		
90	127	13.0	132	13.4	13.5	137	138			
95					13.7	14.1	143			
100	128	133	136	138	139	14.4	14.6			

Note ;

Table A-2-1 (XI) Records of temperature logging

Hole No. 14

Coordinates: X , Y	Elevation: m
Date: from 15/Mar./84 , to 20/Mar./84	Depth, drilled 1010 m
Drilling Method: Rotary	Bit size: 5⅝ inches
Casing:	Casing diameter:

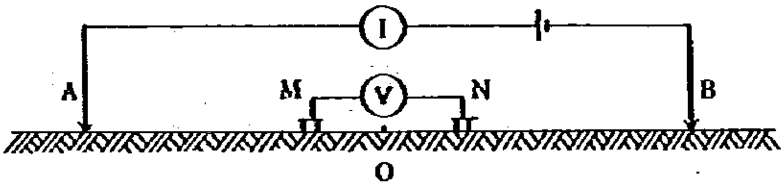
Measurement	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th
Date	20Mar.	20Mar.	20Mar.	20Mar.	20Mar.	21Mar.	22Mar.	24Mar.	26Mar.	5Apr.
Hour	16:30	17:30	18:30	19:30	20:30, 20:45	17:33, 18:00	10:00, 10:21	11:00, 11:25	15:00, 15:20	10:35, 10:55
Weather	fine									
Depth (m)	**Temperature (℃)**									
0	14.2	21.9	22.3	16.1	10.7	21.5	9.9	11.5	10.2	9.8(0)
5					13.3	10.4	10.1	11.6	9.2	(2.5) 9.7
10	20.7	19.8	16.8	16.3	15.7	11.9	11.8	12.8	10.3	9.3(7.5)
15					17.3	12.6	12.5	15.6	11.4	(12.5) 9.4
20	20.6	19.6	19.0	18.4	17.9	13.9	13.4	14.3	11.9	10.9(17.5)
25					18.3	14.6	14.1	15.8	12.7	(22.5)12.0
30	21.0	20.4	20.1	19.6	19.1	15.8	15.0	17.3	14.2	13.0(27.5)
35					19.5	16.4	16.0	18.7	15.4	(32.5)11.6
40	21.3	21.0	20.6	20.5	20.2	17.5	17.1	20.2	16.5	15.9(37.5)
45					21.5	19.5	19.4	20.9	18.3	(42.5)17.3
50	23.7	23.0	22.5	22.2	22.0	21.0	20.6	22.6	20.0	18.7(47.5)
55					21.5	20.6	20.4	24.0	21.3	(52.5)20.6
60	22.1	22.5	22.5	22.5	22.5	22.1	22.1	25.3	22.9	21.5(57.5)
65					23.2	23.3	23.5	27.9	24.3	
70	22.7	23.3	23.6	23.7	24.0	24.5	24.2			
75					25.1	26.1	26.2			
80	23.4	24.4	25.0	25.9	26.1	27.9	27.9			
85					26.3	29.5	30.0			
90	23.9	25.7	26.5	26.9	27.6	32.2	31.8			
95					29.7	33.3	34.4			
100	23.5	26.8	28.1	29.5	30.6	36.0	36.7			

Note ;

Table A-2-3 Calculated geothermal gradients

Hole No.	Case 1		Case 2	
	Geothermal gradient ($\times 10^{-3}$ °C/cm)	Range of calculation (m)	Geothermal gradient ($\times 10^{-3}$ °C/cm)	Range of calculation (m)
1	5.3	5–100	5.3	5–100
2	11.9	74–100	7.3	5–100
3	1.8	80–100	2.7	5–100
4	–	–	–	–
5	4.2	70–100	2.6	5–100
6	1.6	55–95	2.8	5–95
7	0.2	55–100	0.1	5–100
9	6.9	90–120	8.1	5–120
10	0.3	70–100	0.3	5–100
11	1.4	65–100	0.8	5–100
12	0.9	45–100	0.7	5–100
14	4.3	70–100	3.2	5–100
Average	3.53		3.08	

and the other pair of electrodes to measure the potential difference associated with the current. Both sets of electrodes are laid out along a line and the current electrodes are placed on the outside of the potential electrodes, symmetrically around the central point which is often designated as the station. (See Fig. A-3-1)



I : current
V : potential difference
A, B : current electrode
M, N : potential electrode
O : station

Fig. A−3−1 Schlumberger electrode array

In an isotropic homogeneous medium, the resistivity ρ is given as

$$\rho = 2\pi\frac{V}{I}\left(\frac{1}{\overline{AM}}-\frac{1}{\overline{BM}}-\frac{1}{\overline{AN}}+\frac{1}{\overline{BN}}\right)$$

$$=\frac{\pi}{4}\cdot\frac{\overline{AB}^2-\overline{MN}^2}{\overline{MN}}\cdot\frac{V}{I}$$

where: I : a current introduced between two electrodes A and B,

V : a potential difference between two electrodes M and N

$\overline{AM}$, $\overline{BM}$, $\overline{AN}$, $\overline{AB}$, $\overline{MN}$: the distances of corresponding electrodes.

