THE GOVERNMENT OF SULTANATE OF OMAN

HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST OF SULTANATE OF OMAN

FINAL REPORT

VOLUME 3

SUPPORTING REPORT Ⅱ

C. HYDROGEOLOGY
D. GROUNDWATER
E. LAND AND WATER USE

MARCH 1986

JAPAN INTERNATIONAL COOPERATION AGENCY

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SUPPORTING REPORT C

HYDROGEOLOGY

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CHAPTER 1 SUMMARY OF PREVIOUS SURVEYS

Two comprehensive survey reports had been pubished concerning water resources in the Batinah: ILACO (1975) and Gibb (1976). These reports had been compiled, not only using field exploration results, but also drilling logs of around fifty newly sunk exploration wells and aerial photographs of 1974 MAF contract.

The previous surveys presented a distinctive hydrogeologic division of Hard Rock Zone and Soft Rock Zone (in case of Gibb's notation).

Hard Rock Zone was regarded as a poor aquiferous condition which was attributed to the well-consolidated rocks in prevalence at the locality.

Soft Rock Zone was postulated to be a aquiferous zone of potentially good prospect.

In case of ILACO geo-resistivey soundings were extensively carried out. Subsurface structure was thus estimated particularly in the Northern Batinah, where basement rock increases its depth to more than two hundred meters in some locality near the coast.

This structure is valid in the Southern Batinah, too. So far, any exploratory bore holes at the coast have not reached the basement even at the 300 m depth.

A very detailed study was done on the surface geology of the coastal plain of the Southern Batinah. The result clarified various extent of weathering and eventually differentiated surface infiltration property of the sand/gravel plain. The old weathered surface was found to cover more than half of the coastal plains.

However there have not been any appreciable studies about the potentiality of the groundwater resources in the Hard Rock Zone. Consequently a large area had been left void for hydrogeological survey. Unfortunately, this situation was not reformed even by our project.

CHAPTER 2 GEOLOGICAL AND GEOPHYSICAL SURVEY RESULTS

2.1 Stratigraphical Sequence

Stratigraphical sequence is pronounced by various lithology ranging from Pre-Permian to the present formation as shown in Geological log, Geological Map and Geological Cross-section (Fig. C-2-1 and Fig. C-2-2).

Classification of lithology has to be made by considering structural features; large-scaled folding and nappe with thrust fault of which control the lithofacies. From this point of view, the area can be divided into three major units: Pre/Early Tertialy, Tertiary/Pleistocene, and Post-Pleistocene formation as follows:

1) Pre/Early Tertiary Formation

Pre-Tertialy formations, classified into five sub-units:

Pre-Permian Formations

Pre-Permian Basement	-----	The basement is made of dolomite, limestone, quartzite, graywacke and conglomerate.

Triassic-Permian Formation

Akhdar Dolomite	----	Dolomite and dolomitic limestones indicate the age ranging from Permian to Triassic and are made of Mahil Formation and Saiq Formation. Saiq Formation is the basal unit of carbonate shelf sequence, consisting of 700-meter-thick Middle to Upper Permian. The facies is composed of coral bearing limestone and dolomitic limestone. Mahil Formation of Triassic facies consists of several hundred meters of monotonous and commonly saccharoidal dolomite in which poorly developed stromatolitic beddings are common.

Middle Cretaceous-Jurassic Formations

Musandam Limestone	-----	Massive shelf limestones prevail, consisting of foraminiferal wackestone and packstone with subordinate skeleral grainstone. Facies includes the shallow marine origin.

Middle Cretaceous-Permian Formations

Musandam Limestone	-----	Massive shelf limestones prevail, consisting of foraminiferal wackestone and packstone with subordinate skeletal grainstone. Facies includes the shallow marine origin.

Middle Cretaceous-Permian Formations

Hawasinah Allochthonous Unit	-----	Mainly pelagic sediments which are composed of 12 tectonical sub-units including Hamrat Duru Group and other six formations. Facies consists of grainstone, limestone turbidite, radiolarian chert and some volcanic in general. A consistent tectonic order can be recognized within the pile of the Hawasina unit. However, some of the lower unit may be missing locally, so that a formation otherwise found in a relatively high tectonic position, may directly overlie the lower units.

Middle Cretaceous Formations

Semail Ophiolite Nappe	-----	Ophiolite assemblage consists of the following rock facies: 1) Volcanic, extrusive rock 2) Subvolcanic feeder dike 3) Hypabyssal-gabbroid rock 4) Gabbro 5) Transitional rock between gabbro and periodotite

6) Ultramafic rock
Ophiolite assemblage, called Semail
Ophiolite Nappe, forms Frontal Mountains, which stand to 1,000 m above sea level.

Meastr. to Tertiary ----- Late Cretaceous to Early Tertiary limestones which are situated on Semail Ophiolite Nappe with unconformity.
Facies is composed of chert conglomerate, chalk, chalky marl with some reworked pebble and weathered foraminiferal limestone. The bed dips 10^{o} to 20^{o} to northeast.

2) Tertiary/Pleistocene Formation

This formation covers mainly the upper stream of wadi plain and is classified into six-sub-units as following below:

Terrace-III ----- Erosional high terrace occasionally covered by well cemented layers. In the mountain area, terrace surface is over 50 m high above modern wadi channel.
Typical developments are seen near Nakhal and in the Sahtan basin. Highest surface is about over 1,000 meters above sea leve.

Terrace-II ----- Middle terrace having 20 to 30 m relative height.
Extensive distribution is seen on the midstream area and traceable over 10 km downstream area and traceable over 10 km downstream from mountain channel. The surface slope is 1/50. Facies is marked by the consolidated layers consisting of limestone, serpentinite and periodotite gravel. Surface gravel is well varnished and wind etched.

Terrace-1 ----- Low terrace plains remain around Hibra', Jamma' and Houqain. The terrace surface slope is 1/200 in average, traceable over 10 km downstream from mountain-foot. Facies are of unconsolidated gravel with some intercalations of sand and gravel.

Sand and Gravel Flats ----- Sandy flat plains remain between modern wadi channels. Facies are marked by much amount of sand. Surface condition is slightly weathered and varnished.
Occasionally seif dunes are developed.

Eroded Fans ----- These are old composit fans with eroded plain. The largest one is seen along Wadi Al-Ma'awail. Facies is composed of green schist, quartzite, breccia, mountain limestone gravel with clay rich matrix.

3) Post-Plestocene Formation

This formation mainly covers the lower rech of Wadi Plain and is classified into the following sub-units:

Fan-1 ----- These are recent fans washed out from mountain channels. Facies are of very poorly sorted gravel of up to boulder size.

Ancient Channels ----- Ancient wadi courses remain as topographical depressions on the older fans and terrace plains. Typical developments are seen around the midstream of Wadi Bani Kharus and Wadi Al-Fara'.

Modern Wadi Beds	-----	These are active wadi channels across the inter-fluvial plains. Facies are made of poorly sorted gravel and sand with a few clay component.
Fluvial	-----	This is interfluvial area of modern wadi. Extensive distribution are recognized along each wadi. Many of interfluvial plains are probably similar to the Ancient Channel. Facies are finer than the surrounding Modern Wadi Bed.
Seif Dune	-----	Seif dunes develop between Wadi Bani Kharus and Wadi Al-Fara'. Many dunes align N-S to NNE-SSW direction, having over 20 meters height above modern Wadi Bed.
Wind Blown Sand	-----	Medium sand to silty-sand flats overlie silt layers at the downstream of wadi plains. The thickness of sand layer varies in localities.
Silt Flat	-----	Silt flat is composed of laminated layers of silt, clay and granule. Occasionally saline facies of marine origin are included.
Coastal Dune	-----	Seif dunes or barchans develop.
Sabkha	----	Shallow sand flats overlie the extensive Sabkha deposits.
Sand Flat	-----	This is shallow sand flats with shell debris and silt layers.

Fig. C-2-1(1) Geological Log of Observation Well, BA1

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AHIN
HOLE NO.	BA 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR MIJAZ SAGHIRAH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		2	2		SILT	Light brown to light gray silt with sand, partly consolidated by carbonate material and gravelly layer contained.
		4	2			
		5	1		SAND	Sand with gravel, grayish sandy sediment made up of medium sand and granule gravel.
		8	3			
		10	2			
		16	6		GRAVEL	Brownish gravel with sand and a few carbonate fragments, the proportion of sand gradually increase in order to the lower horizon. The shell crusts are included through whole horizon.
		22	6		SAND	Light grayish beach sand, medium sand facies with a few intercalation of marly clay.
		30	8		SILT	Silt with sand and gravel, light yellow orange colored. The marly facies and sand/gravel dominant facies interbeded.

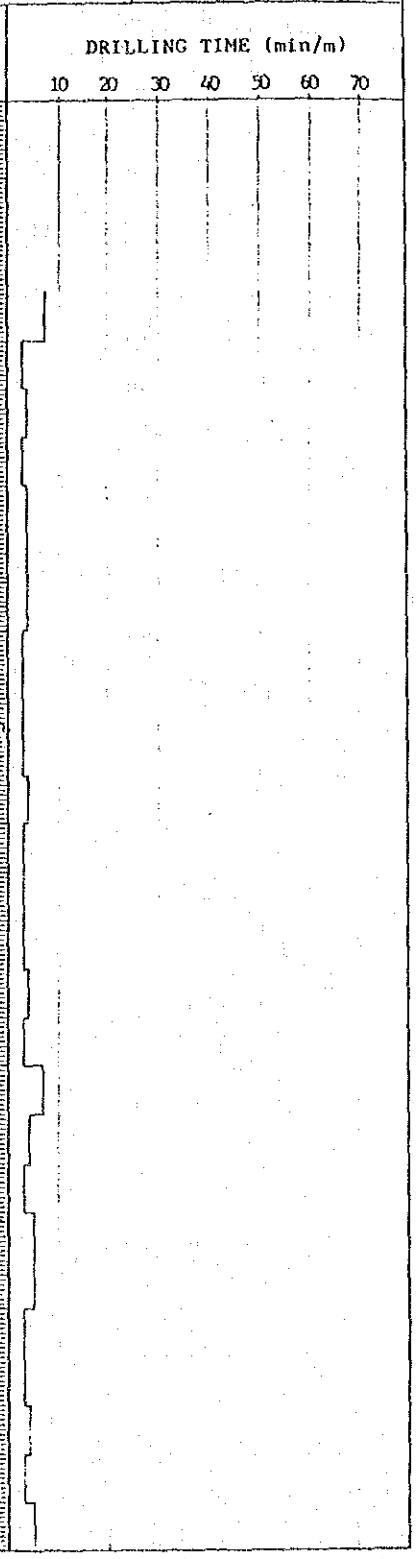


Fig. C-2-1(1) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGOC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AHIN
HOLE NO.	BA 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR MIJAZ SAGHIRAH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		36	6		GRAVEL	Gravel with sand, dark brown gravel dominant facies with sand, clay and carbonate fragment
		37	1		SAND	Dark brown sand with a few carbonate fragments.
		41	4		CLAY	Light yellow orange clay with a little of carbonate material, partly change to the marly facies.
		54	13		GRAVEL	Gravel and sand with carbonate fragments, dark brown to black, carbonate coated gravel are included.
		58	4		CLAY	Light gray clay to marly clay with a few gravel.
					CLAY	Light gray marly clay with sandy material.

