CHAPTER 3 GEOCHEMICAL INVESTIGATION

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The geochemical investigation was conducted to determine the distribution of chloride (Cl^-) ions in soils and wadi sediments. The purpose of this investigation is to identify soil contamination caused by the deposition of fugitive dust (dust fall) from the smelter and salt leakage from the tailings dam.

3.1 Soil (Dust fall) Investigation

3.1.1 Location of the Soil Sampling Points

The purpose of the soil investigation is to identify soil contamination caused by the deposition of dust from the copper smelter and other sources. . Soils in the Study area are distributed on terrace surfaces, alluvial terrace plains, alluvial beds and weathered basement rocks. However, suitable places for the soil sampling, where stable soil exists with enough amounts to be sampled, are limited to the terrace plains only. Hence, the terrace plains were selected as soil sampling points. And these points are selected at random in zones of 500 m, 1 km, 2 km, and 3 km distance from the smelter.

A total of 31 soil samples were collected for the geochemical investigation. The locations of the sampling points are shown in Figure 3.1.

3.1.2 Soil Sampling and Pretreatment

At the time of soil sampling, the gravel on the land surface was removed. The soil samples were taken from 0 to 5 cm in depth. However, topsoil (alluvial soil) in the area is developed very weakly in general.

As a pretreatment for soil chemical analysis, samples were screened by a 50-mesh sieve after natural drying. The under-size materials (- 50 mesh) were used for analysis. Analytical parameters were, as follows:

: Hg, Cd, Cr, As, Pb, Cu, Mn, Fe, Ni, Sn, Zn, SO_4, and Cl（13）

3.1.3 Analytical Result

Analytical test results for the soil samples collected for the geochemical investigation are shown in Table 3.1. The concentration distribution for each component is shown in Figure 3.2 (1) to (3) and refers to Appendix -1.

Mercury (Hg) concentrations fluctuate within a small range from 0.04 to 0.2 mg/kg. Peaks of 0.2 mg/kg can be seen in the 1 km to 2 km zone on the southeast and 2km north. However, low-leveled distribution of mercury is found in an east-northeast to west-southwest direction.

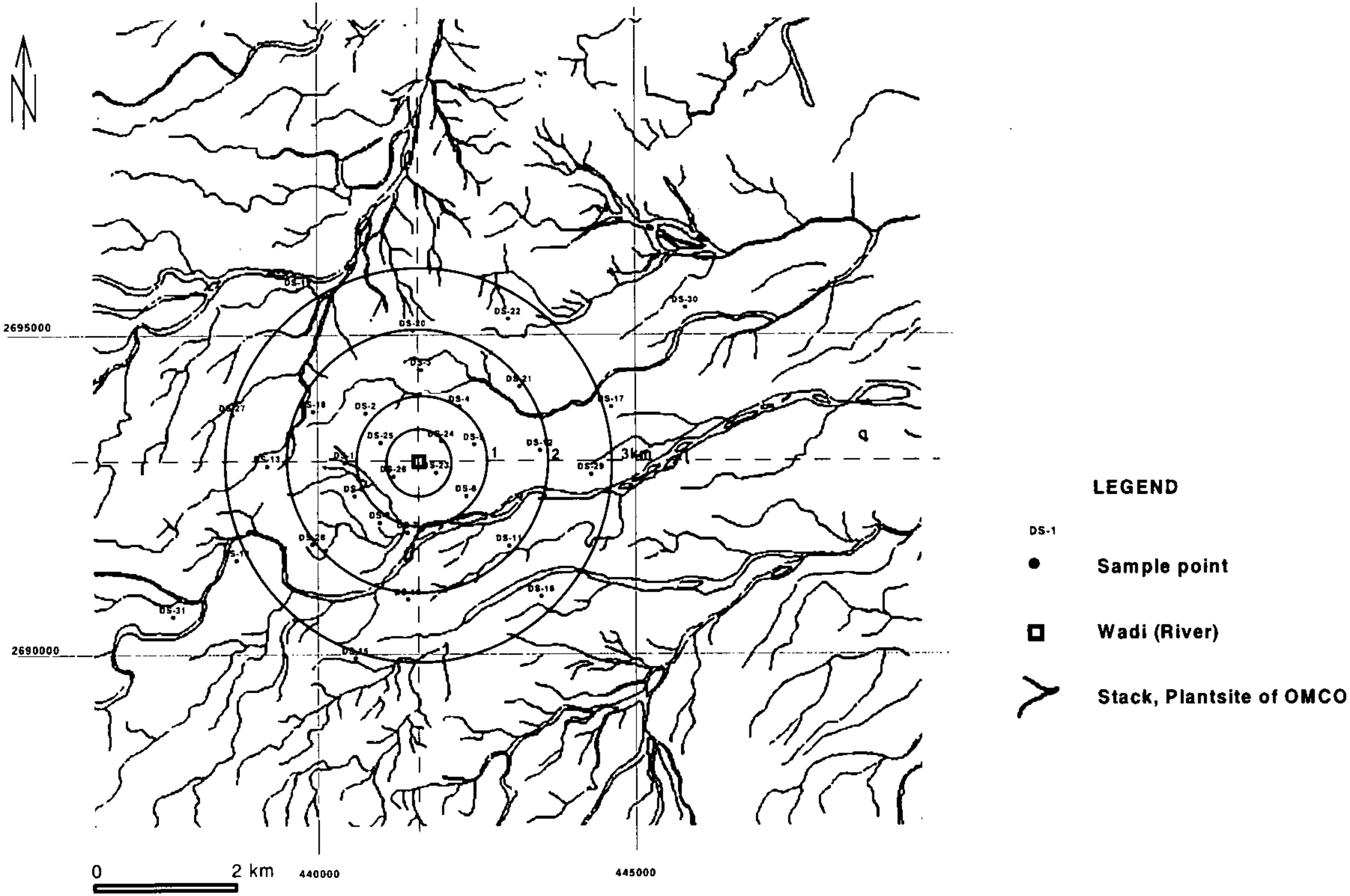


Figure 3.1 Sample Points of Soil for Geochemical Investigation

Table 3.1 Analysis Result of Soil Geochemical Investigation

Sample Number	Coordinates		Hg	Cd	Cr	As	Pb	Cu	Mn	Fe	Ni	Sn	Zn	SO_4	Cl
	Northing	Easting	mg/kg												
DS-1	2688025	440475	0.10	4	350	14	285	14,750	9,350	39,900	16,250	350	750	2,100	490
DS-2	2688775	440800	0.05	4	455	9	10	1,170	10,800	43,700	17,750	350	150	900	360
DS-3	2689430	441650	0.15	4	320	16	10	865	8,350	26,000	14,000	400	110	3,900	580
DS-4	2688880	442230	0.10	4	150	6	200	940	11,300	50,000	3,900	500	125	2,000	340
DS-5	2688300	442450	0.10	9	90	9	65	2,675	10,100	45,400	950	200	220	600	190
DS-6	2687525	442330	0.15	9	410	12	45	750	9,300	35,100	18,100	250	220	900	250
DS-7	2686975	441430	0.15	8	430	13	35	645	9,400	23,000	20,800	250	85	160	210
DS-8	2687125	441010	0.15	8	430	9	40	255	9,650	39,300	19,950	300	10	630	180
DS-9	2687525	440625	0.05	14	500	11	320	6,050	9,850	26,400	1,400	100	235	950	200
DS-10	2685975	441435	0.20	14	280	9	25	510	9,750	29,200	630	100	270	460	140
DS-11	2686780	442985	0.20	13	375	10	255	550	9,650	25,000	16,700	100	45	610	190
DS-12	2688210	443460	0.15	14	245	7	20	760	7,300	25,100	9,550	100	30	850	170
DS-13	2687975	439300	0.05	14	300	6	485	900	8,500	21,800	10,000	200	35	930	130
DS-14	2686560	438830	0.15	13	380	9	20	330	8,900	25,600	16,050	100	20	800	140
DS-15	2685100	440635	0.15	18	270	11	295	255	7,850	19,700	13,600	200	55	680	150
DS-16	2686020	443475	0.05	19	245	7	10	435	8,700	31,500	8,150	200	225	510	170
DS-17	2688870	444550	0.05	19	300	9	185	485	9,200	31,200	10,150	200	40	500	190
DS-18	2688800	440000	0.05	14	510	15	30	1,320	9,500	31,300	16,850	250	100	690	180
DS-19	2690650	439780	0.20	19	560	14	305	425	11,750	42,500	24,650	600	20	140	170
DS-20	2690025	441525	0.20	19	160	15	735	340	9,300	41,800	2,900	300	65	120	220
DS-21	2689180	443150	0.10	24	115	11	45	865	13,900	38,700	1,600	400	70	420	150
DS-22	2690200	442980	0.15	19	270	12	655	1,180	7,600	24,200	13,000	100	60	1,530	170
DS-23	2687875	441870	0.10	23	135	12	65	9,550	7,500	69,400	1,550	100	660	1,160	120
DS-24	2688350	441950	0.15	24	145	13	50	4,700	12,450	48,300	1,750	150	155	880	180
DS-25	2688325	441025	0.05	23	155	10	495	4,150	10,850	43,700	1,400	150	550	1,150	140
DS-26	2687820	441220	0.15	23	115	11	455	5,575	11,350	65,200	200	150	500	2,140	100
DS-27	2688750	438775	0.05	23	375	14	60	880	8,000	23,100	18,750	150	25	1,110	150
DS-28	2686800	439980	0.10	24	330	11	270	750	8,900	27,500	10,550	300	35	950	110
DS-29	2687850	444240	0.05	23	340	16	5	510	8,600	22,900	12,900	300	45	920	120
DS-30	2690370	455685	0.04	<0.01	70	4	75	671	537	25,533	733	90	93	544	184
DS-31	2685720	437870	0.05	<0.01	70	4	80	194	551	29,645	1,085	60	66	427	150

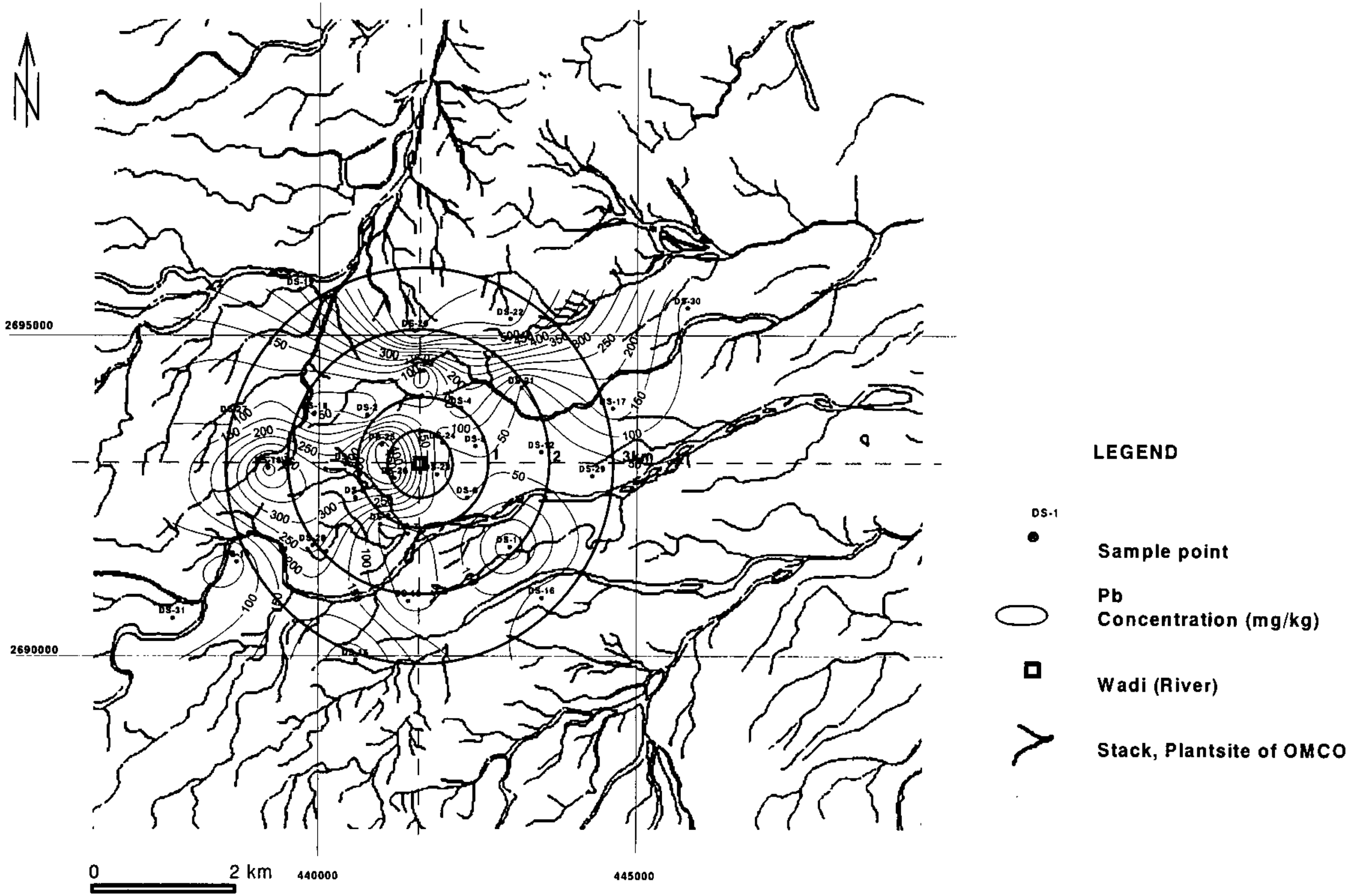


Figure 3.2 Concentration Contour map of soil (1)