If the subsurface consists of layers separated by the horizontal interfaces and if the separations of electrodes are increased in a systematic manner, the change in the resistivity as defined in the equation makes it possible to determine the variation of resistivity with depth. The value of resistivity obtained from the equation is now designated as the apparent resistivity ρ_a.

The apparent resistivity is plotted versus the electrode separation on a logarithmic scale, and the resulting curves are called as the Vertical Electric Sounding curves. By analysing these curves, a vertical distribution of the resistivity in the subsurface can be determined.

A.3.2 Method of Electrical Prospecting

In the field, the distance of potential electrodes is fixed and the distance of current electrodes is increased, the latter being five times bigger than the former ($\overline{AB} \geq 5\overline{MN}$).When the current electrodes spacing becomes some 30 times bigger than that of potential electrodes, the potential difference becomes smaller and a measurement error becomes larger. Then, the distance of potential electrodes is expanded and the measurements are repeatedly made within a range where the relation of spacing $\overline{AB} \geq 5\overline{MN}$ is maintained to the maximum separation of current electrodes. The combinations of electrode spacings is shown in Table A-3-1.

Table A-3-1 Schlumberger electrode spacing

	AB/2 (m)	MN/2 (m)		AB/2 (m)	MN/2 (m)
1	10	4	15	250	20
2	15	4	16	300	20
3	20	4	17	400	20
4	30	4	18	400	100
5	40	4	19	500	20
6	50	4	20	500	100
7	60	4	21	600	100
8	80	4	22	750	100
9	80	20	23	1000	100
10	100	4	24	1250	100
11	100	20	25	1500	100
12	130	20	26	1750	100
13	160	20	27	2000	100
14	200	20			100

To minimize an effect of polarization potential induced by the introduction of direct current, the multi pulse of transmitted current was selected, as shown in Fig. A-3-2. The on-time and off-time of current are set at four seconds under the measurements up to 600 m of the spacing of current electrodes and at eight seconds under the measurements from 800 to 4,000 m of spacing.

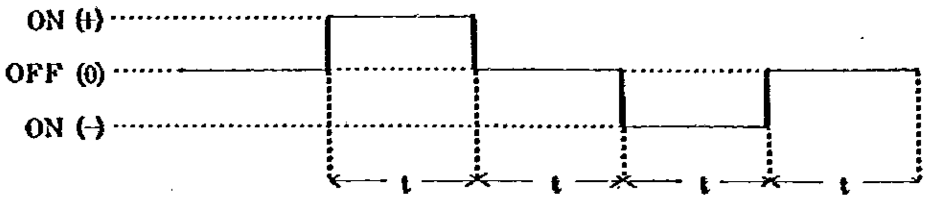


Fig. A-3-2 Current-wave of transmitter

The received voltages are continuously recorded, after a compensation of self-potential, by an analogue recorder of automatic balancing type.

Stainless stakes of 10 mm in diameter were used for the current electrodes and porous-pots with copper and solution of copper sulphate were used as the non-polarizing electrodes of receiver-side.

A.3.3 Instruments

Transmitter	:	Time Domain IP Transmitter, Model CH-8310A CHIBA ELECTRIC RESEARCH Ltd.
Receiver	:	Receiver Model EPR-200A TOA ELECTRONICS Ltd.
Generator	:	2.5KVA generator SCINTREX Co., Ltd.

A.3.4 Analysis of Electrical Prospecting

A flow chart of analyses is shown in Fig. A-3-3.

(1) Terrain correction

Generally, the value of apparent resistivity obtained in the field has an influence from topography.

In case of the Schlumberger array, an apparent resistivity decreases in a ridge and increases in a valley. A trial of terrain correction was applied over an area at the east of Line A, where topography was steep. There are several methods to correct the effect of topography such as calculation with a computer or experimental determination using a water tank. The electric conductive paper method was applied for this study and resulted in showing that an effect of topography remained within a range of several per cents at the most. Therefore, no correction was made on the data measured in the field.