DRILLING TIME (min/m)

10 20 30 40 50 60 70

Fig. C-2-1(1) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AHIN
HOLE NO.	BA 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR MUAZ SAGHIRAH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		63	5		GRAVEL	Gravel with sand, dark brown gravel dominant facies, matrix filled by medium sand, clay and carbonate material.
		68	5		SAND	Brown sand and clay, alternation of sand and clayey layers dirived from ophiolite.
		72	4		GRAVEL	Brown gravel with clay, alternation facies of gravel and clay.
		80	8		GRAVEL	Dark gray to black gravel facies with a few carbonate and clayey material.
		84	4		GRAVEL	Gravel and sand, sand dominant facies partly interbeded especially between 81 meters and 83 meters.
		87	3		SAND	Reddish brown sand, medium sand with a little of carbonate material.
					GRAVEL	Gravel and sand, brown to black rounded gravel made up of granule to pebble and sorted clean sand layer.

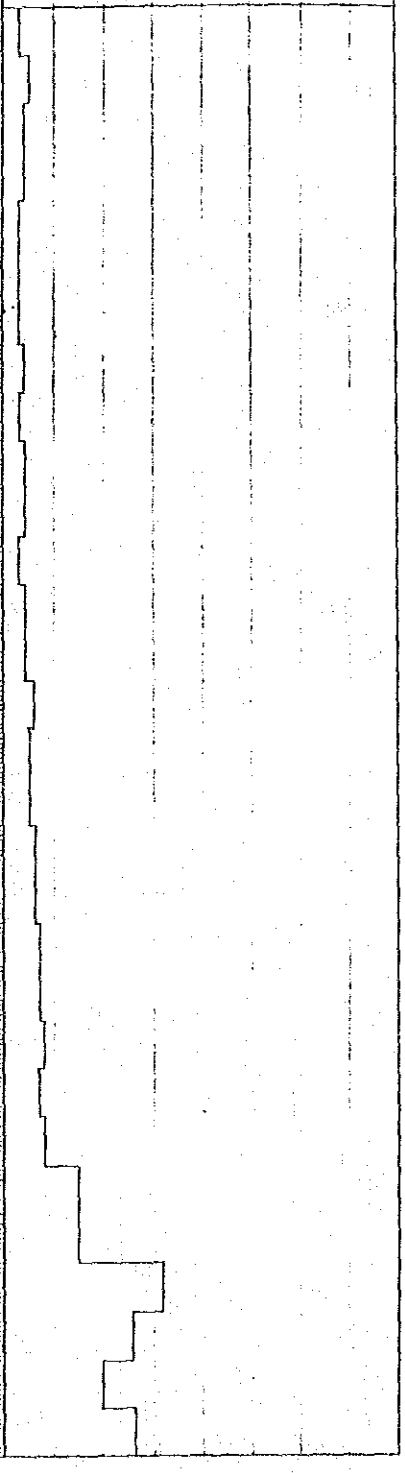


Fig. C-2-1(1) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AHIN
HOLE NO.	BA 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR MIJAZ SAGHIRAH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		102	15		GRAVEL	-- Same as abave mentioned description --	

Fig. C-2-1(2) Geological Log of Observation Well, JT20A

GEOLOGICAL LOG OF WELL

PROJECT	HYDROGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI BANI GHAFIR
HOLE NO.	JT 20 A	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	10 KM DOWN STREAM FROM AL-HOQAIN	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		7	7		SAND	Brown to light brown sand with silt and gravel, silt dominant layer and much amount of granule gravel intercalate at the upper horizon.	
		8	1		GRAVEL	Granule gravel with sand and a few clayey material.	
		14	6		GRAVEL	Gray to light brown gravel layer, pebble to granule with sandy matrix, the alternate facies of pebble and granule.	
		17	3		GRAVEL	Much proportion of limestone granule gravel with sand and a few carbonate fragments. brown to light brown colored facies.	
		18	1		CLAY	Reddish brown clay wtih a few granule gravel.	
		19	1		SAND	Medium to coase sand with gravel, light brown colored facies.	
		23	4		GRAVEL	Light brown gravel, much amount of pebble with carbonate fragments.	
					GRAVEL	Gray gravel, much amount of pebble with fine to medium sand.	

Fig. C-2-1(2) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI BANI GHAFIR
HOLE NO.	JT 20A	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	10 KM DOWN STREAM FROM AL HOUQAIN	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
	33	10			GRAVEL	Gray gravel, much amount of pebble with fine to medium sand.	
	36	3			SILT	Light brown silt with gravel .	
	40	4			SAND	Brown to light brown medium to coarse sand.	
	48	8			SAND	Light brown sand with slit and gravel, the intercalation of sandy layer at the 43 to 44 metres horizon.	
	52	4			MUDSTONE	Mudstone to marly mudstone with a few content of granule gravel.	

Fig. C-2-1(3) Geological Log of Observation Well, BG1

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	UPSTREAM OF AL-MUDAYO	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		2	2		SAND	Light gray sand with gravel, fine to very fine sand with rounded gravel
		5	3		SAND	Dark brown sand with gravel, poorly sorted medium to coarse sand.
		11	6		SILT	Light brown to gray, silt with sand and granute, proportion of sand to silt is a like quantity.
		18	7		SAND	Gray to light gray sand with gravel, poorly sorted sand with gravel, a few carbonate and clayey material .
		22	4		GRAVEL	Gray to white gravel with sand, and much content of carbonate fragments included facies.
		24	2		SAND	Gray to white sand with gravel, abundant carbonate material .
		29	5		GRAVEL	Gravel, clean gravelly facies with a few sandy particles. carbonate fragments are common through the whole horizon.
					GRAVEL	Gravel with sand and carbonate material.

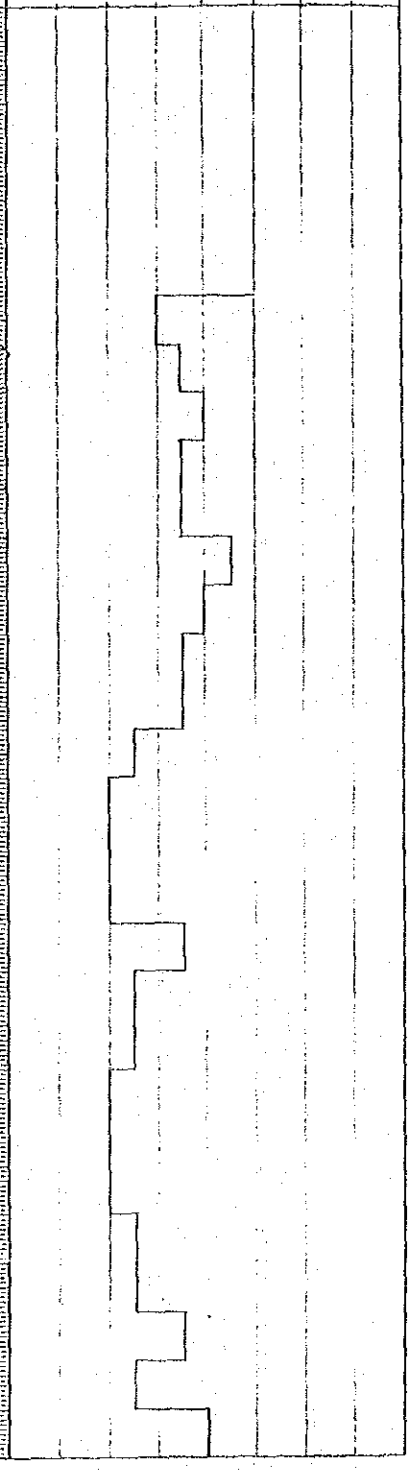


Fig. C-2-1(3) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	UPSTREAM OF AL-MUDAYBI	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		31	2		GRAVEL	-- same as above mentioned description --
		34	3		SAND	Light gray sand, medium to coarse sand with much amount of carbonate material.
		42	8		SAND	Light gray sand with gravel, a few clay and fine sand, abundant carbonate material are contained.
		46	4		SAND	Sand, a few clay and much quantity of carbonate fragments and very fine sand are also included.
		50	4		SAND	Sand with gravel, abundant carbonate fragments.
		53	3		SAND	Sand, clean fine to medium sand, well sorted and facies seems to be beach sand.

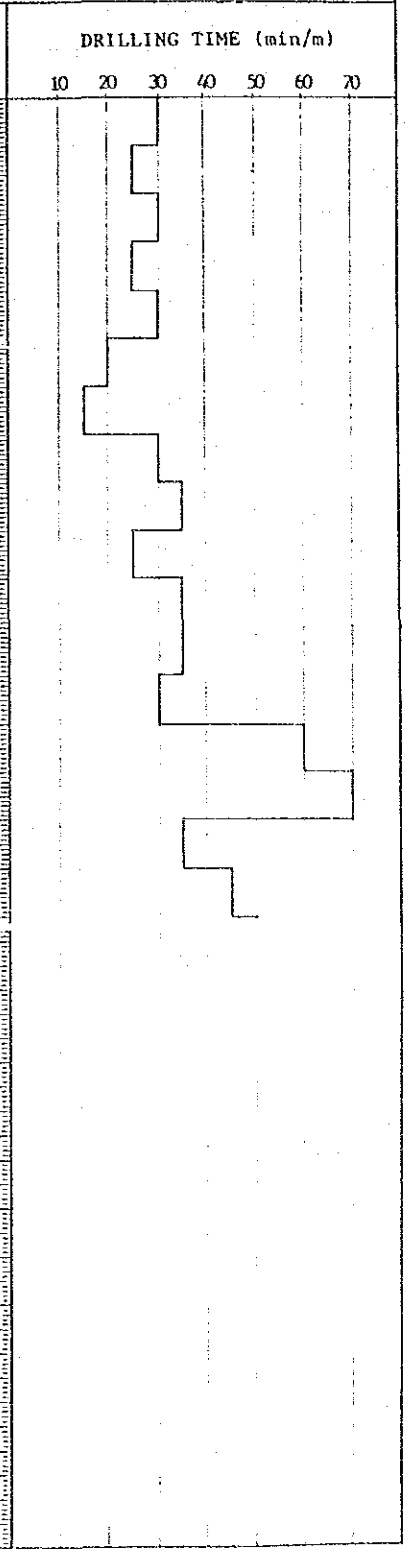


Fig. C-2-1(4) Geological Log of Observation Well, BG2

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	DOWNSTREAM OF DARIS	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		2	2		GRAVEL	Gravel, gray colored clean gravel with a little of sand.
		4	2		GRAVEL	Gravel with sand, gray colored medium sand.
		9	5		GRAVEL	Light gray gravel, clean gravel composed of granule to pebble.
					GRAVEL	Gravel with clay, gravel dominant layer is at 13 meters to 14 meters and 17 meters to 26 meters. Clay rich gravelly layers intercalate at 9 meters and between 15 meters and 18 meters. Reddish brown clay facies interbed the lower horizon