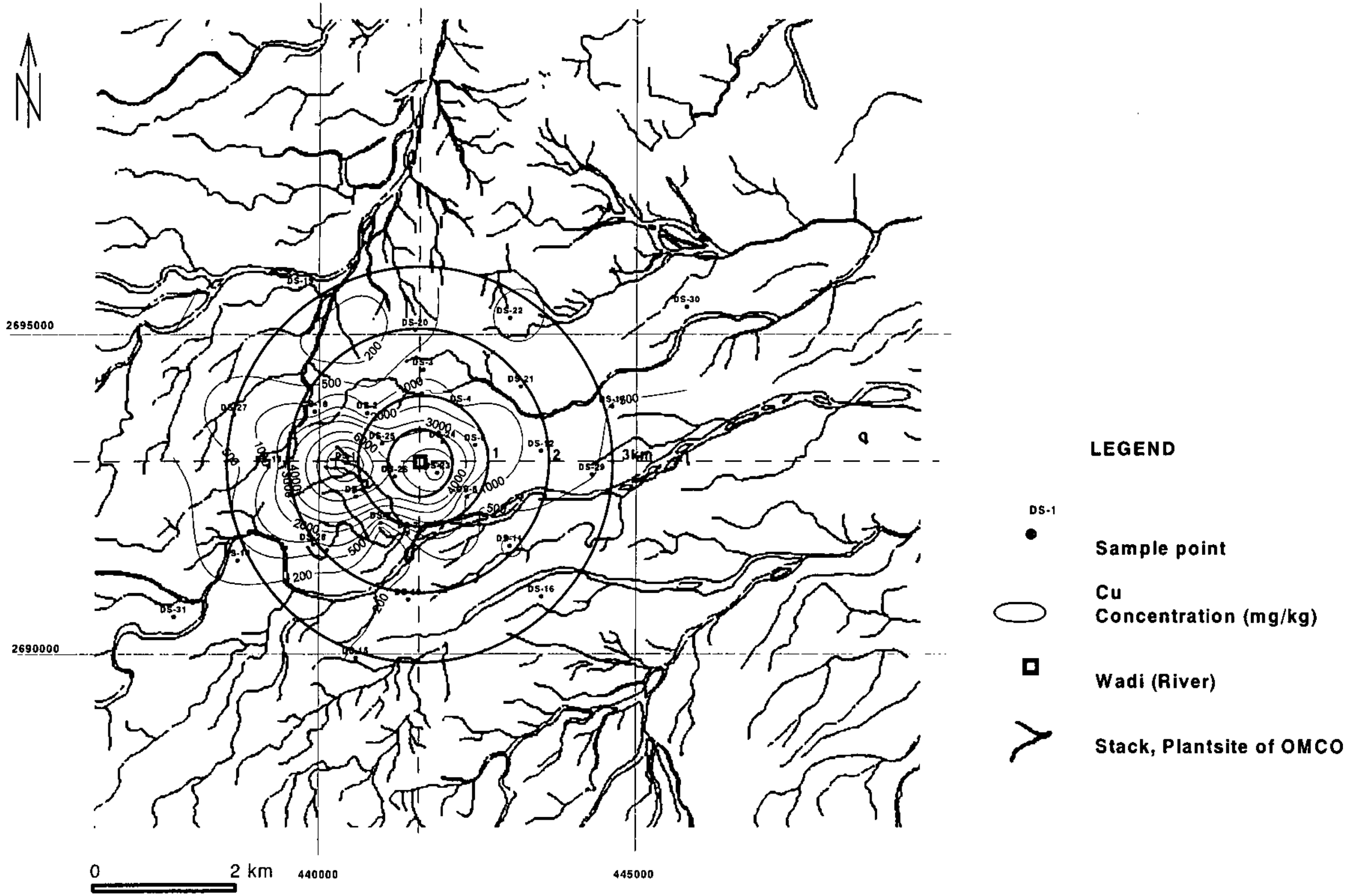


Figure 3.2 Concentration Contour map of soil (2)

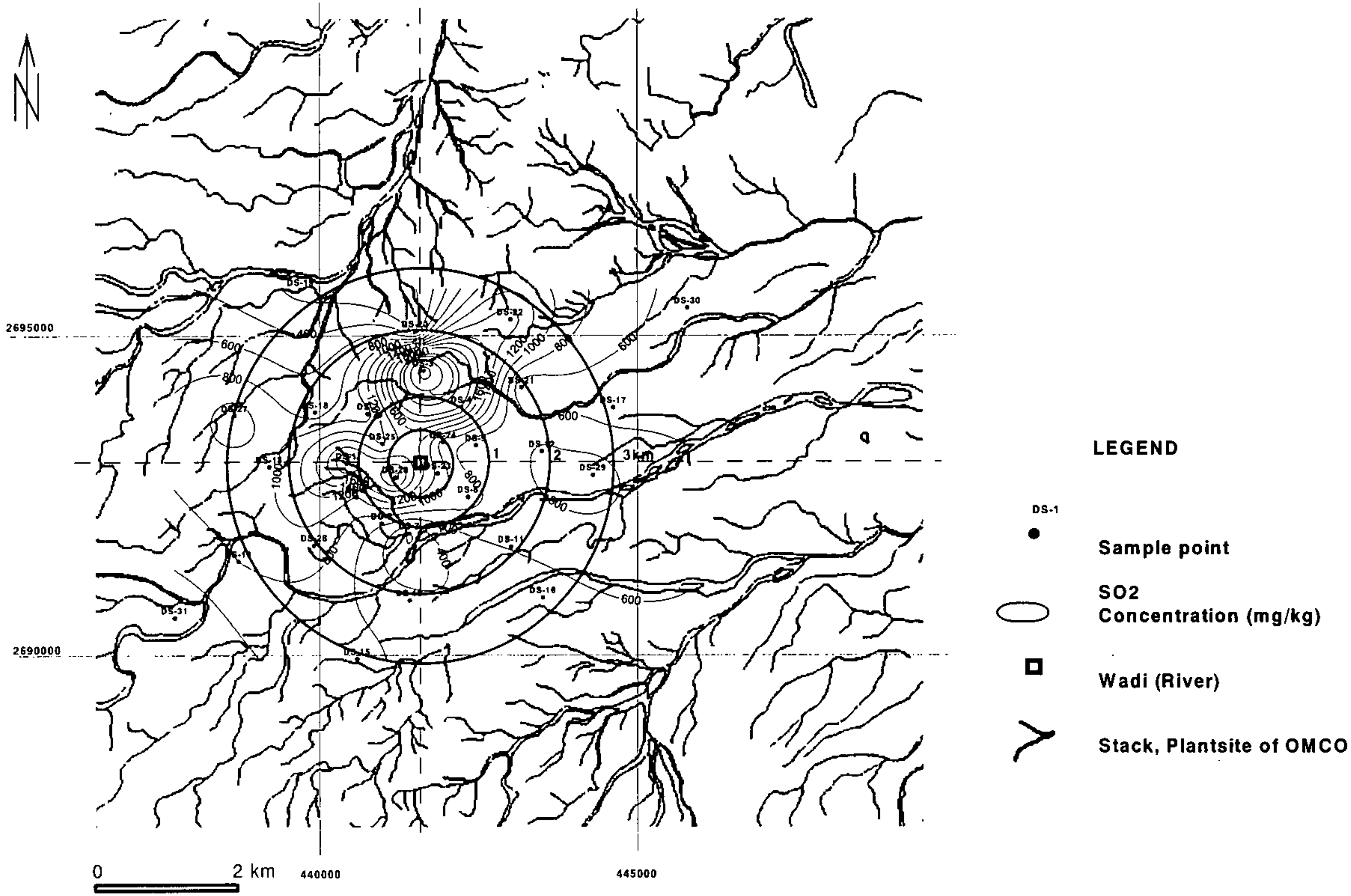


Figure 3.2 Concentration Contour map of soil (3)

Cadmium (Cd) concentrations vary in a range from <0.01 to 24 mg/kg with a uniform tendency in direction. Relatively high concentrations are distributed near the border of the smelter plant site and at points 2 km or more from the smelter.

Chromium (Cr) concentrations fluctuate in a range from 70 to 560 mg/kg. A significant peak can be seen in the 1 km zone toward the south to southwest, and a low concentration plume extends more than 3km. It is possible that higher concentrations may exist in zones further than 3 km.

Arsenic (As) concentrations ranging from 4 to 16 mg/kg with some higher concentrations exist in the zone from 0.5 to 1.5 km from the smelter. In addition, a peak in arsenic concentrations was identified at a distance of 1.5 km toward north. This peak seems to be influenced by the tailing dam.

Lead (Pb) concentrations are distributed in a wide range from 5 to 735 mg/kg. Higher concentration zones can be seen in two places, i.e. from 0.5 to 2.3 km west from the plantsite and further than 1.5 km to the north. The tailing dam probably affects the northern side of the terrace.

Copper (Cu) concentrations are widely and uniformly distributed geographically and in a wide range of concentrations, i.e. from 194 to 14,750 mg/kg. However, on the west side of the smelter, peaks of higher concentration are found.

Manganese (Mn) concentrations are distributed in a very wide range from 537 to 13,900 mg/kg, including the background soil samples. Manganese concentrations are distributed rather uniformly as a whole. However, a peak exists 2 km toward east-northeast.

Iron (Fe) concentrations are also distributed in a very high range from 19,700 to 69,400 mg/kg dispersing in all directions with the peak values extending toward the northeast.

Nickel (Ni) concentrations are distributed in concentrations ranging from 200 to 24,650 mg/kg, with the higher concentration zones extending toward the east-southeast to west-southwest.

Tin (Sn) concentrations uniformly range from 60 to 600 mg/kg.

Zinc (Zn) concentrations range from 10 to 750 mg/kg and are dispersed in all directions. The highest zinc concentrations extend in along an east/west axis.

Sulfate (SO_4) concentrations range from 120 to 3,900 mg/kg, with the higher concentration zones distributed in the northern and central parts of the area. In the central part of the area, significant sulfate concentrations extend in a direction from east to west. High sulfate concentrations in the northern area appear to be attributable to the tailing dam.

Chloride (Cl) concentrations are rather low, i.e.100 to 580 mg/kg. However, chloride concentrations around the tailing dam tend to be higher.