(2) Apparent resistivity section

A general idea of apparent resistivity can be seen on a section. The relations between the spacing of current electrodes and apparent resistivity were plotted over all stations. The

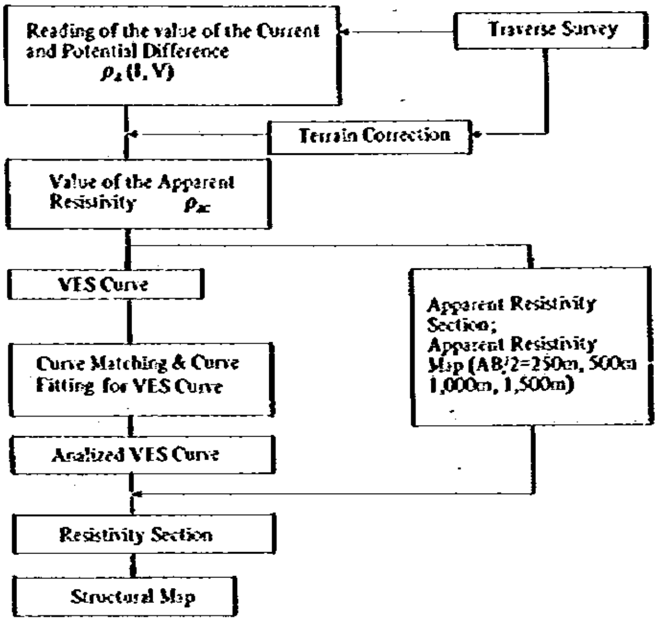


Fig. A-3-3 Flow chart for analyses of electrical prospecting

ordinate shows a half distance of the electrode spacing.

(3) Apparent resistivity map at the different depths

The measurements of apparent resistivity on the half distance of current electrode spacing plotted to give a general idea of areal distribution in depths.

(4) Vertical Electric Sounding curve

The curve on each station was plotted on a logarithmic scale. The abscissa is the logarithm of the half distance of current electrode spacing and the ordinate is the logarithm of the value of the apparent resistivity.

(5) Analyses

The obtained Vertical Electric Sounding curves are compared with the standard curves of Schlumberger's to set a primary model of multi-layered structure. The theoretical VES-curve of the primary model is calculated and compared with the actual curve. From the difference of two sets of curves, a primary model is corrected by the non-linear least squares method. These corrections are repeated until an approximation of the theoretical curve on a corrected model with the curve obtained in the field. The optimum model is automatically calculated by a computer, and is compared and adjusted to be in concordance with the models of neighboring stations or models of intersecting lines. The correction and adjustment are made with a computer in a way of try-and-error.

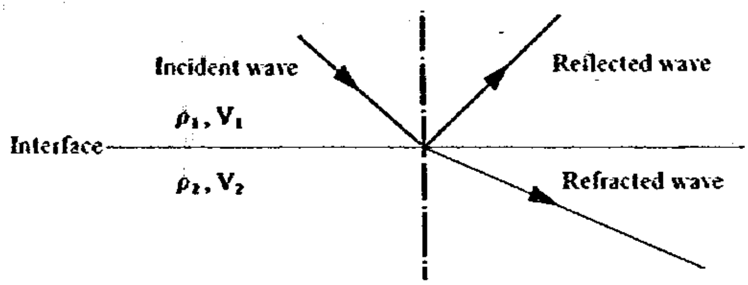
The results are shown in Fig. A-3-4.

A.4 Seismic Prospecting

A.4.1 Outline of Reflection Method

An elastic wave generated at shallow depth propagates into the ground and when a seismic wave strikes an interface between the two elastic media of different elastic properties, part of energy is reflected at the interface and the balance of energy is refracted into the second medium. With the reflection method, the structure of subsurface formations is mapped by measuring the times required for a wave to return to the surface.

The relative amplitude of the reflected and incident waves is designated as the reflection coefficient R and expressed in the form.



$$R = \frac{\rho_2 V_2 - \rho_1 V_1}{\rho_2 V_2 + \rho_1 V_1}$$

Where the ρ_1 and ρ_2 are the densities and the V_1, V_2 are the wave velocities in the media. The more two velocities differ, the coefficient becomes bigger, indicating an increase of amplitude of reflected waves.

The seismic reflection method is one of the indispensable methods employed for exploration of oil and gas. In the field of geothermal investigation, the seismic reflection method is now being used to detect effectively the faults or crushed zones in the subsurface or to find out the depths of the basements, etc.

The principle of Mini-Sosie process was invented in France and the instrument used in this survey was developed by the Input/Output Inc. of the U.S.A. In case of Mini-Sosie, the seismic waves are generated by a tamping rammer, widely used in the world of civil engineering. Although energy created by tamping is small, stacking of several hundred to several thousand impulses improves the signal to noise ratio.