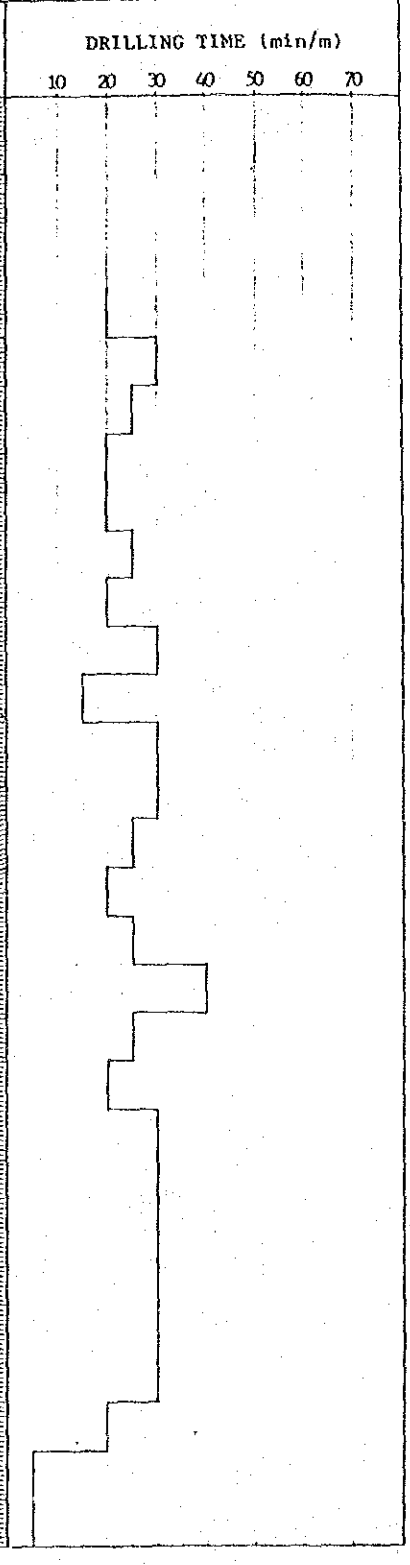


Fig. C-2-1(4) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	DOWNSTREAM OF DARIS	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		32	23		GRAVEL	-- Same as above mentioned description --
		34	2		SAND	Light gray to light brown sand composed of medium sand
		39	5		GRAVEL	Gravel with clay and sand, light gray to light brown colored granule to pebble.
		41	2		CLAY	Brown clay with gravel
		43	2		CLAY	Brown clay with a few gravel
		44	1		CLAY	Brown clay with granule to pebble
		46	2		GRAVEL	Gravel with clay, light gray to light brown gravelly facies.
		50	4		GRAVEL	Light gray to white gravel, consolidated facies filled up of carbonate material.
		57	7		GRAVEL	Gravel with clay, brown to reddish brown consolidated facies.
					CLAY	Clay with sand and a few granule gravel. Light brown colored facies.

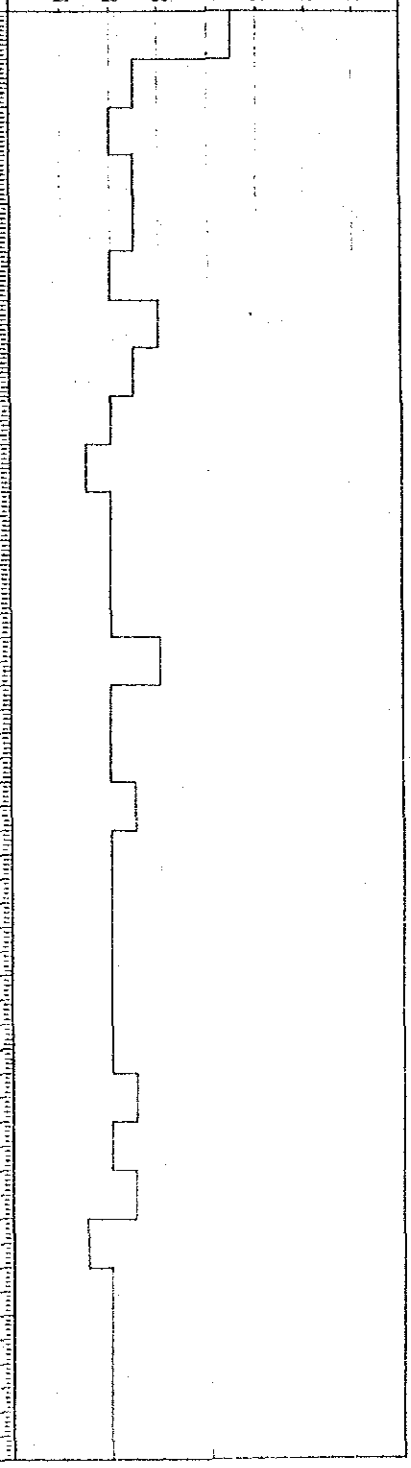


Fig. C-2-1(4) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	DOWNSTREAM OF DARIS	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		65	8		CLAY	Light brown clay with sand and a few gravel.
		67	2		CLAY	Reddish brown clay, a little of granule gravel are contained.
		70	3		CLAY	Light brown to reddish brown clay with sand, sandy particles are of very fine to fine sand.
					MARL	White to light gray marl with gravel, the upper facies seems to be a conglomerate with carbonate matrix, the lower horizon mainly consist of marlstone with a few gravel drived from ophiolite.

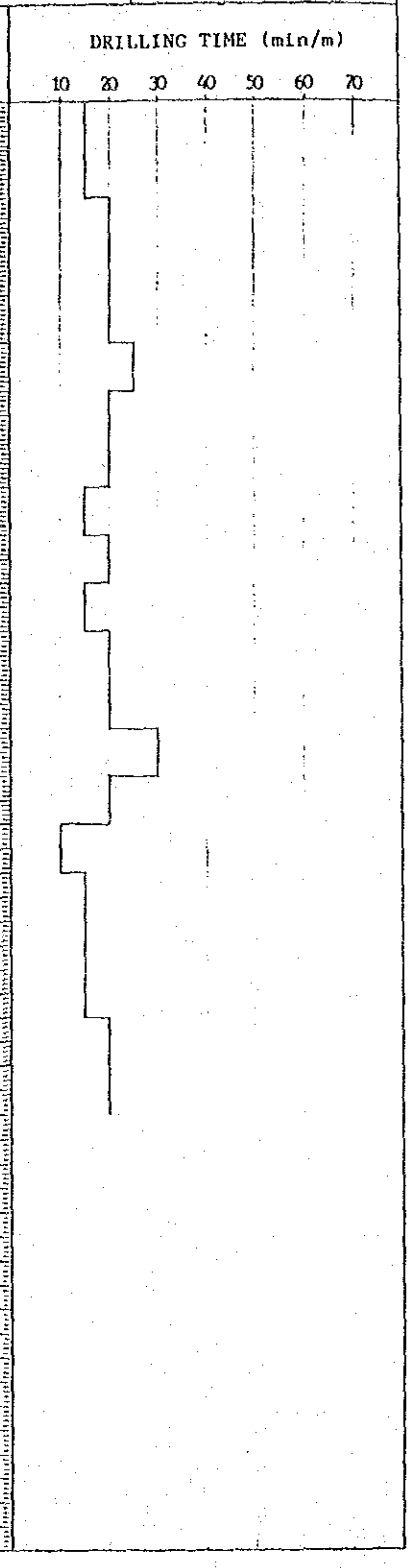


Fig. C-2-1(4) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BG 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	DOWNSTREAM OF DARLS	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		91	2		MARL	-- same as above mentioned desdription --

Fig. C-2-1(5) Geological Log of Observation Well, BF1

GEOLOGICAL LOG OF WELL

PROJECT	HYDROGIC OBSERVATION PROJECT IN THE BATINAH COAST	SITE	WADI AL-FARA'
HOLE NO.	BF 1	ANGLE FROM HORIZONTAL: PERPENDICULAR	FOREMAN	
LOCATION	NEAR THE AL-MUSANA'A	COMMENCED	LOGGED BY	
HOLE DIA.	10 "	COMPLETED	CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		3	3		SILT	Light gray sandy silt.
		4	1		SILT	Light gray silt with sand.
		6	2		SILT	Light gray semi-consolidated silt with a few sandy material.
		7	1		SAND	Light gray to gray sand, fine to medium sand.
		8	1		GRAVEL	Light gray to gray gravel with sand, much content of granule gravel.
		10	2		SILT	Light gray silt with granule gravel and a few pebble.
		14	4		GRAVEL	Light gray to gray gravel with sand a few clayey material.
		19	5		SAND	Light gray to gray sand and gravel, fine to medium sand granule gravel.
		21	2		GRAVEL	Light gray to gray gravel with sand, subrounded granule gravel with a few sandy particles.
		29	8		GRAVEL	Light gray gravel with sand, much proportion of granule gravel.

DRILLING TIME (min/m)

10 20 30 40 50 60 70

Fig. C-2-1(5) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BF 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR THE AL-MUSANA'AH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		36	7		SAND	Gray sand with gravel and carbonate fragments medium to coase sand.	
		42	6		GRAVEL	Gray gravel with sand, much amount of granule gravel and a few carbonate fragments	
		48	6		SAND	Gray colored fine to medium sand with marly material .	
		54	6		SAND	Gray fine to medium sand.	
					SAND	Gray fine to medium sand with the intercalation of marly material .	