By chemical analysis of topsoil samples obtained from the terraces, high heavy metal content, such as Cd, Pb, Cu, Fe, Zn and SO_4, appear to be the result of fugitive dust emissions from the smelter stack. All of these metals appear to be dispersed a central point at the plantsite. Some of these metals are presumed to be dispersing beyond 3 km. Anomalies in the concentrations of Pb, Fe, Ni, SO_4 and Cl can be found around the tailing dam. These anomalies are apparently caused by wind transport out of the tailing dam.

3.2 Salt Concentration in the Soil

Samples of wadi sediments and alluvial soil along the wadis around the tailing dam were collected and analyzed to identify leakage of salt from the tailing dam.

3.2.1 Location of Soil Sampling Points

In order to identify leakage of salt from the tailing dam, sampling points were limited to the wadi. All small and large-scale valleys around the tailing dam were selected as sampling points. The sampling points selected in Wadi Suq extended especially far downstream in order to determine the extent of contaminant dispersion compared with background levels. Background levels were determined by sampling soils in the upper reaches of Wadi Bani Umar al Gharbi.

In collecting samples of wadi sediments, fine-grained soils were selected preferentially. A total of 102 soil samples were collected for analysis of their salt concentrations (Figure 3.3).

3.2.2 Soil Sampling and Pretreatment

Gravel on the land surface was removed prior to collecting the soil samples. Soil samples were dug from 0 to 10 cm in depth. As a pretreatment for soil chemical analysis, samples were screened using a 50-mesh sieve after natural drying. Only the under-sized materials (- 50 mesh) were submitted for laboratory analysis. Chloride (Cl) was the only analytical parameter measured for these samples.

3.2.3 Analysis Results

Analysis results of the soil for Cl are shown in Table 3.2, and the distribution of chloride concentration is shown in Figure 3.4 (1) to (2). Figure 3.4 (2) shows an enlarged detail of the results.

Chloride concentrations fluctuate in an extremely wide range, from 106 to 146,500 mg/kg. Background concentrations in the Study area range from 106 to 180 mg/kg. These background concentrations appear

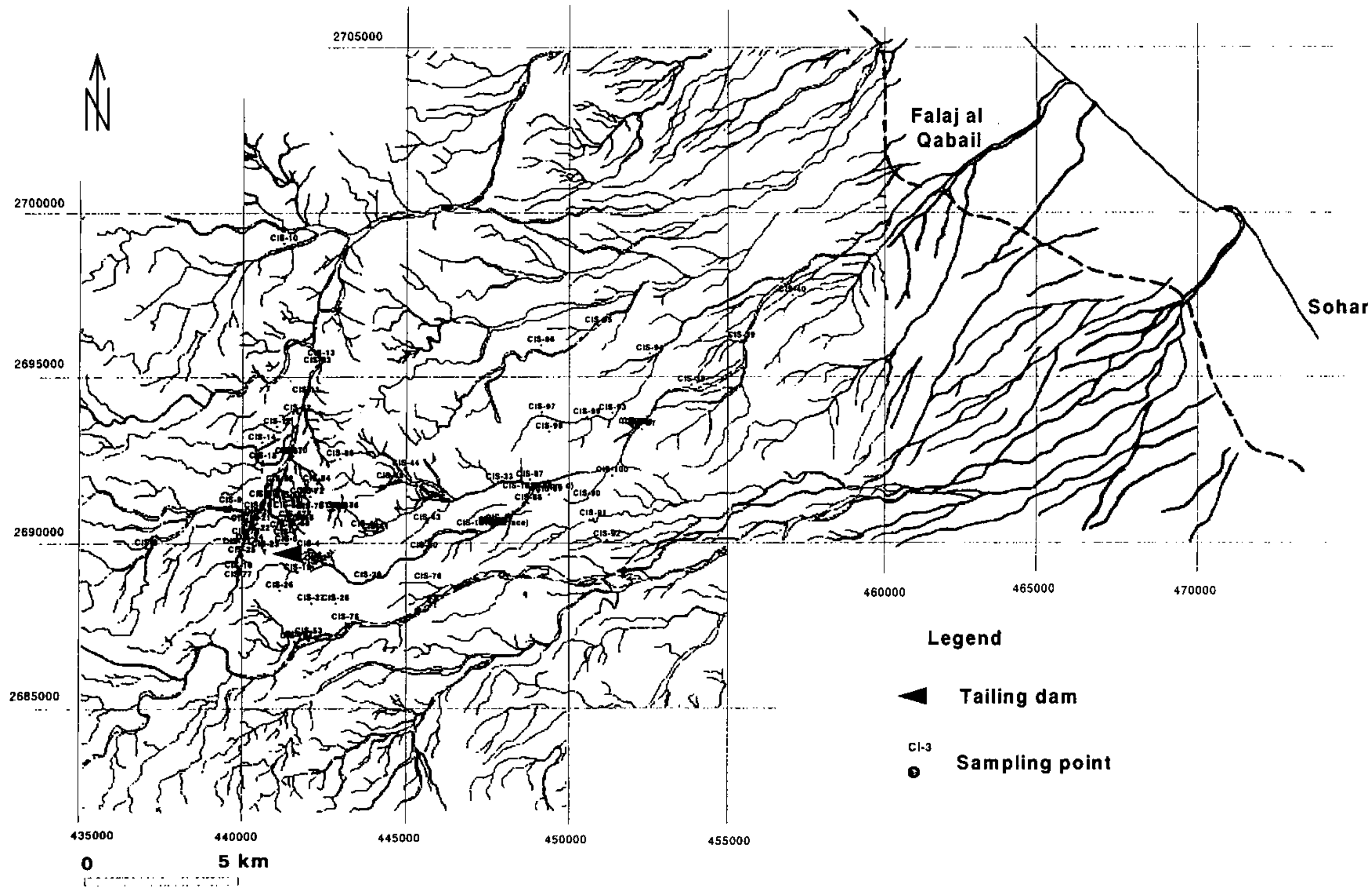


Figure 3.3 Sample Points of Soil for Cl Investigation

Table 3.2 Analysis Result of Cl Soil Investigation

Sample N0.	Coordinates		Cl	Sample No.	Coordinates		Cl
	Northing	Easting	mg/kg		Northing	Easting	mg/kg
ClS-1	2689200	442075	200	ClS-52	2687055	441660	220
ClS-2	2689300	442170	390	ClS-53	2687150	441960	250
ClS-3	2689375	442275	280	ClS-54	2690427	447520	410
ClS-4	2689730	441950	210	ClS-55	2690408	447526	8,450
ClS-5	2689875	441280	250	ClS-56	2690387	447542	55,500
ClS-6	2690075	441250	130	ClS-57	2690367	447536	143,000
ClS-7	2690290	441130	120	ClS-58	2690347	447540	61,300
ClS-8	2689770	437080	140	ClS-59	2690357	447520	5,850
ClS-9	2691030	439600	180	ClS-60	2690357	447520	25,000
ClS-10	2698870	441200	160	ClS-61	2690357	447520	25,000
ClS-11	2694315	441875	330	ClS-62	2691650	441080	187
ClS-12	2693370	441000	140	ClS-63	2691215	440825	157
ClS-13	2695425	442325	130	ClS-64	2691175	441350	167
ClS-14	2692890	440550	200	ClS-65	2690500	441700	138
ClS-15	2692340	440570	300	ClS-66	2690325	441575	148
ClS-16	2690485	440030	240	ClS-67	2690600	441470	587
ClS-17	2689800	439800	170	ClS-68	2690490	441425	167
ClS-18	2689090	439850	190	ClS-69	2691030	441290	167
ClS-19	2689025	441620	20,120	ClS-70	2692490	441500	3,415
ClS-20	2690675	440430	6,260	ClS-71	2691280	441810	502
ClS-21	2690500	440400	280	ClS-72	2691290	442000	207
ClS-22	2690200	440380	170	ClS-73	2690840	441990	443
ClS-23	2689725	440650	170	ClS-74	2687000	441510	246
ClS-24	2689920	440180	190	ClS-75	2687555	443070	266
ClS-25	2689550	439950	210	ClS-76	2688750	445575	344
ClS-26	2688500	441080	280	ClS-77	2688825	439840	197
ClS-27	2688125	442030	240	ClS-78	2690100	440070	266
ClS-28	2688120	442770	330	ClS-79	2690870	440425	3,415
ClS-29	2688800	443750	190	ClS-80	2691200	440585	6,653
ClS-30	2689675	445450	300	ClS-81	2692475	441360	276
ClS-31	2690330	447540	2,660	ClS-82	2693780	441605	404
ClS-32	2691425	448925	200	ClS-83	2695200	442205	394
ClS-33	2691700	447750	190	ClS-84	2691660	442200	650
ClS-34	2693350	451775	150	ClS-85	2690875	441305	266
ClS-35	2693350	451875	180	ClS-86	2692400	442905	157
ClS-36	2693325	451980	200	ClS-87	2691780	448675	472
ClS-37	2693285	452075	150	ClS-88	2691080	448630	325
ClS-38	2694630	453575	190	ClS-89	2691340	449250	266
ClS-39	2695950	455090	280	ClS-90	2691200	450410	246
ClS-40	2697320	456630	280	ClS-91	2690620	450600	285
ClS-41	2690225	443970	200	ClS-92	2690000	451020	207
ClS-42	2690310	443650	260	ClS-93	2693770	451180	106
ClS-43	2690500	445540	290	ClS-94	2695565	452310	177
ClS-44	2692100	444900	150	ClS-95	2696410	450750	142
ClS-45	2691730	444415	190	ClS-96	2695820	449000	248
ClS-46	2690855	443050	180	ClS-97	2693800	449030	248
ClS-47	2690860	442890	190	ClS-98	2693210	449250	780
ClS-48	2690870	442675	200	ClS-99	2693650	450400	248
ClS-49	2690487	447740	3,190	ClS-100	2691900	451175	355
ClS-50	2690430	447660	1,150	ClS-101 (surface)	2690330	447540	146,500
ClS-51	2690390	447580	47,000	ClS-102 (20cm d)	2691425	448925	14,050

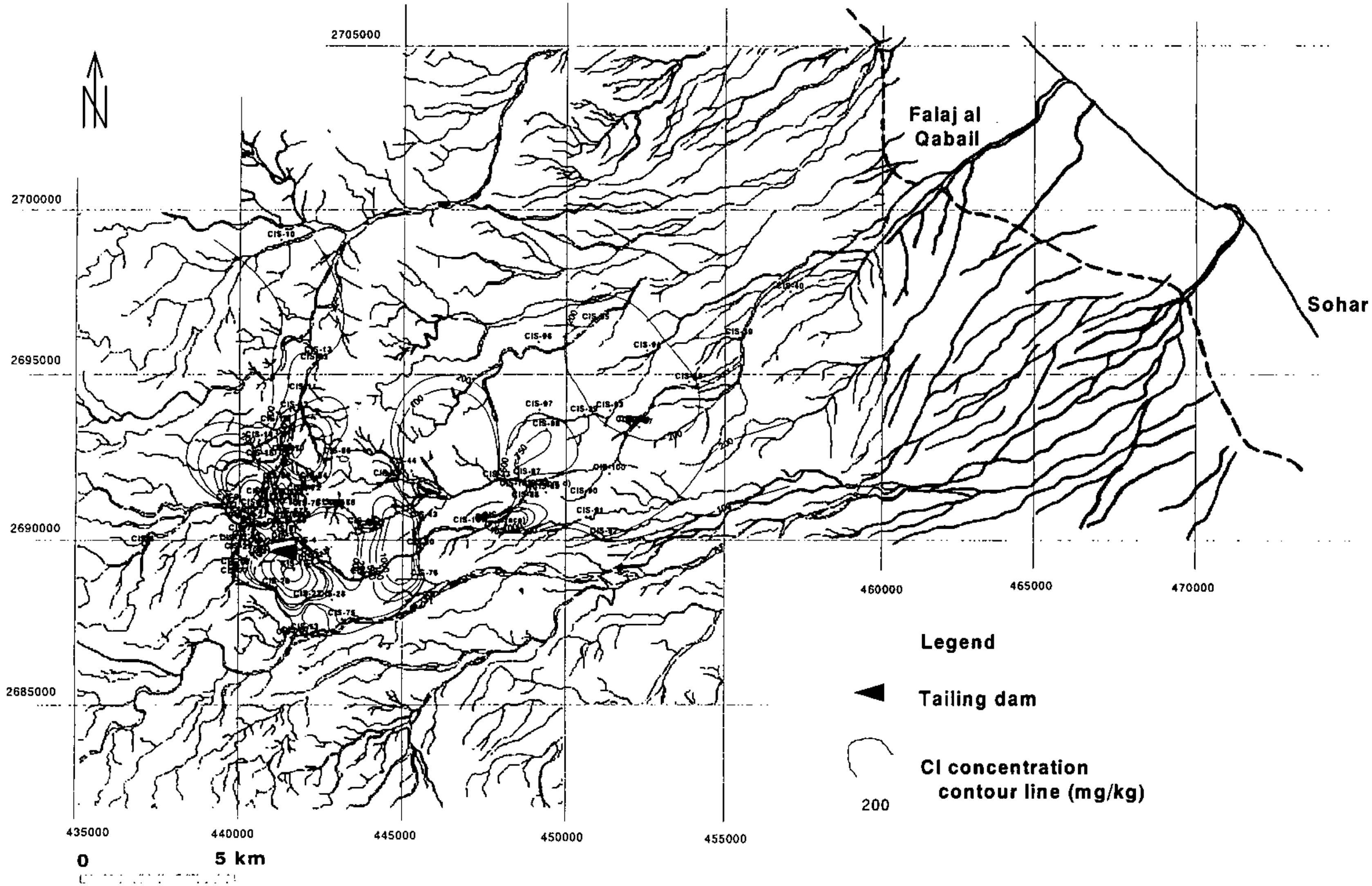


Figure 3.4 Concentration Contour Map of Cl in the Soil (1)