The Mini-Sosie method is widely employed in civil engineering, geothermal prospecting, and investigations of deposits of oil, gas, coal and sedimentary uranium in shallow depths of less than 1,000 m.

A-4.2 Seismic Field Tests

(1) Noise analysis

The wave-length of surface waves on this field was dominant of 5 to 15 m, having an apparent velocity of 150 to 330 m/sec, with a frequency of 22 to 33 Hz. To attenuate these surface waves, geophones are grouped with the patterns of 18 geophones spaced at 1.2 m intervals.

The array is illustrated in Fig. A-4-1.

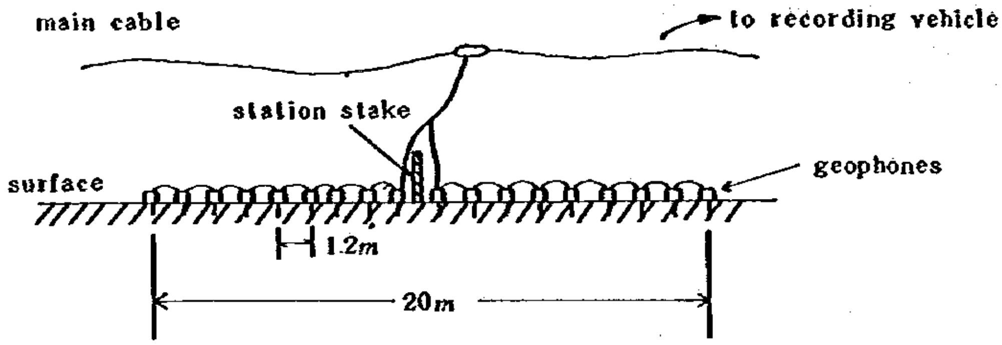


Fig. A-4-1 Geophone array

(2) Filters

To attenuate the noises differing from the signals of reflection in frequencies, the low-cut filter of 30 Hz and the high-cut filter of 250 Hz were used. Selections of filters are made on the front panel of the recording unit.

(3) Number of pops

Usually the number of pops is in a range of 1,000 to 3,000. The number of pops should be chosen to keep quality of the data and to avoid time loss of working due to an excess number of pops. After the field test, the number was set at 2,000 pops per record.

A.4.3 Seismic Field Procedures

i) A series of geophones of more than thirty is laid on a line as illustrated in Fig. A-4-2.

ii) At the station No. 1, stacking of 2,000 pops is made with two or three rammers and signals are received at the stations Nos. 4 to 50 in 24 channels and transmitted to the recording instrument of DHR-2,400 which was designed and built Input/Output Inc. and mounted on the vehicle. Signals are shifted and stacked, and then recorded automatically in magnetic tapes after the completion of 2,000 stacks (see Fig. A-4-2).

iii) Rammers are moved to the station No. 3, and receiving stations are transferred to Nos. 6 to 52. After the completion of 2,000 stacking, data are recorded in a magnetic tapes.

iv) Thus, the shooting point and receiving stations are moved every 20 meters.

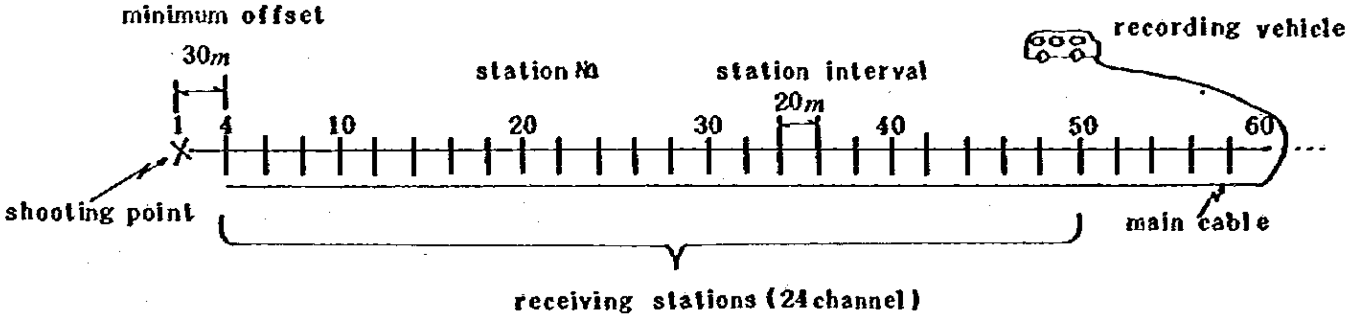


Fig. A-4-2 Schematic diagram of seismic prospecting

Geophones and a main cable of completed stations are transferred to the stations to be investigated.

v) This method is called the twelvefold common depth point method, and illustrated in Fig. A-4-3.