Fig. C-2-1(5) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BF 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR AL-MUSANA'AH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		61	7		SAND		
		74	13		GRAVEL	Carbonate coated old gravelly facies, dark brown to gray granule / pebble with sand and carbonate fragments. The sandy horizons intercalated between 63 and 66 meters, and between 67 and 70 meters.	
		79	5		GRAVEL	Grey to dark brown gravel and sand with carbonate fragments, much content of granule to pebble and moderate proportion of medium to coarse sand.	
		86	7		MARL	Dark brown marl with sand, medium to coarse sand drived from ophiolite and hard calcarious clayey layer. The alternate facies of sand and marl at the 54 to 61 meters horizon.	
					MARL	White to light gray marl with sandy layer and a few granule gravel.	

Fig. C-2-1(5) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BF 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NEAR AL-MUSANA'AH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		94	8		MARL	-- Same as above mentioned description --	
		99	5		SAND	Dark brown to light gray sand with clay and a little of granule to pebble.	
		105	6		GRAVEL	Dark brown gravel with sand and carbonate fragments, carbonate coated old gravel with coarse sandy matrix.	

Fig. C-2-1(6) Geological Log of Observation Well, BMET

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-FARA'
HOLE NO.	BMET	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	AL-MULADDAH	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRILLING TIME (min/m) 10 20 30 40 50 60 70
		2	2		SANDY SILT	Light gray unconsolidated sandysilt	
		4	2		SAND	Sand with granule and silt, occasionally contains carbonate fragments.	
		9	5		GRAVEL	Light gray gravel with clay, the proportion of clay varies each horizon, example for at 4 meters to 6 meters intercaltes clay layer.	
		10	1		CLAY	Light gray semi-consolidated to consolidated clay.	
		13	3		CLAY	Light gray clay with gravel, semi-consolidated to consolidate clay with granule to pebble.	
		17	4		GRAVEL	Light gray gravel with clay, semi-consolidated clay with granule to pebble.	
		24	7		CLAY	Clay with gravel, semi-consolidated clayey facies with a little proportion of gravel less than 10 mm/mm in diameter.	

Fig. C-2-1(7) Geological Log of Observation Well, BM1

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	BARKA	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		5	5		SILT	Silt, light gray to light brown silt with a little of sand.
		10	5		SAND	Sand with granule and silt, light gray to light brown semi-consolidated silt with gravelly intercalation.
		12	2		SAND	Light gray clean sand.
		13	1		SAND	Light gray sand with clay.
		18	5		SAND	Light gray clean sand, well sorted medium to fine sand, partly contained semi-consolidated calcarious clay.
		20	2		SAND	Light gray sand with gravel.
		22	2		SAND	Light gray sand with clay.
		25	3		SAND	Light gray to light brown coarse sand.
		26	1		SILT	Light gray calcarious silt.
		28	2		SAND	Light gray sand with calcarious clay.
		29	1		SILT	Light gray silt.
					SAND	Light gray medium sand.

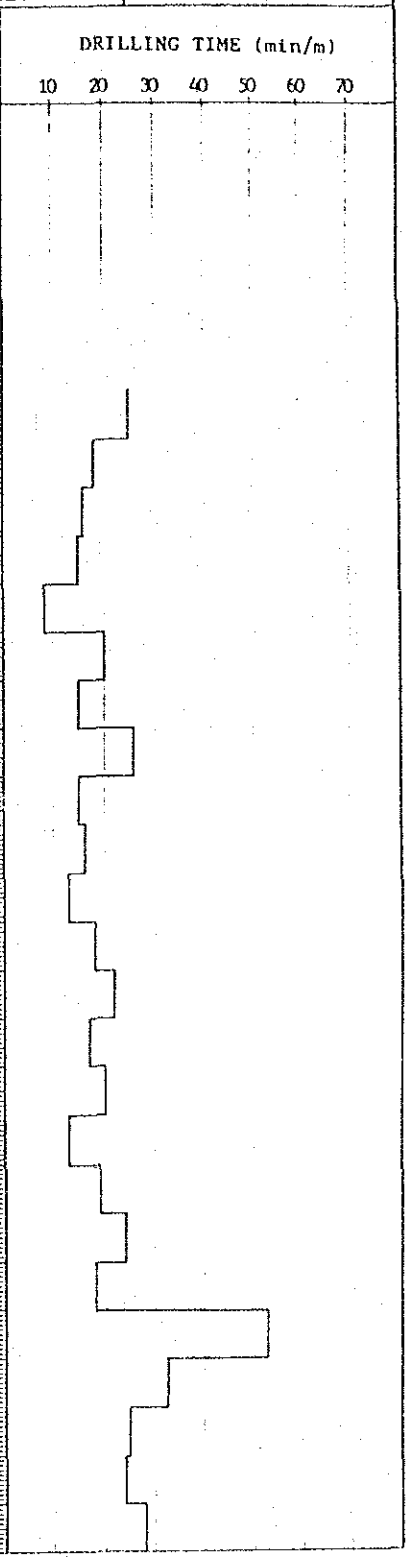


Fig. C-2-1(7) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	BARKA	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		31	2		SAND	Light gray medium sand.
		32	1		SILT	Light gray silt with sand.
		34	2		SAND	Light gray to light brown medium sand.
		35	1		SAND	Light gray to gray sand with granule gravel.
		36	1		SAND	Light gray medium sand.
		37	1		SILT	Light brown silt to sand.
		40	3		SAND	Light gray fine sand with clay and a few carbonate fragments.
		41	1		SILT	Light gray silt, semi-consolidated calcarious facies.
		43	2		SAND	Light gray fine to medium sand with carbonate material.
		44	1		SAND	Light gray sand with gravel.
		45	1		SAND	Light gray to light brown sand with clay and carbonate fragments.
		48	3		SAND	Gray sand with granule gravel, especially at 48 meters much amount of granule gravel.
		52	4		SAND	Gray gravel with carbonate particles.
					MARL	Light brown to white marlstone with a little of granule gravel.

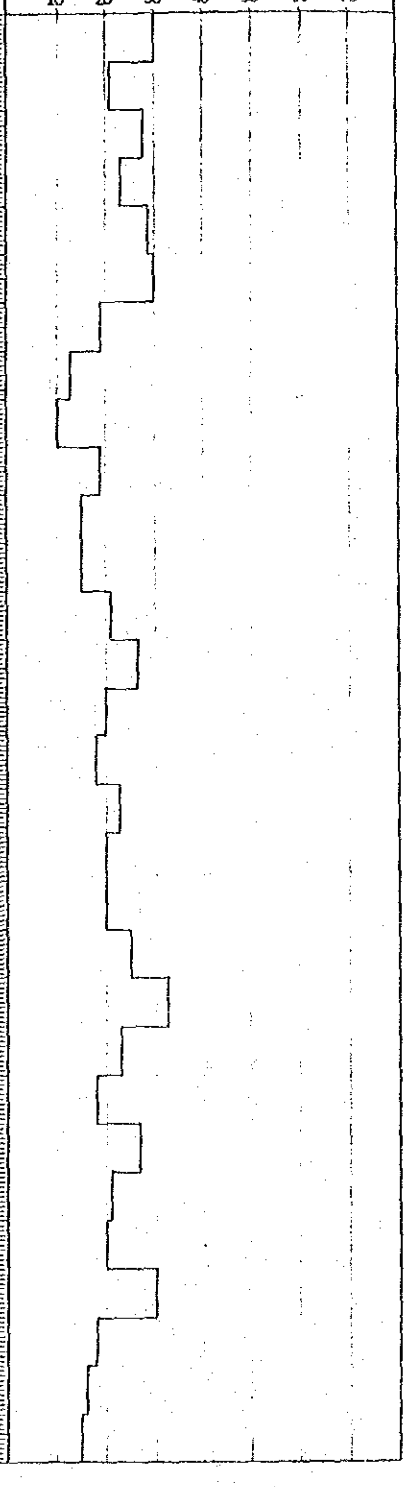


Fig. C-2-1(7) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	BARKA	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		61	9		MARL	-- Same as above mentioned description --
		70	9		MARL	Light gray to white marl with sand, facies is rather soft than the above marly horizon.
		85	15		MARLSTONE	Light gray to white marlstone with gravel, sandyclay layers partly intercalated.
		87	2		MARLSTONE	Light gray to white marlstone with sandy material.
					MARLSTONE	Light gray to white marlstone with gravel.

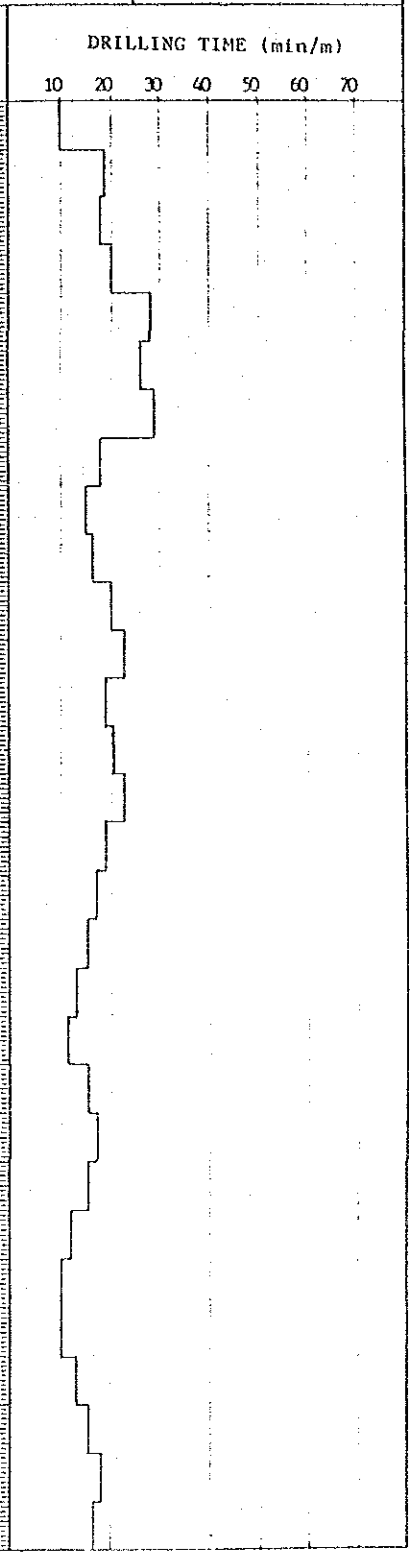


Fig. C-2-1(7) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OVSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 1	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	BARKA	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		93	6		MARLSTONE	-- Same as above mentioned description --
		94	1		MARLSTONE	Light gray to white marlstone with clay.
		98	4		MARLSTONE	Light gray to white marlstone with gravel.
		102	4		MARLSTONE	Light gray to white marlstone with clay and gravel.
		104	2		MARLSTONE	Light gray to white marlstone with granule.