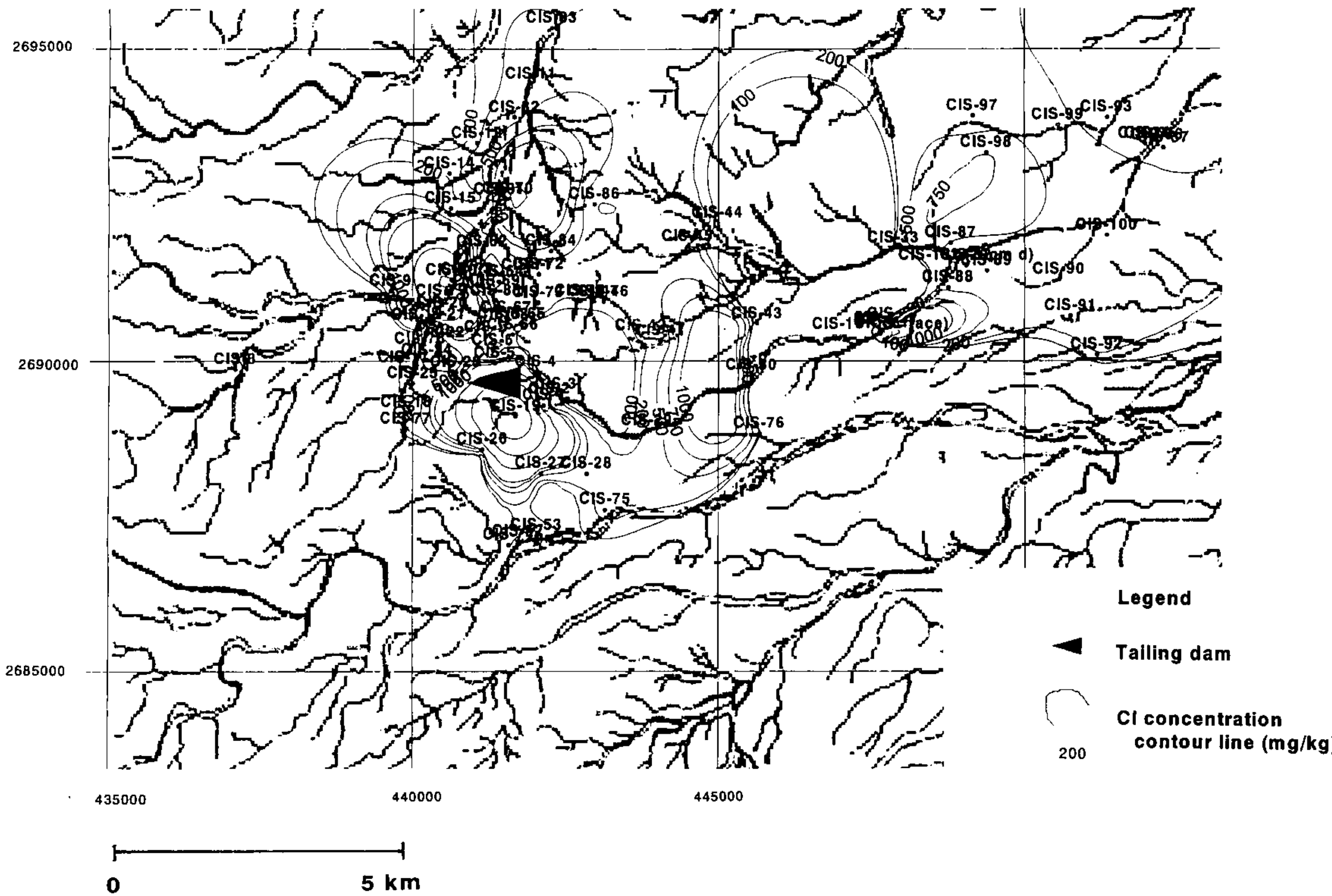


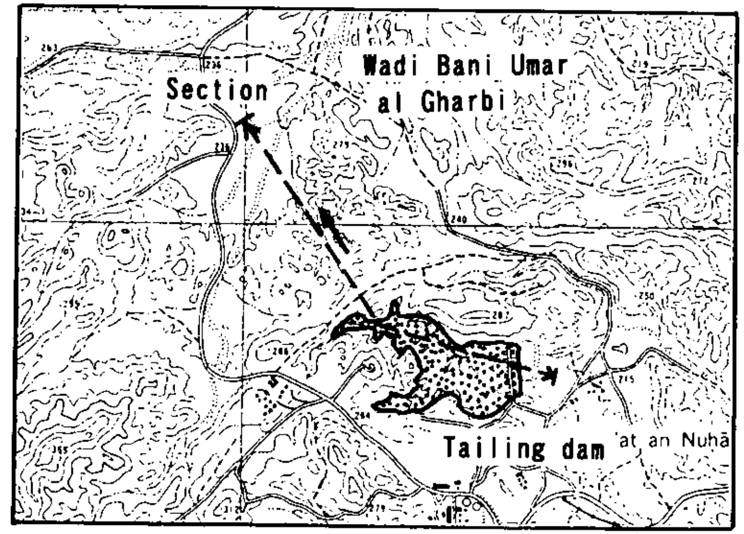
Figure 3.4　Concentration Contour Map of Cl in the Soil (2)

consistent with results of chloride concentrations from the soil dust fall investigation. Zones where the concentrations exceed 5,000 mg/kg are limited to areas downstream of the tailing dam and upstream of the KM14 point (Sagha village) i.e. OMCO PS-2 point, and upstream of Wadi Bani Umar al Gharbi.

Seepage from the tailing dam permeates downstream. Hence, chloride concentrations become higher immediately downstream of the tailing dam. OMCO's seawater pumping station PS-2 is located just upstream of KM14 (Sagha Village). It has been reported that seawater leaked from the pump station during its operation.

Aarja village is located on the northwest side of the tailing dam in the upper reaches of Wadi Bani Umar al Gharbi at the altitude of sampling point (ClS-20) at 230 m in elevation. Chloride concentrations in this area seem to be affecting groundwater around Bayda village. It is strongly suggested that the seepage out of the tailing dam migrates into the ClS-20 point through fractures in and along the faults that may strike toward the tailing dam and the ClS-20 point. It is possible based on the difference in elevations that a spring fed by the tailings dam exists at this point, i.e. the elevation of the tailing dam is at approximately 233 m and the sampling point ClS-20 is at 230 m (Figure 3.5).

It was estimated that leakage of brine occurred at backside of the tailing dam mainly through points near drilling hole of DH-11 and the impact of this leakage has reached Bayda village. The relationship between distance from tailing dam to Aarja and Bayda villages along Wadi Bani Umar al Gharbi and salt concentration in soil is presented in Figure 3.6.



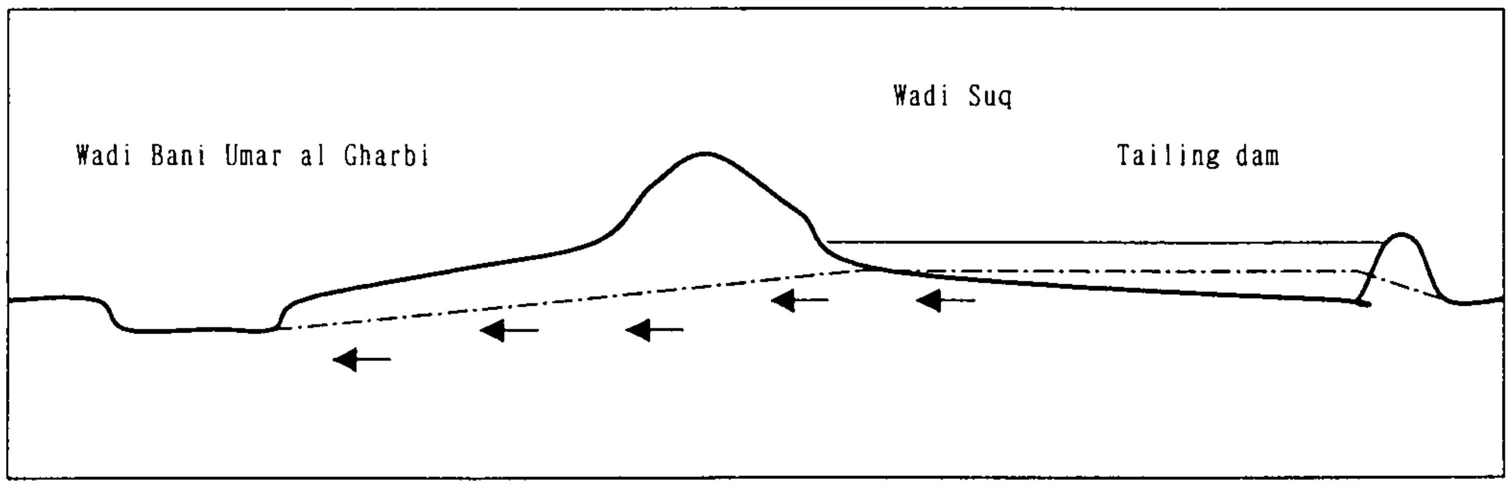


Figure 3.5 Relationship between Distance from Contaminant Source and Cl Concentration of the Soil