A.4.4 Instruments

Recording instrument	:	DHR-2,400. Input/Output Inc.
Camera	:	R-6B, S.I.E.
Geophone	:	L-21A of 27 Hz, 18/group, Mark Products Inc.
Rammer	:	MTR-80G, 85 kg x 2~3 pcs.
		MIKASA Industry Co., Ltd.

A.4.5 Seismic Data processing

The purpose of data processing is to convert the complex wave pattern recorded on magnetic tapes into record section that can be used to determine the underground structure.

A flow of processing is shown in Fig. A-4-4.

i) Gain recovery & Editing

The gain of channels is controlled and unwanted data are deleted.

ii) Sorting

The records are sorted and rearranged to groups of each common-depth-point. Where a line is crooked, reflecting points are scattered. Records on crooked line are converted and edited on the line which passes the center of scattering points of reflection. This editing was made at No. 620, Nos. 710 to 700 of Line A and at No. 170 of Line D.

iii) Static correction

In case that shooting and receiving stations are at various elevations, time variations in reflection, which are associated with such elevations at the surface, yield. Static correction for elevation is that such variations in reflection time are corrected by proper subtraction or addition of the time increment, chosing an arbitraily datum plane.

In this study, elevation of each point was corrected to the floating datum plane which surface irregularities were smoothed, and then converted to the fixed datum plane, using a velocity of 2,380 m/sec.

iv) Correction of normal moveout

In the Fig. A-4-5(i), the traveltime of reflected waves increases depending on a distance of path and a delay time is expressed with a horizontal distance between a shooting point and a receiving point. From this relation, a velocity can be calculated and using an adequate velocity, the normal moveout is corrected as illustrated in Fig. A-4-5(ii). Signals are summed to eliminate random noises and multiples to obtain reflection records with an acceptable ratio of signal to noise.

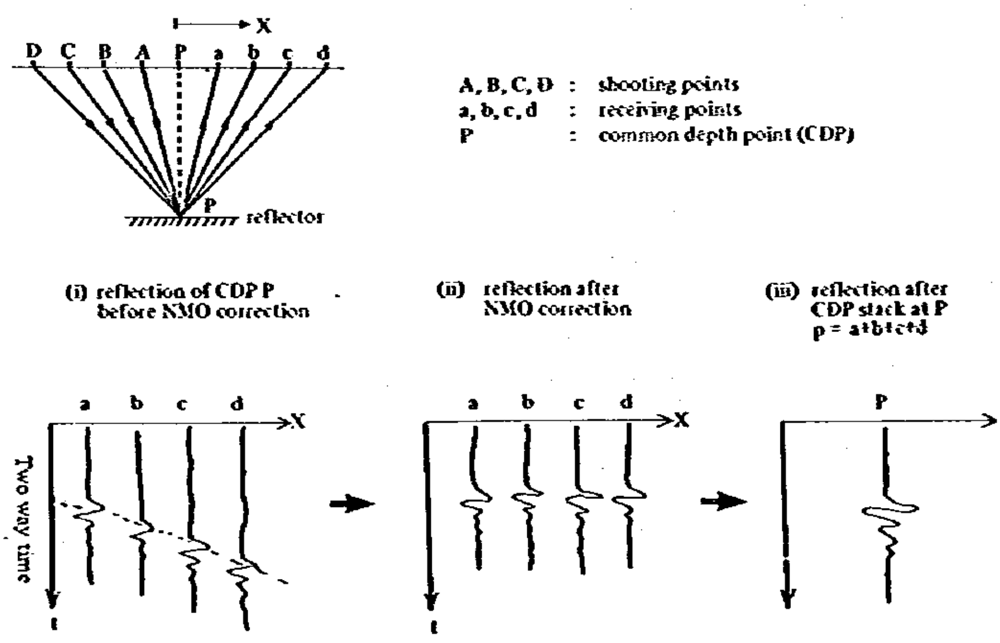


Fig. A-4-5 Schematic diagram for CDP stack (4-fold)

v) Migration

The processed data are plotted on record sections, of which the ordinates represent the time. Where the reflecting beds dip, the point from which each reflection originates is not located vertically below. An adjustment of this point closed to its true position in space is called migration.

Finally, adjusted information is presented on depth sections. The Fig. A-4-6 shows the relationship of two-way time to the depths.