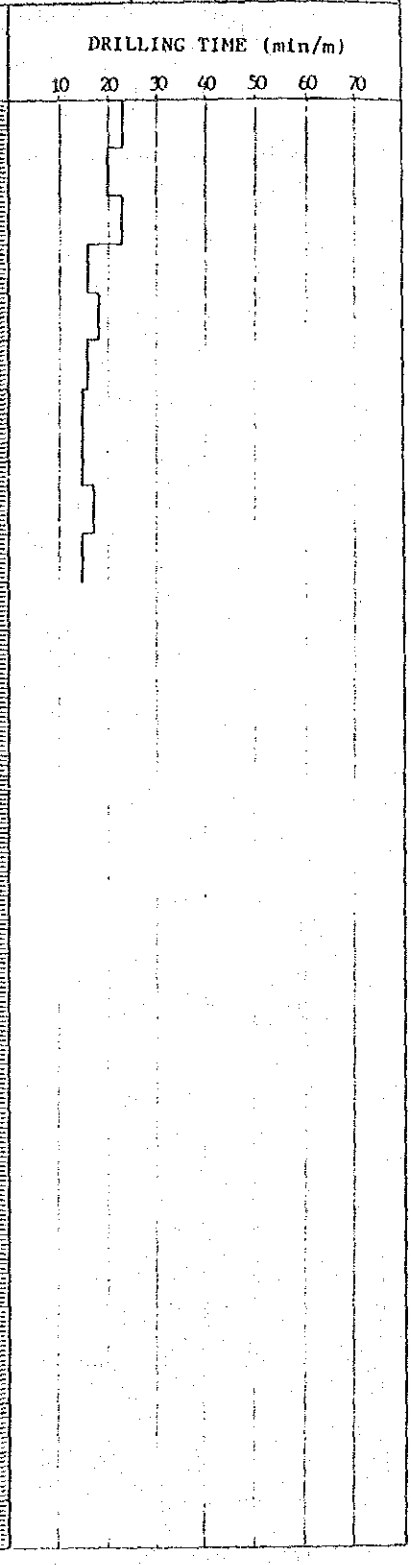


Fig. C-2-1(8) Geological Log of Observation Well, BM2

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NORTH OF AL WASIT	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		2	2		GRAVEL	Gravel with silt, white to light gray colored facies, and clay dominant layer is much at the lower horizon.
		7	5		GRAVEL	Gray gravel with a few fine sand
		14	7		GRAVEL	Gravel with fine sand and a little of clay material, the lower facies contain medium sand in matrix.
		16	2		GRAVEL	Gray gravel with sand.
		20	4		GRAVEL	Gravel with silt and sand.
		21	1		GRAVEL	Gravel with sand.
		29	8		GRAVEL	Light gray to gray gravel with silt and a little of sand.
					GRAVEL	Gravel with silt and carbonate fragments.

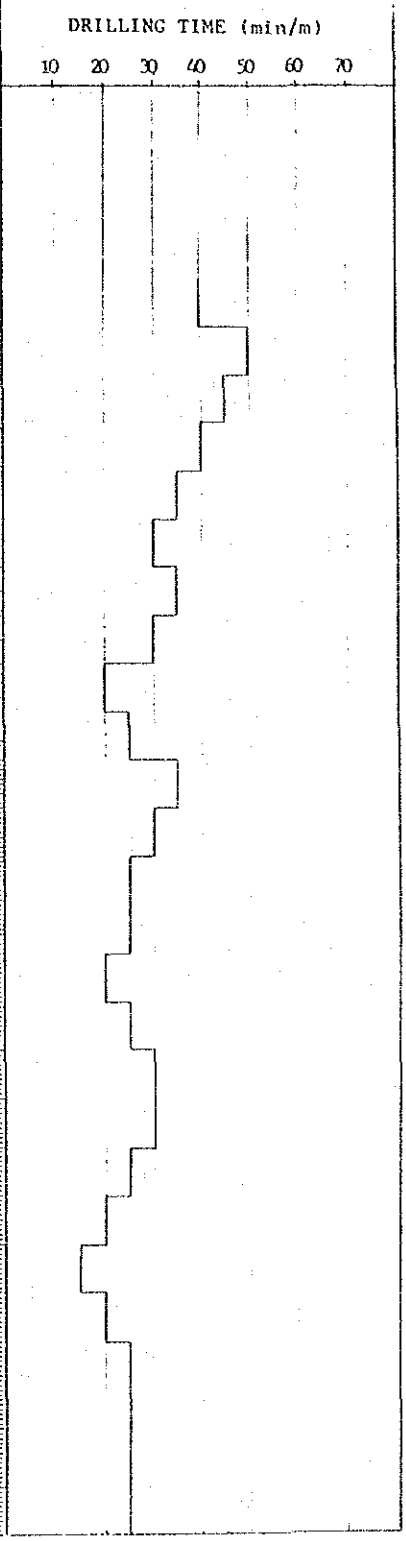


Fig. C-2-1(8) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NORTH OF AL-WASIT	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		31	2		GRAVEL	-- Same as above mentioned description --
		35	4		GRAVEL	Gravel with sand and clay, gray colored facies.
		36	1		GRAVEL	Gravel with sandyclay and carbonate fragments.
		47	11		GRAVEL	Gray gravel with sandyclay.
		49	2		GRAVEL	Gray gravel with sand, clay and carbonate fragments.
		52	3		GRAVEL	Gray gravel with sand and clay.
		54	2		GRAVEL	Gray to light gray gravel with sandyclay and carbonate fragments.
		55	1		GRAVEL	Gravel, clean gravel included large sized gravel.
		57	2		CLAY	Brown sand and clay with a little of granule.
					GRAVEL	Gravel with siltysand and carbonate fragments.

DRILLING TIME (min/m)

10 20 30 40 50 60 70

Fig. C-2-1(8) Continued

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL-MA'AWIL
HOLE NO.	BM 2	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	NORTH OF AL-WASIT	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
					GRAVEL	Gray gravel with sandysilt and carbonate material .
					GRAVEL	Gray gravel with carbonate material, the large sized gravel are contained.
					GRAVEL	Light gray gravel with sand and carbonate material, facies is concreated by carbonate matrix.
					GRAVEL	Light gray gravel with silt and a few sand.
					GRAVEL	Dark gray gravel, facies is composed of much amount of large sized gravel.

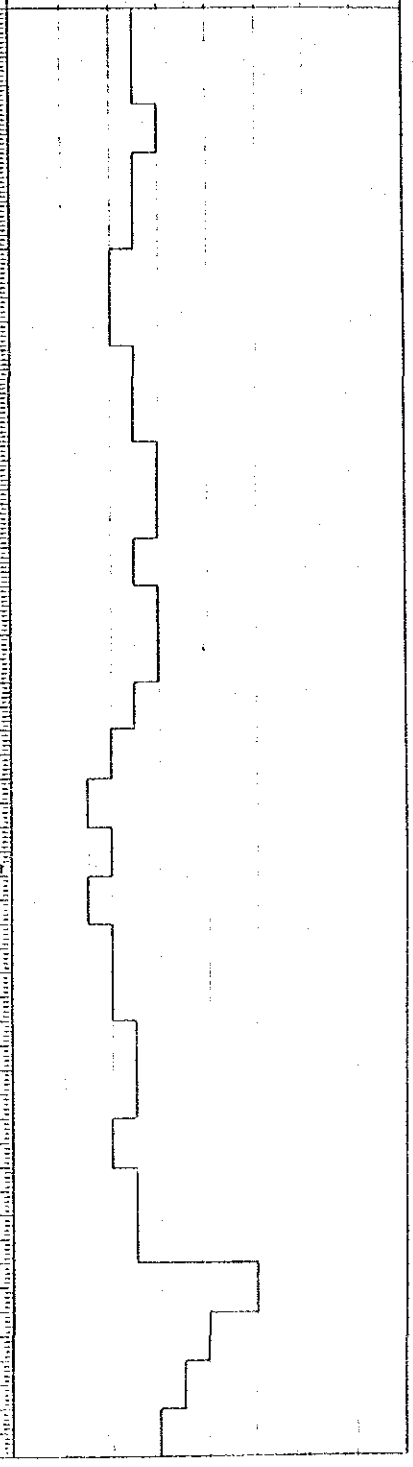


Fig. C-2-1(9) Geological Log of Observation Well, BM3

GEOLOGICAL LOG OF WELL

PROJECT	HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST	SITE	WADI AL MA'AWIL
HOLE NO.	BM 3	ANGLE FROM HORIZONTAL	FOREMAN	
LOCATION	UPSTREAM OF HIFRI	COMMENCED	LOGGED BY	
HOLE DIA.	10 "	COMPLETED	CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		2	2		SAND	Reddish brown sand with granule and a few silt.
		4	2		CLAY	Clay with sandy particles, light gray colored calcarious sediments.
		6	2		GRAVEL	Gray gravel with sand and carbonate fragments.
		7	1		GRAVEL	Gray gravel with clay.
		12	5		GRAVEL	Gray gravel with sand and clay.
		19	7		GRAVEL	Gravel with clay, gray to light gray colored gravelly layer filled up clayey matrix.
		20	1		SAND	Gray to light gray sand with much content of clayey matrix.
		25	5		GRAVEL	Gravel and sand with much amount of clay.
		27	2		GRAVEL	Gravel, gray colored clean gravel with a few sand.
		29	2		GRAVEL	Gray to light gray gravel with much content of clayey material.
					GRAVEL	Gray gravel layer made up of granule gravel.

DRILLING TIME (min/m)

10 20 30 40 50 60 70

Fig. C-2-1(9) Continued

GEOLOGICAL LOG OF WELL

PROJECT	TYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST			SITE	WADI AL MA'AWIL
HOLE NO.	BM 3	ANGLE FROM HORIZONTAL	PERPENDICULAR	FOREMAN	
LOCATION	UPSTREAM OF HIFRI	COMMENCED		LOGGED BY	
HOLE DIA.	10 "	COMPLETED		CHECKED BY	

DATE	ELEVATION (m)	DEPTH (m)	THICKNESS (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES
		31			GRAVEL	-- same as above mentioned description --
		42			GRAVEL	Gravel and sand, gray sand rich facies and gravel dominant layer are alternately interbeded, carbonate fragments are rare through the whole horizon.
		48			GRAVEL	Brownish gray gravel with sand and carbonate fragments.
		51			CLAY	Brownish gray clay with sand and granule, calcarious sediments are contained.