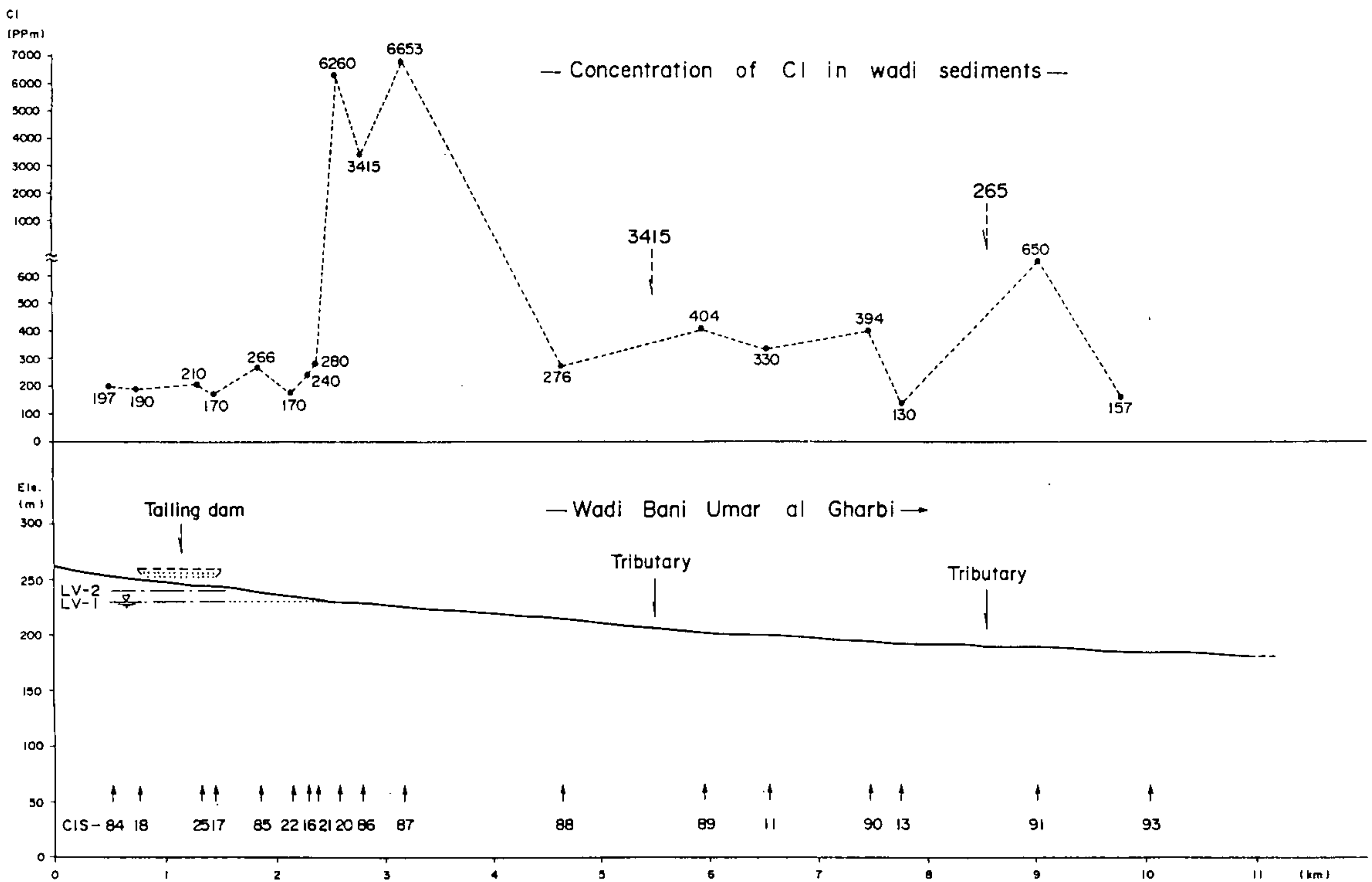


Figure 3.6 Leakage Route of Contaminated Groundwater

CHAPTER 4 GEOPHYSICAL SURVEY

CHAPTER 4 GEOPHYSICAL SURVEY

The purpose of the geophysical survey is to identify the underground structure of the basement, assess the current conditions of the basement rock, evaluate the distribution and characteristics of the loose sediments (mainly sediments in the wadi, waste, and so on), and investigate groundwater conditions and groundwater quality. In order to accomplish this purpose, Nano-Transient Electromagnetic Method (Nano-TEM) with micro-gravity methods are expected to be effective based on the topography of the site, geological situation, rock characteristics, sediment situation, underground water situation, and situation of the contamination. Moreover, result of the geophysical survey are supplemented by the results of the drilling investigation in which the geophysical characteristics (density, resistivity etc.) of the rocks, soils, and sediments were directly determined.

The content and quantity of Nano-TEM and micro-gravity survey methods and measurement of rock characteristics are shown in Table 4.1.

Table 4.1 Contents and Quantities of Geophysical Survey

Measurement Line No.	Length (m)	Gravity survey No.	Nano-TEM survey No.
L-1	1,000	51	51
L-2	1,000	51	51
L-3	300	32	26
L-4	300	23	16
L-5	200	19	11
L-6	1,500	114	76
L-7	3,200	255	161
L-8	2,000	126	99
L-9	300	31	-
L-10-11	500	62	-
L-12	200	21	-
L-13	160	17	160
Number of measurement points		802	651
Total length (m)		10,660	9,660
Physical measurement		Density (g/cm^3)	Resistivity
		52 pieces	47 pieces

4.1 Nano-TEM Survey Method

4.1.1 Measurement and Analysis

Ten Nano-TEM survey lines were programmed in the upper, middle and lower parts of Wadi Suq. The location of each survey line is shown in Figure 4.1. Measurement intervals for each survey line were set at 20 m, and the positioning of each measurement point was performed by simple surveying methods.

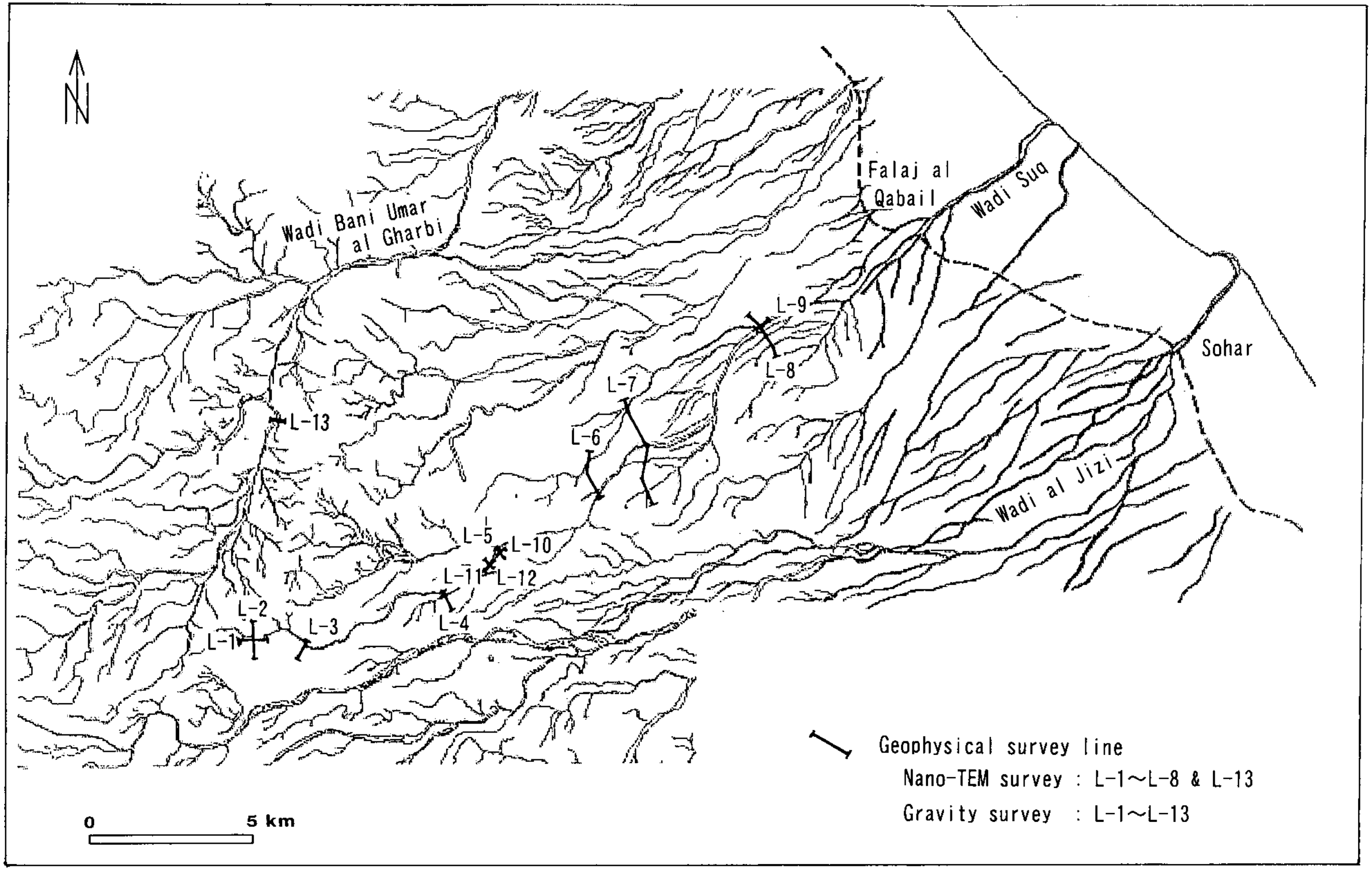


Figure 4.1 Location of Geophysical Survey Lines

The Nano-TEM instrument used for taking the site measurements consisted of a GDP-16/3ch receiver and transmitter manufactured by Zonge Co. The transmitting source consisted of a 20-meter square outer loop, while the receiving line consisted of a 5-meter square loop placed inside the transmitting loop. A stopping wave with a frequency of 32 Hz was used as the signal source. Three measurements were made at each measurement point in order to minimize influence of noise.

The GDP-16/3ch receiver was used to treat and analyze the measured data. The data from the multiple measurements were averaged, and then two-dimensional analysis was conducted using TEMIXX as the TEM analyzing software.

4.1.2 Analysis Result

Cross-sectional drawings illustrating the results of the Nano-TEM survey are shown in Figures 4.2 (1) to (4) and Appendix-2. In the cases of the measurement lines L-1 and L-2 passing through the tailing dam located in uppermost reach of Wadi Suq, the specific resistivity basement appears as an almost horizontal line about 30 m under the ground surface with a layer with low specific resitivity spreading horizontally over the basement.

Measurement line L-3 is located downstream of measurement lines L-1 and L-2. In this case, a low resistivity layer cannot be found, but a relatively low resistivity zone is distributed almost horizontally from approximately 10 m below the wadi ground surface to the deep part of a terrace. It can be inferred that there exists a basement with high resistivity under the low resistivity zone.

Under measurement lines L-4 and L-5 in the middle reach of Wadi Suq, high resistivity basements exist 50 to 100 m under the ground surface, relatively deep compared with the upstream lines. High resistivity basements under measurement lines of L-6, L-7 and L-85 located in the middle to lower reaches of Wadi Suq exist 50 to 100 m under ground surface at almost the same elevation as the basement in the middle reach of the wadi. Resistivity values associated with the high resistivity basement under the measurement line L-8 are lower by almost half compared with measurement lines L-6 and L-7. Similarly, resistivity values of the low resistivity zone are relatively low, having zone thickness of about 30 m.

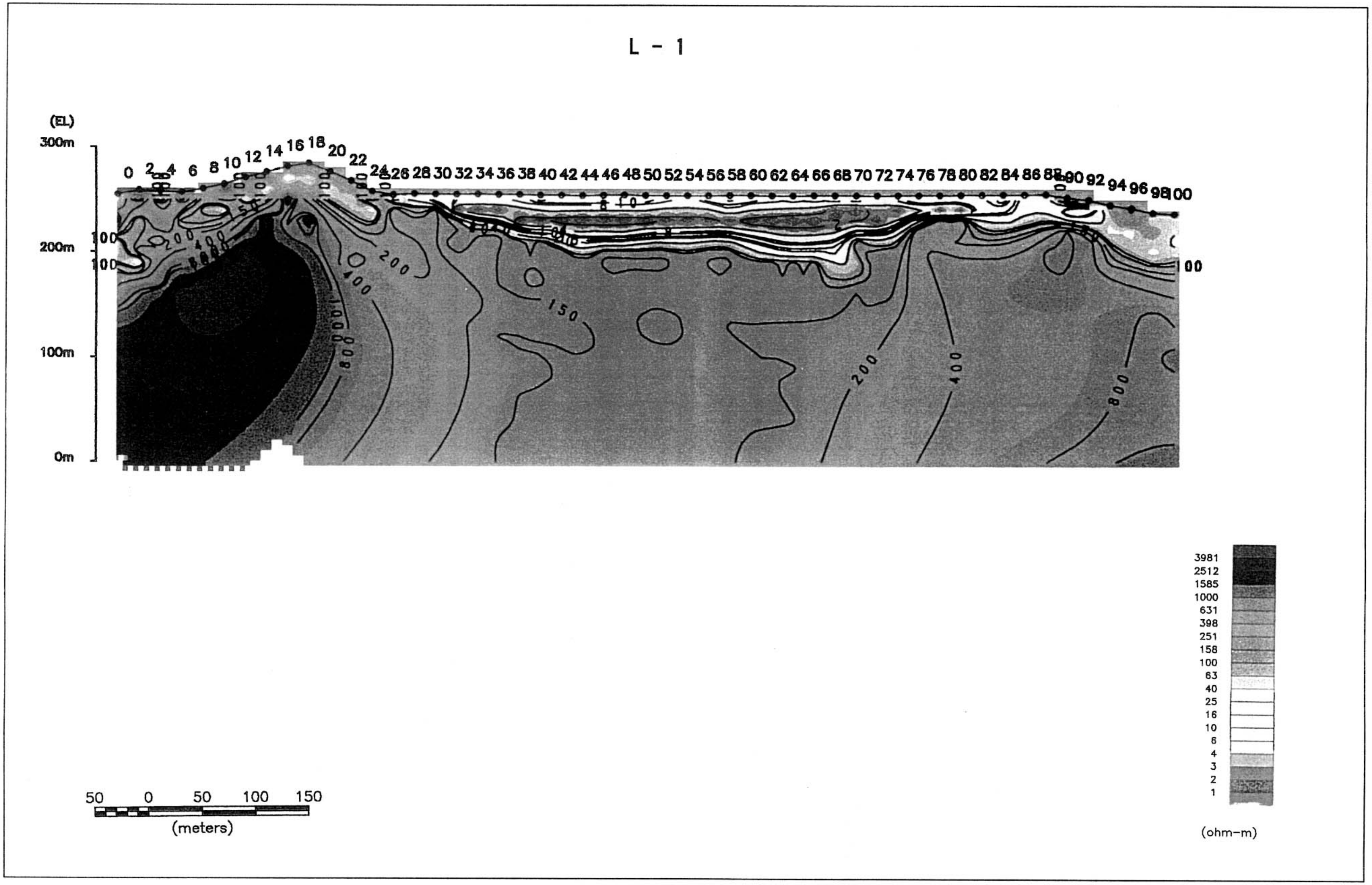


Figure 4.2 Resistivity section analyzed by Nano-TEM Geophsical Survey (1)

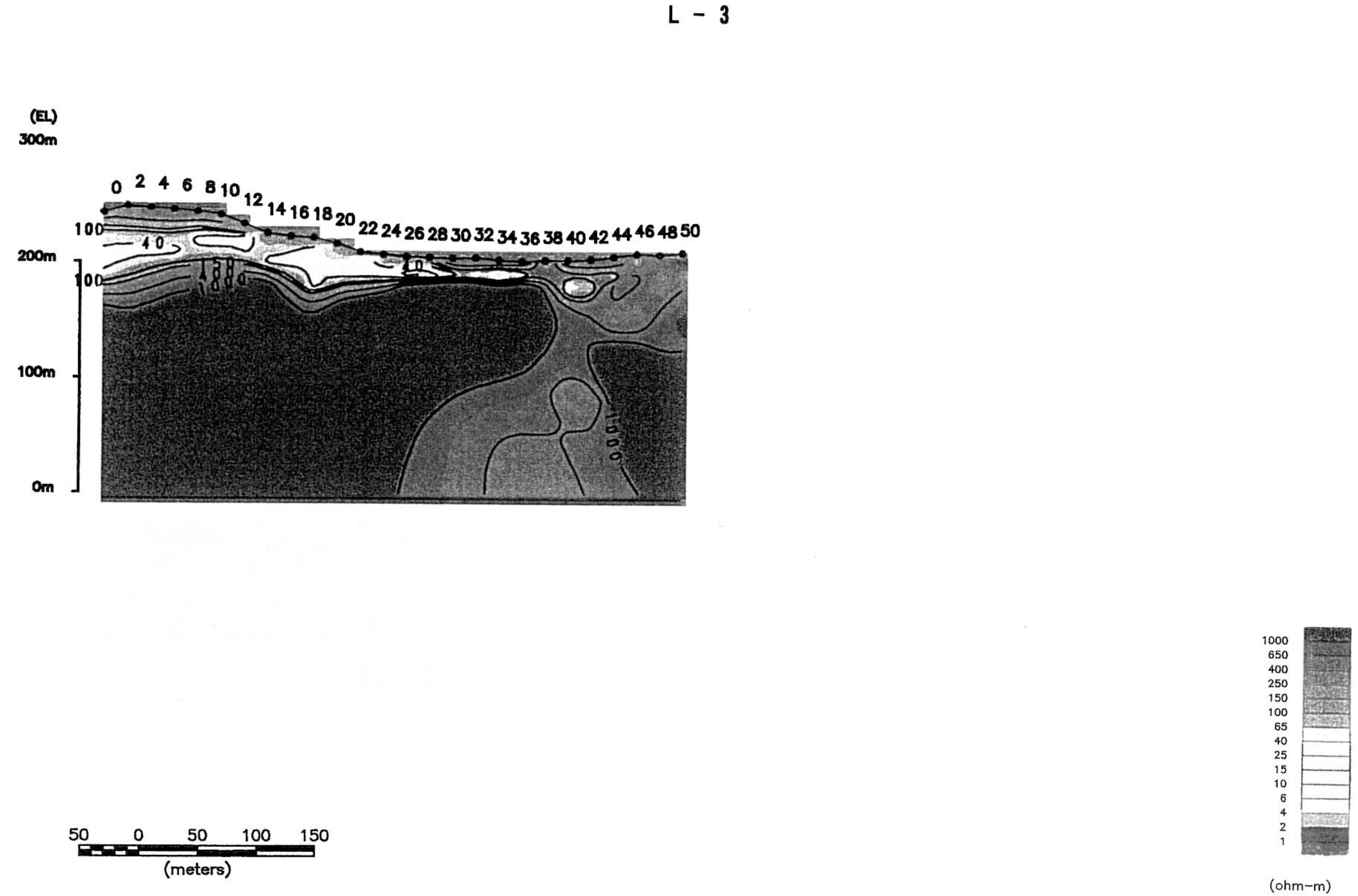


Figure 4.2 Resistivity section analyzed by Nano-TEM Geophsical Survey (2)

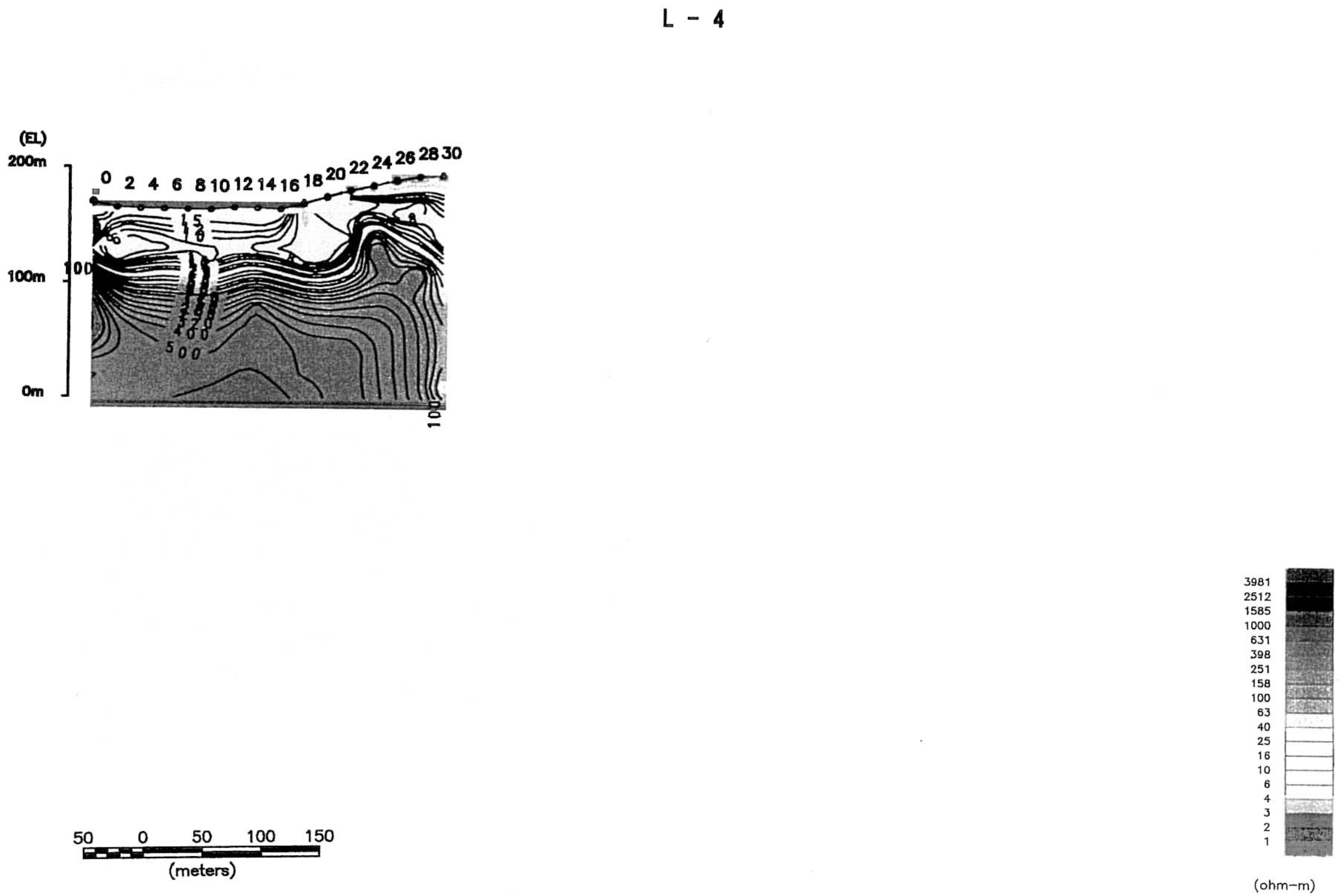


Figure 4.2 Resistivity section analyzed by Nano-TEM Geophsical Survey (3)