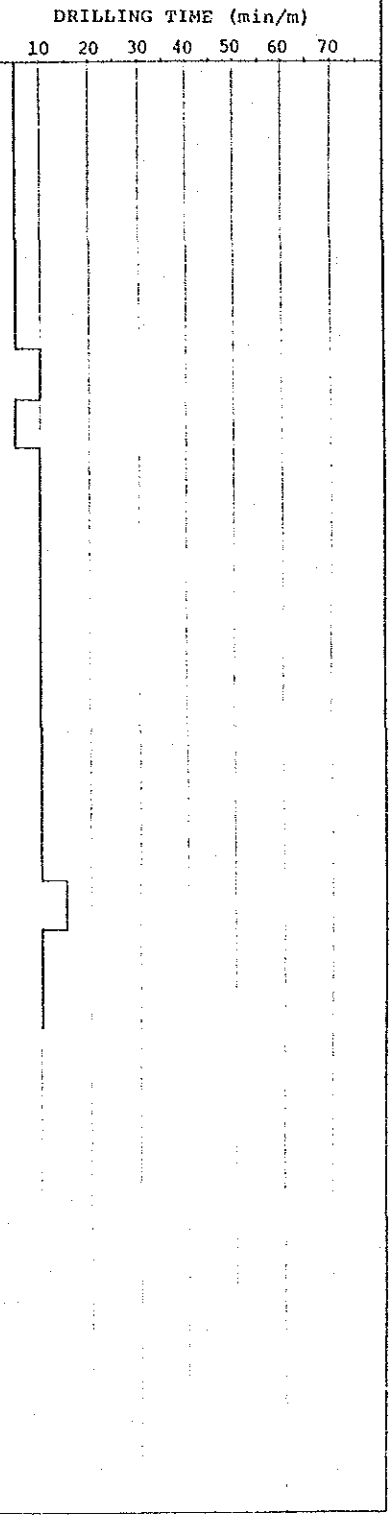
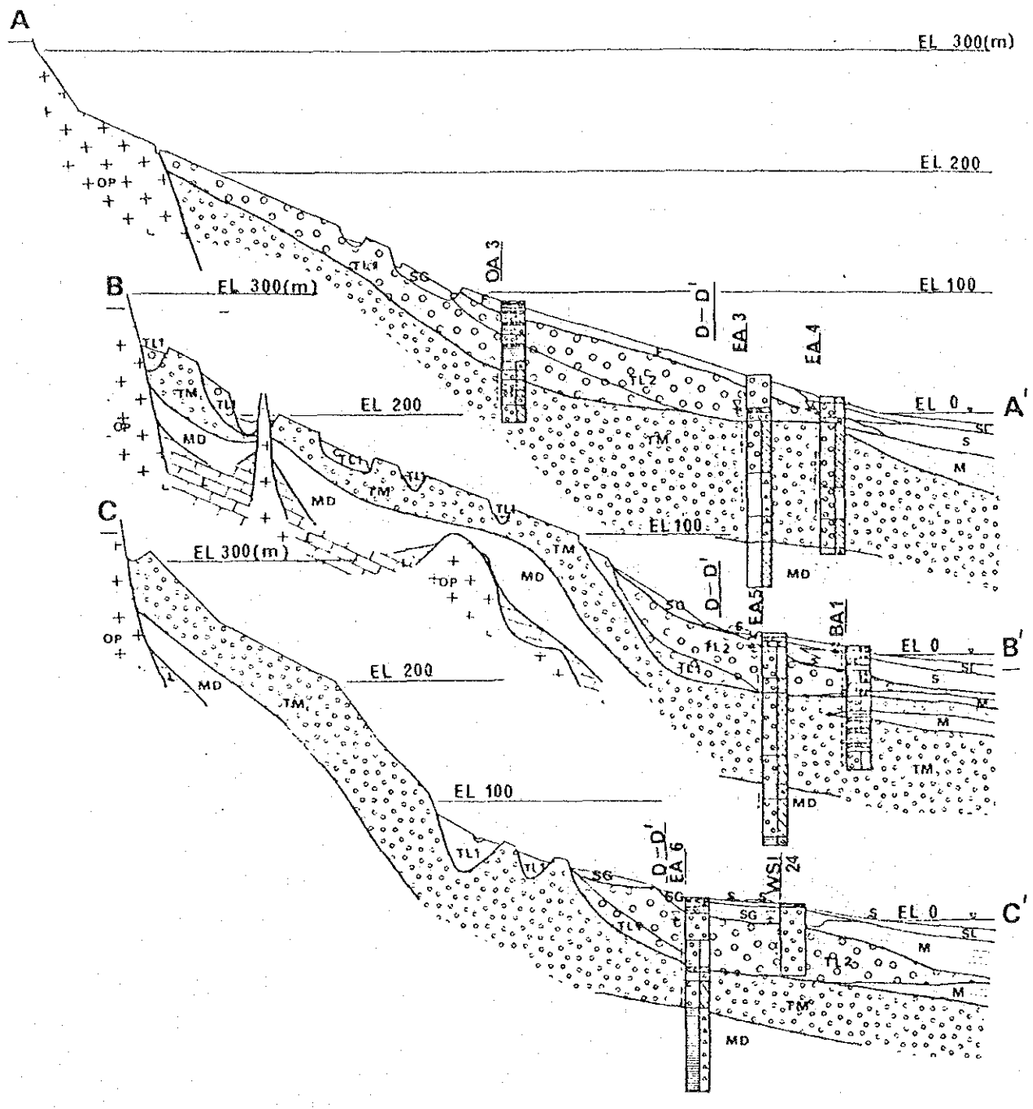
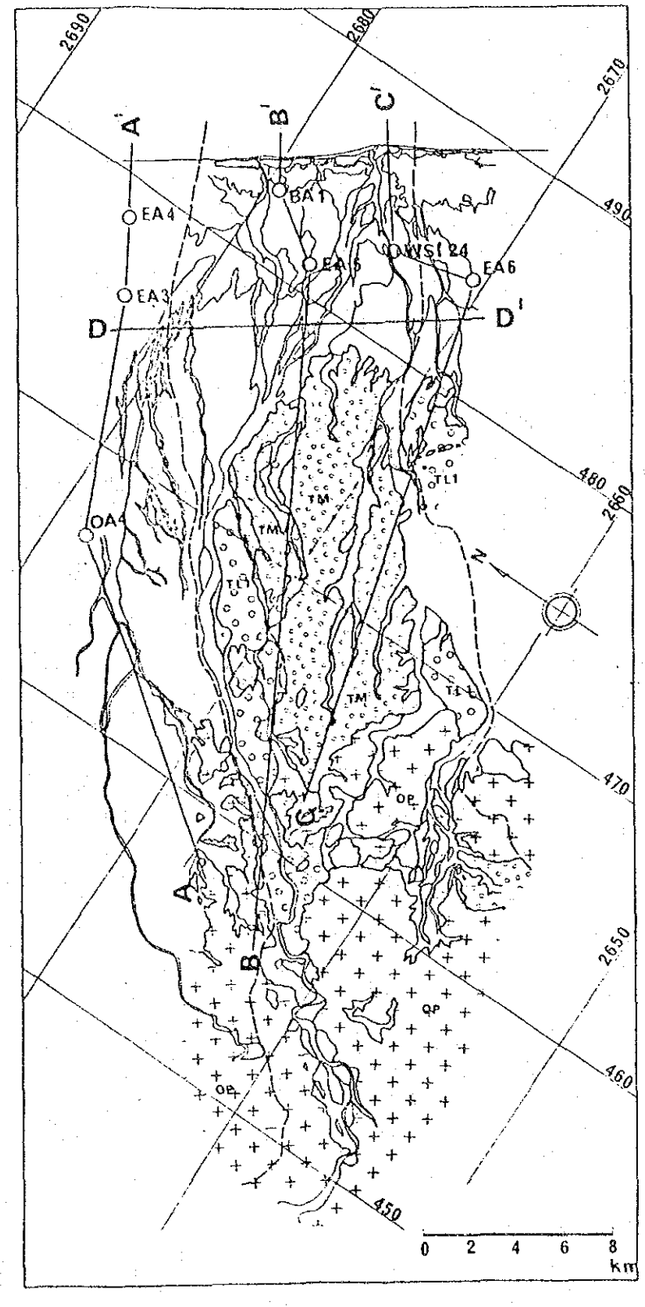
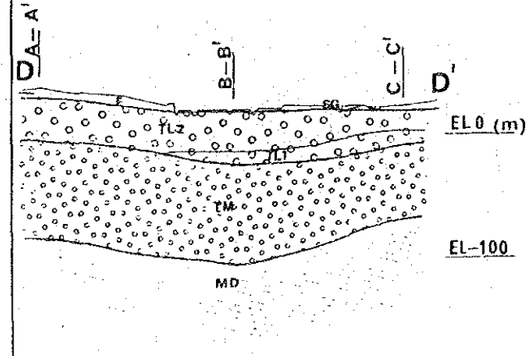