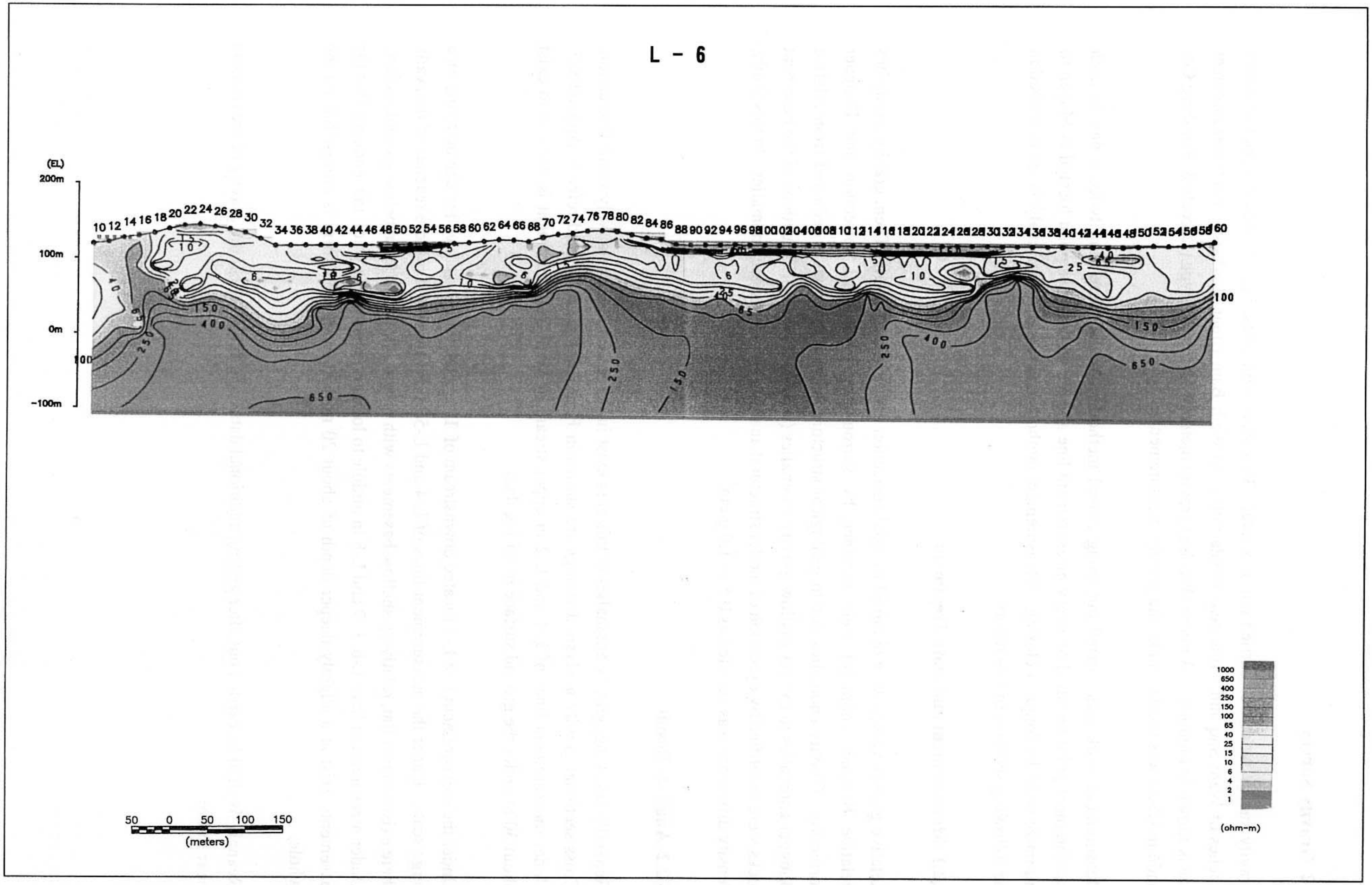


Figure 4.2 Resistivity section analyzed by Nano-TEM Geophsical Survey (4)

4.2 Gravity Survey

Gravity survey work was carried out at a total 13 measurement lines, i.e. 12 lines in upper to lower reaches of Wadi Suq and 1 line near Bayda village in Wadi Bani Umar al Gharbi. Each measurement line is shown in Figure 4.1. A micro (Precise) gravity meter of Lacoste D-type (Lacoste & Romberg Co. made in USA) was used to make the gravity measurements.

Measurement work was carried out using closed methods, closing more than twice a day to each measurement point installed on every measurement line and a tentative base point located in Magan to minimize drifts by frequent closing. Measurement methods and results of the analysis are described in the following sections of this report.

4.2.1 Measurement and Data Treatment

Relative gravity values were obtained by tidal correction and drift correction. Then, gravity anomalies (relative Bouguer anomaly) were obtained by surrounding topological correction and Bouguer correction. Gravity anomalies due to geological structure in wide range were deducted from relative Bouguer anomalies to extract shallow gravity anomalies (residue anomaly). Situations of the basement rocks were identified by execution of model structural analysis for the residue anomalies. In this Study, density difference was selected as 0.5 to 1.0 g/cm^3.

4.2.2 Analysis Result

Generally speaking, gravity anomalies in this area exist in range of 5 mgal, relatively small fluctuation. Cross sectional gravity analysis drawings are shown in Figure 4.3 (1) to (4) and refer to Appendix-3. Under measurement lines of L-1 and L-2 in upper stream of Wadi Suq, basement is deemed to exist about 30 m under the ground surface in tailing dam.

Under the measurement line L-3 located downstream of L-1, a landform like a valley can be found on a large scale. Under the measurement lines of L-4 and L-5 in the upper and middle reaches of the wadi, there exists almost flat, relatively shallow basements with ranging from 5 to 10 m below ground surface. Under measurement lines L-6, L-7 and L-8 in middle to lower reaches of the wadi, the tendency that the basements exist at a slightly deeper depth of about 20 m. However, their form is almost flat on the whole.

Reanalysis shall be carried out after getting additional data regarding the specific gravity of the rocks in near future.

LINE-1

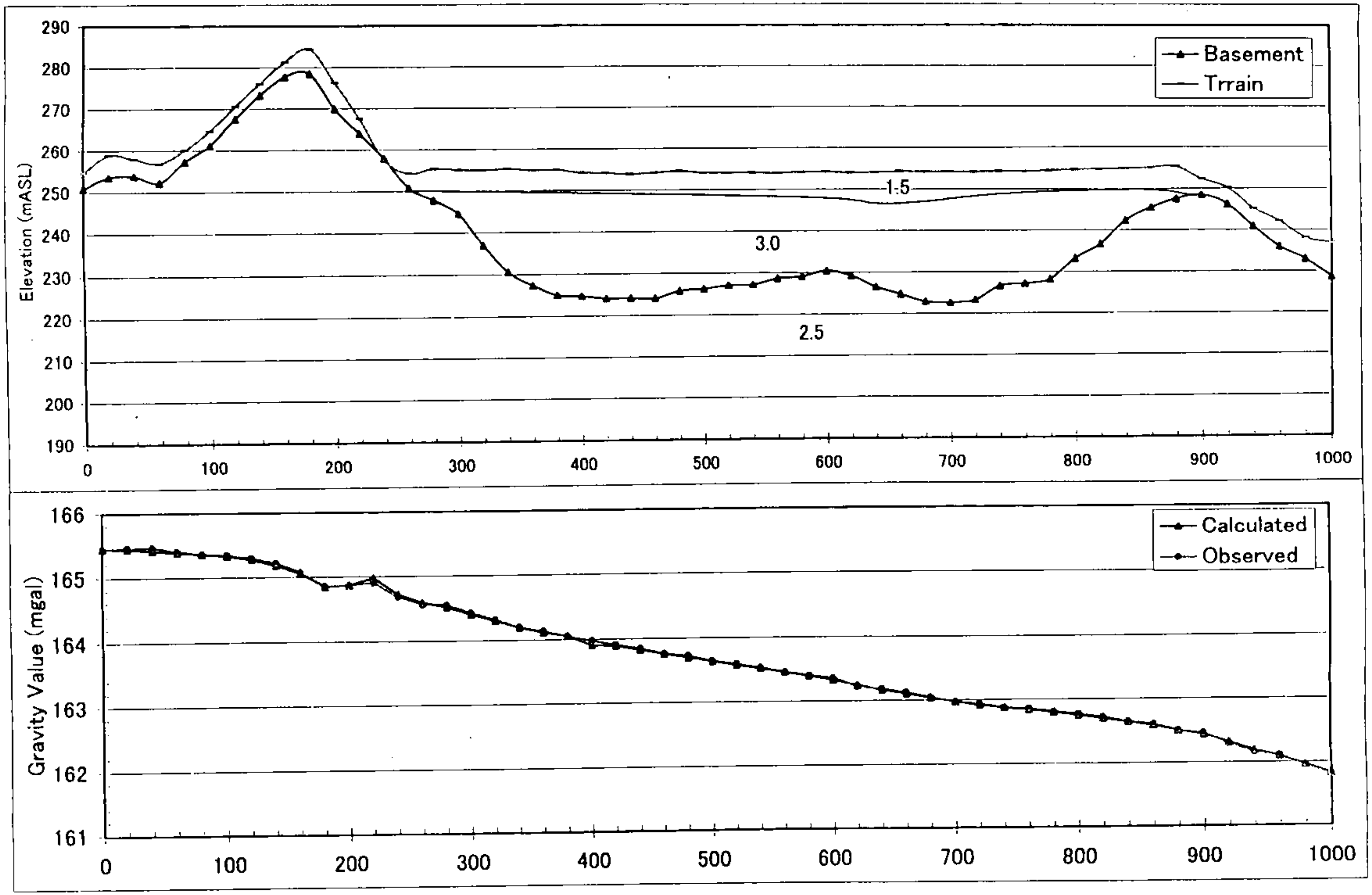


Figure 4.3 Gravity Profile by Sectional Analysis (1)

LINE-3

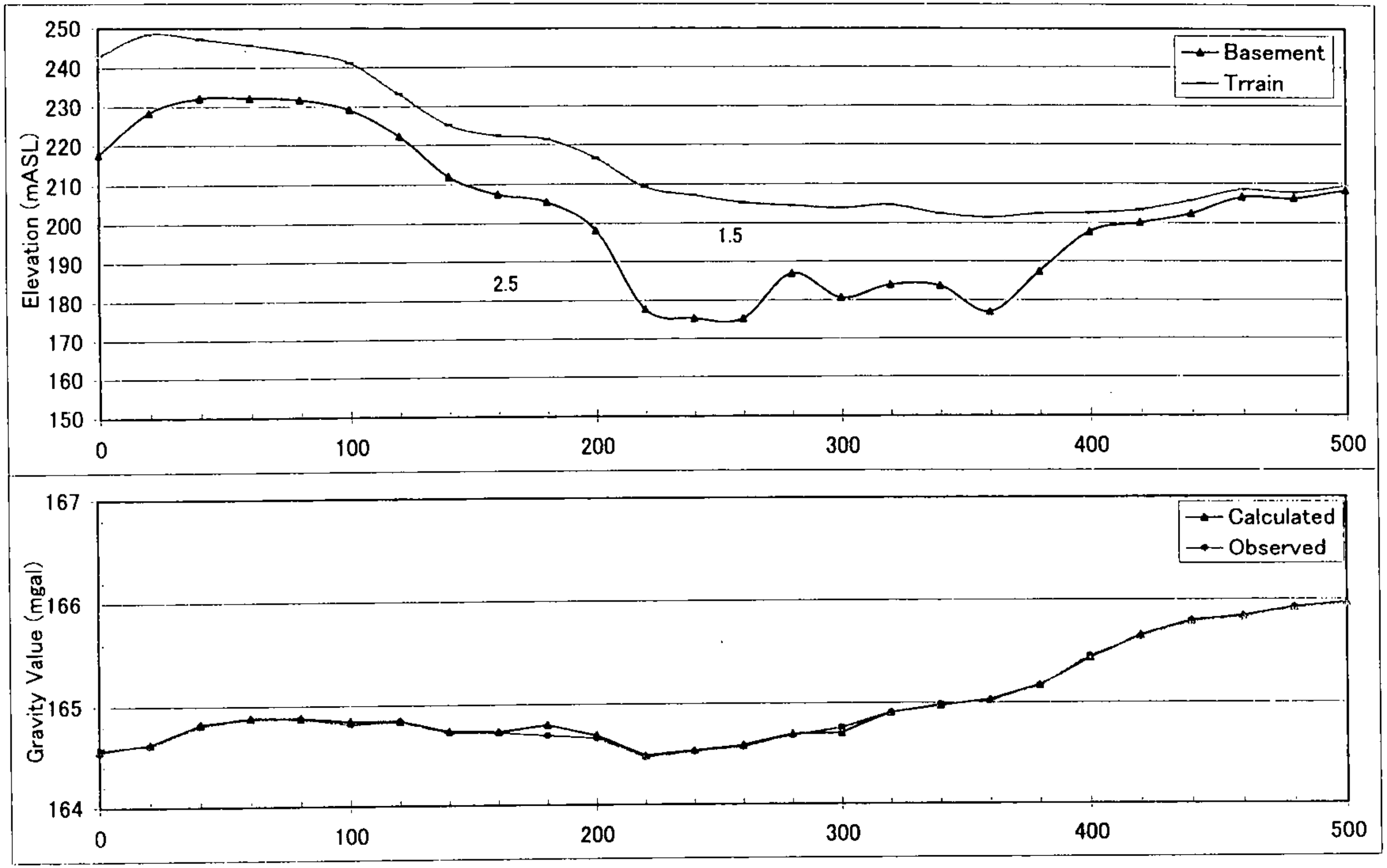


Figure 4.3 Gravity Profile by Sectional Analysis (2)

LINE-4

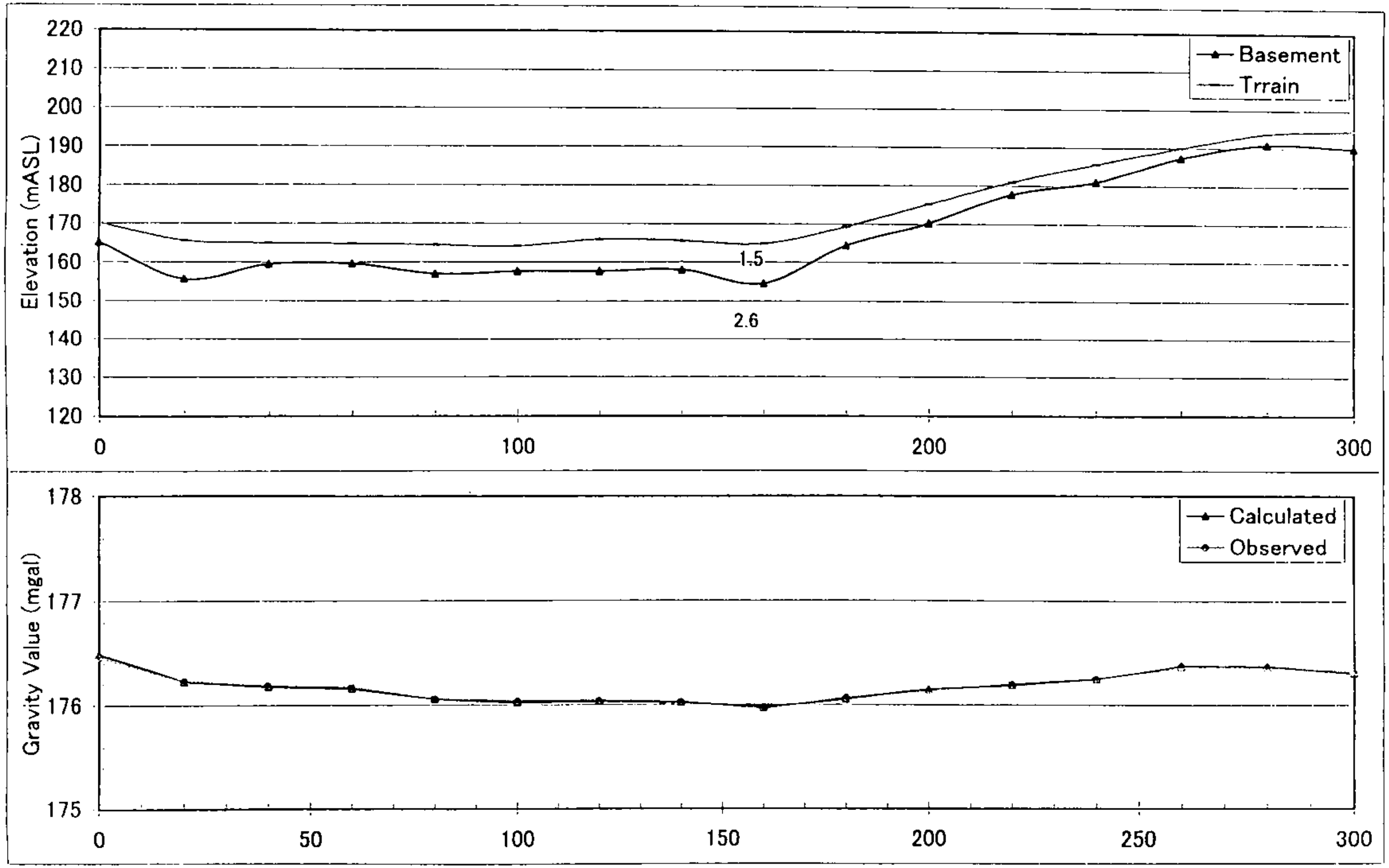


Figure 4.3 Gravity Profile by Sectional Analysis (3)

LINE-6

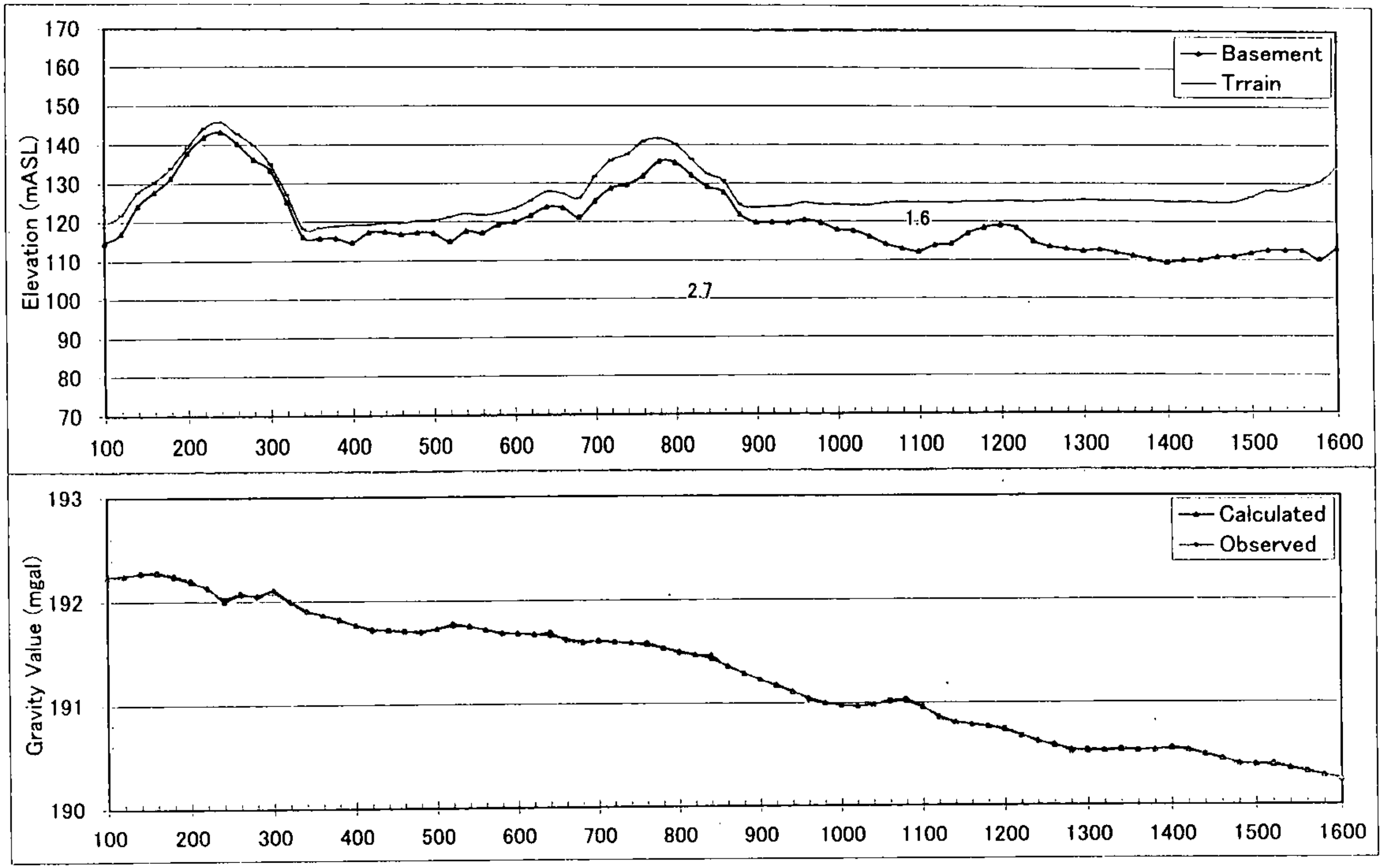


Figure 4.3 Gravity Profile by Sectional Analysis (4)

4.3 Measurement of Physical Characteristics of Rocks

Knowledge of the physical characteristics of basement rocks is necessary for analysis of Nano-TEM and gravity surveys. Hence, the density of the rocks for gravity data and specific resistivities were measured on rocks distributed along each measurement line. Rock samples for measurement were taken from out-crops and drilling core samples. These measurements were made on a total of 52 rock samples. Rock samples were shaped into cylinders or cubes, and then measurements were conducted under wet conditions.

The measurement results are shown in Table 4.2.

4.3.1 Density

Densities of rock samples range from 1.8 g/cm^3 to 2.9 g/cm^3, averaging 2.56 g/cm^3. Prevailing densities range between 2.6 and 2.7 g/cm^3. The density of the alluvial layer was 2.4 g/cm^3. Drilling core D-2 showed low density of 1.88 g/cm^3. D-2 is basalt but weathered and altered. Densities of other rocks are distributed in a slightly narrow range of 2.48 to 2.75 g/cm^3. Rocks along measurement line L-7 consist of shale and calcareous shale and so on, having relatively higher density of 2.71 g/cm^3.

4.3.2 Specific Resistivity

A total of 47 samples were used for measurement of the specific resistivity. All samples showed higher resistivities than 1,000Ω-m. Measurement under the wet conditions during the drilling of core D-2 was difficult. Therfore, theresistivity values from this core are determined under dry conditions. Specific resistivities along each measurement line range between 1,409 and 12,359Ω-m, averaging 5,152Ω-m. In a frequency distribution chart, values in 103.4 to 103.7Ω-m are dominant. The specific resistivities of rock samples for basement rock of alluvial beds and calcareous shale exhibit relatively low values of 2,559 to 2,824 and 1,409Ω-m, respectively. All rocks along the measurement line L-7 show 10,000Ω-m.

Consequently, basement rocks and alluvial deposits along the measurement line L-8 correspond to rocks with low density and low specific resistivity, while the shaly rocks along the measurement line L-7 correspond to rocks with high density and high specific resistivity. In addition, it was found that the specific resistivity might fluctuate widely depending on the distribution of fissures even in the case of the same rock type.

Table 4.2 Measurement of Physical Feature of Rocks

Sample point		Density	Average	Resistivity (ohm・m)	Average	Remarks
1	Alluvium	2.38		2513		Sandy
2	(Drilling core)	2.41		2749		Coarse sand
3		2.42	2.40	3254	2824	Gravel
4	(1)-1	2.68		4051		
5	basalt	2.66		3440		
6		2.64	2.66	2505	3265	
7	(1)-2	2.60		4452		
8	basalt	2.58	2.59	5181	4787	
9	(1)-3	2.70		2557		Cracky
10		2.63	2.66		2559	Broken
11	L-3-1	2.59		2152		
12		2.65		6291		
13		2.65		5210		
14		2.61	2.62	2901	3784	Cracky
15	L-3-2	2.61		3024		
16		2.55		1981		
17		2.64	2.60	4321	2958	
18	L-4-1	2.56				Broken
19		2.58		3220		
20		2.56		3270		
21		2.58	2.57	3526	3334	
22	L-4-2	2.70		44905		
23		2.68	2.69	2848	11298	Cracky
24	L-5	2.66		5071		
25	basalt	2.70	2.68	3115	3971	
26	L-5	2.60		10850		
27	massive	2.47		3468		
28		2.37	2.48	4670	5598	
29	L-6	2.69		6433		
30		2.56		2548		
31		2.70	2.65	13050	5984	
32	L-6-1	2.82		4756		
33	chert	2.54		7200		
34		2.60	2.66	7073	6237	
35	L-6-2	2.71				Broken
36		2.71		3280		Cracky
37		2.68	2.70	5930	4405	Cracky
38	L-7-1	2.67		31100		
39		2.69	2.68	4215	11455	
40	L-7-2	2.64		4094		
41	silica	2.70		53300		
42		2.77	2.71	34710	19634	
43	L-7-3	2.73		23010		
44		2.81		9075		Cracky
45		2.71	2.75	9040	12359	
46	L-8	1.98				Broken
47	(D-2)	1.80		1705		Dry-base
48		1.85		1163		Dry-base
49		1.90	1.88		1409	Broken
50	L-8	2.43		7243		
51		2.41		7132		
52		2.41	2.42	4913	6324	
		Ave.	2.56	Ave.	5152	