Fig. C-2-2(1) Hydrogeological Map and Cross Section of Wadi Ahin



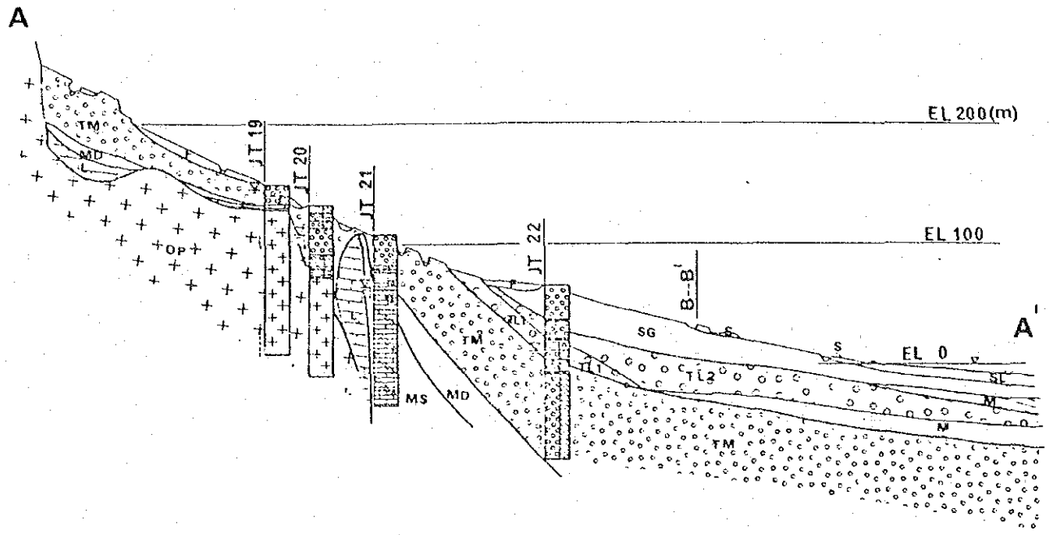


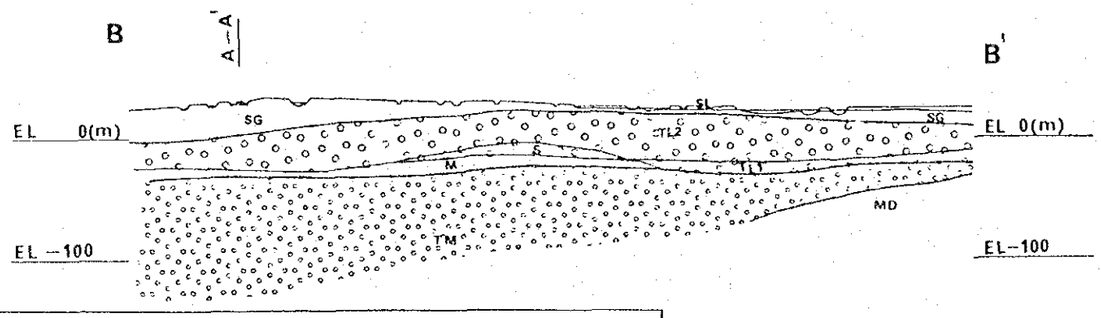


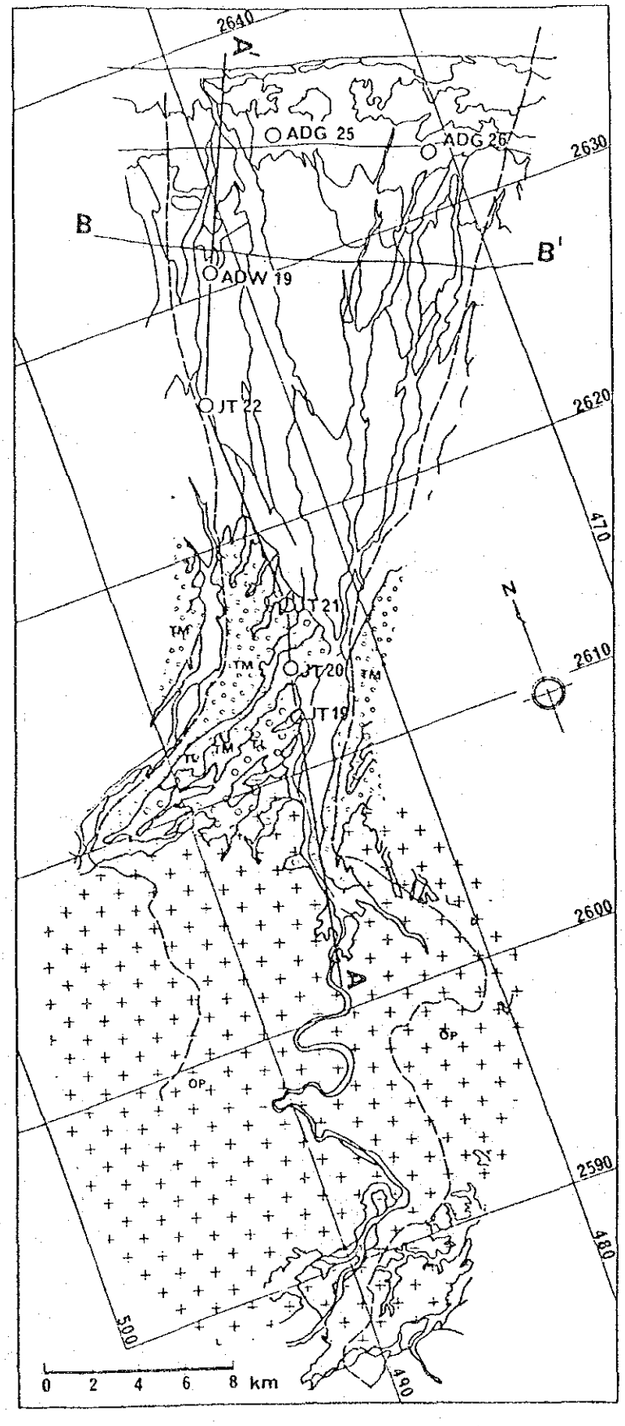
LEGEND

GEOLOGICAL FACIES		AQUIFER
S	Sand	Upper Aquifer
SL	Silt, Clay	
F	Fan deposit (Gravely facies)	
M	Marl, Marly clay	
SG	Sand and Gravel	
TL1	Terrace I deposit (Clayey gravel)	Middle Aquifer
TL2	Terrace I deposit (Sandy gravel, gravel)	Lower Aquifer
TM	Terrace II deposit (Concreated gravel)	
MS	Marlstone	Aquiclude
MD	Mudstone	
L	Limestone	Aquifuge
OP	Semail ophiolite	
HA	Hawasina complex (Chert, Sandstone, Limestone)	
HJ	Upper Hajar super GP. (Limestone, Marlstone)	
P	Pre-Permian metamorphics (Quartzite, Schist, Gneisses)	

Fig. C-2-2(2) Hydrogeological Map and Cross Section of Wadi Bani Ghafir



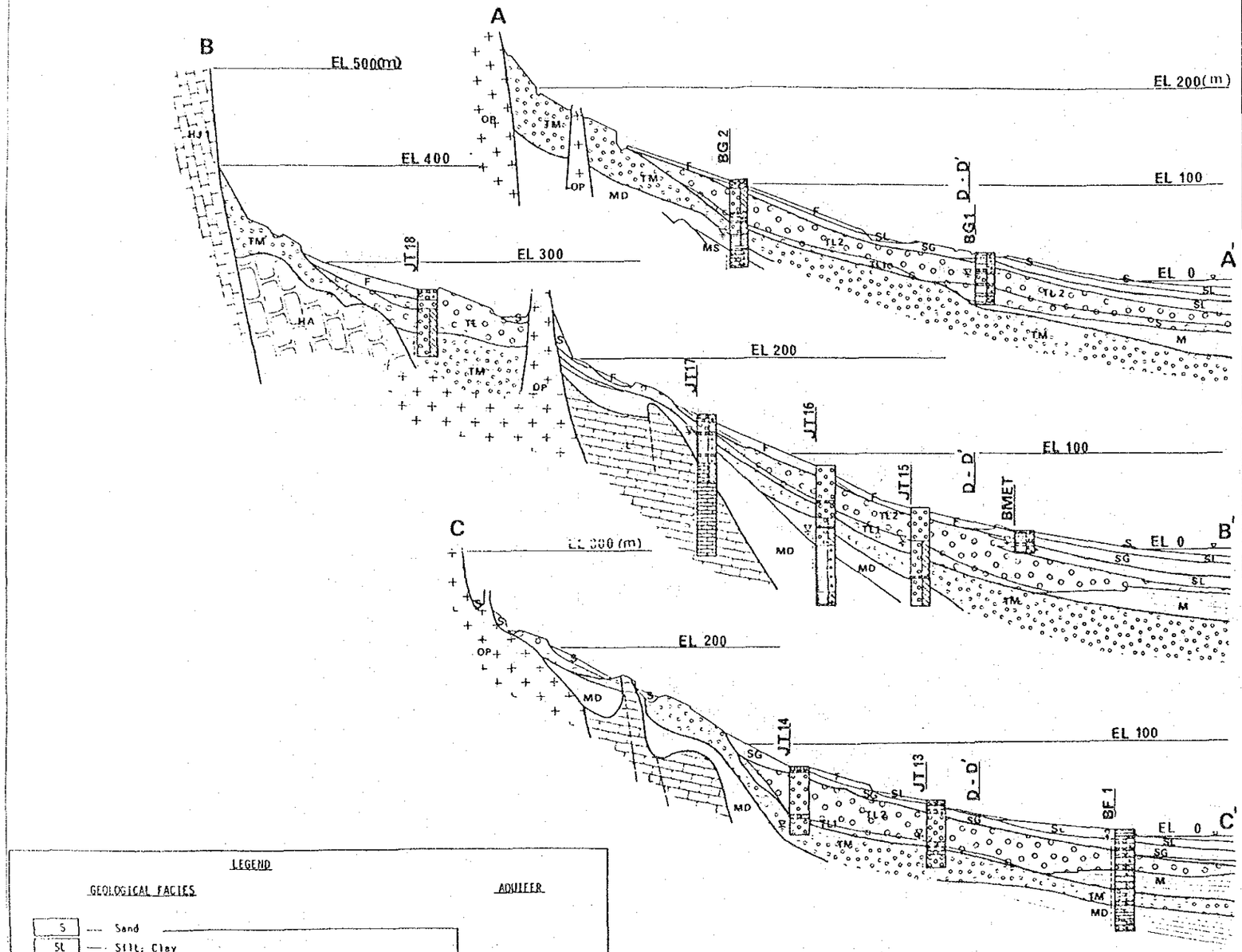


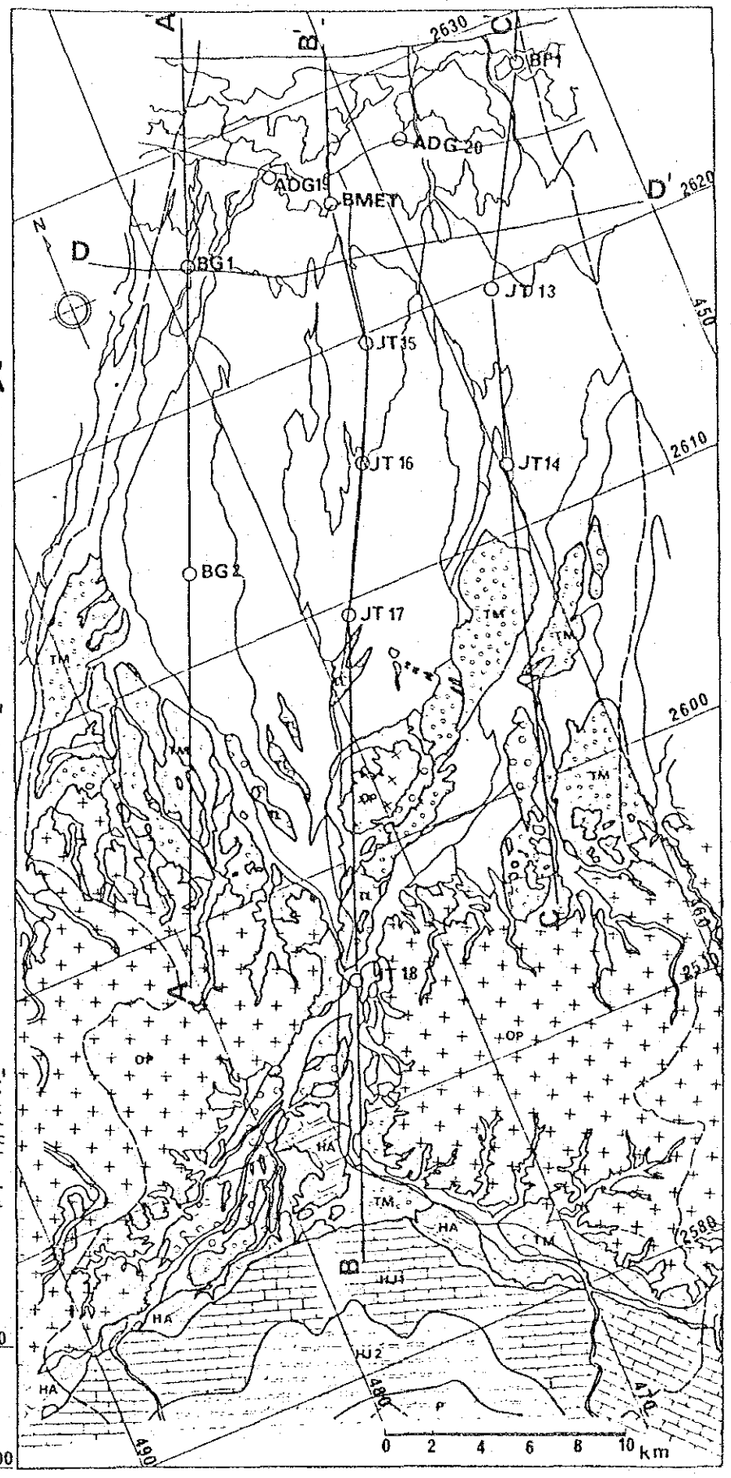


LEGEND

GEOLOGICAL FACIES		AQUIFER
S	Sand	Upper Aquifer
SL	Silt, Clay	
F	Fan deposit (Gravely facies)	
M	Marl, Marly clay	
SG	Sand and Gravel	
TL1	Terrace I deposit (Clayey gravel)	Middle Aquifer
TL2	Terrace I deposit (Sandy gravel, gravel)	
TM	Terrace II deposit (Concreated gravel)	Lower Aquifer
MS	Marlstone	Aquiclude
MD	Mudstone	
L	Limestone	Aquifuge
OP	Semail ophiolite	
HA	Hawasina complex (Chert, Sandstone, Limestone)	
H2	Upper Hajar super GP. (Limestone, Marlstone)	
P	Pre-Permian metamorphics (Quartzite, Schist, Gneisses)	

Fig. C-2-2(3) Hydrogeological Map and Cross Section of Wadi Al-Fara'

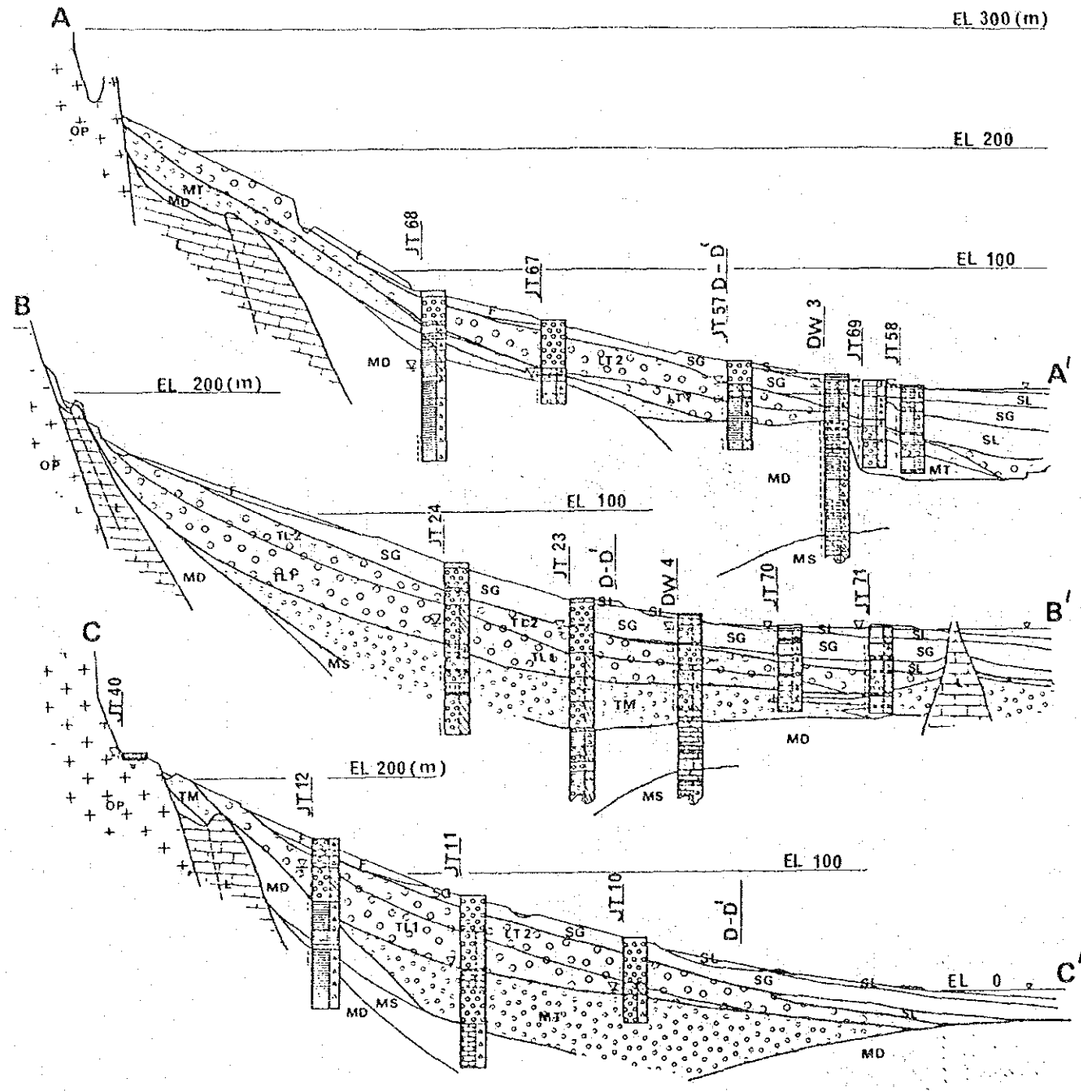


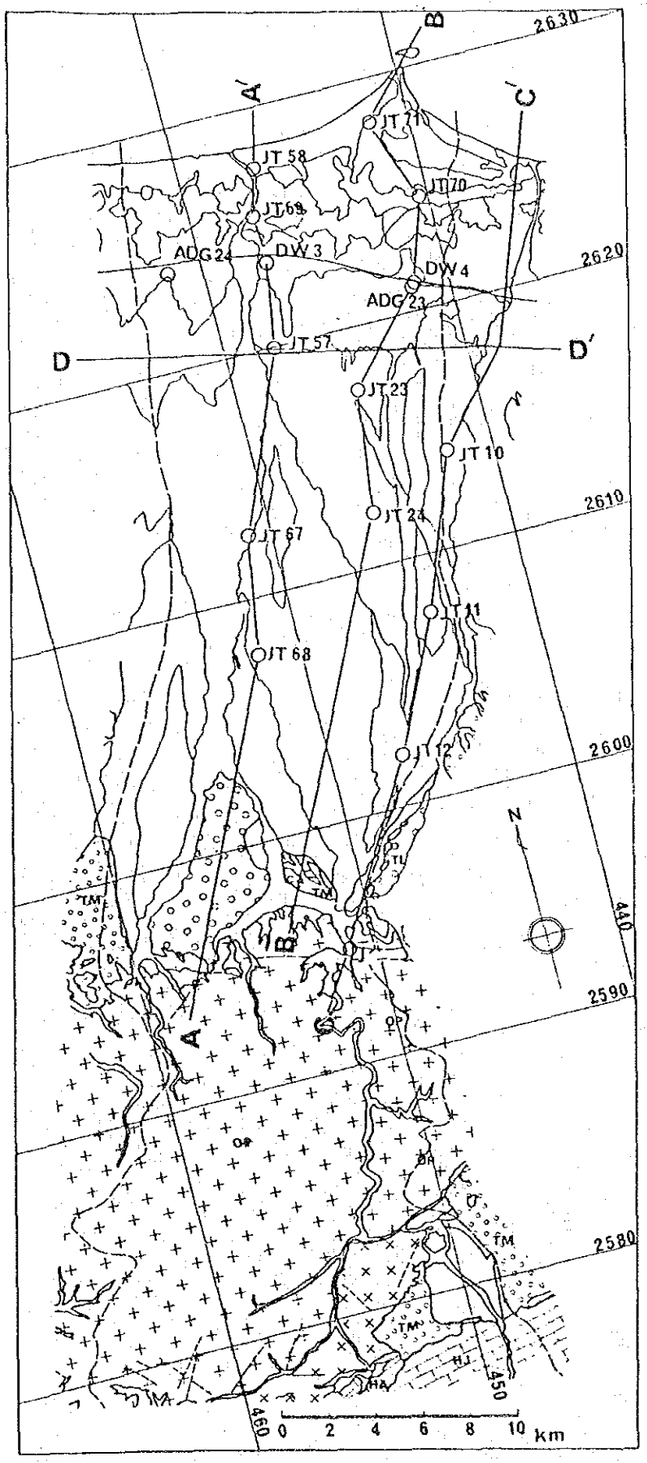


LEGEND

GEOLOGICAL FACIES		AQUIFER
S	Sand	Upper Aquifer
SL	Silt; Clay	
F	Fan deposit (Gravely facies)	
H	Marl, Marly clay	
SG	Sand and Gravel	
TL1	Terrace I deposit (Clayey gravel)	Middle Aquifer
TL2	Terrace I deposit (Sandy gravel; gravel)	
TM	Terrace II deposit (Concreated gravel)	Lower Aquifer
MS	Marlstone	Aquiclude
MD	Mudstone	
L	Limestone	Aquifuge
OP	Semail ophiolite	
HA	Hawasina complex (Chert, Sandstone, Limestone)	
HJ1	Upper Hajar super GP, (Limestone, Marlstone)	
HJ2	Lower Hajar super GP (Dolomite)	
P	Pre-Permian metamorphics (Quartzite, Schist, Gneisses)	

Fig. C-2-2(4) Hydrogeological Map and Cross Section of Wadi Bani Kharus

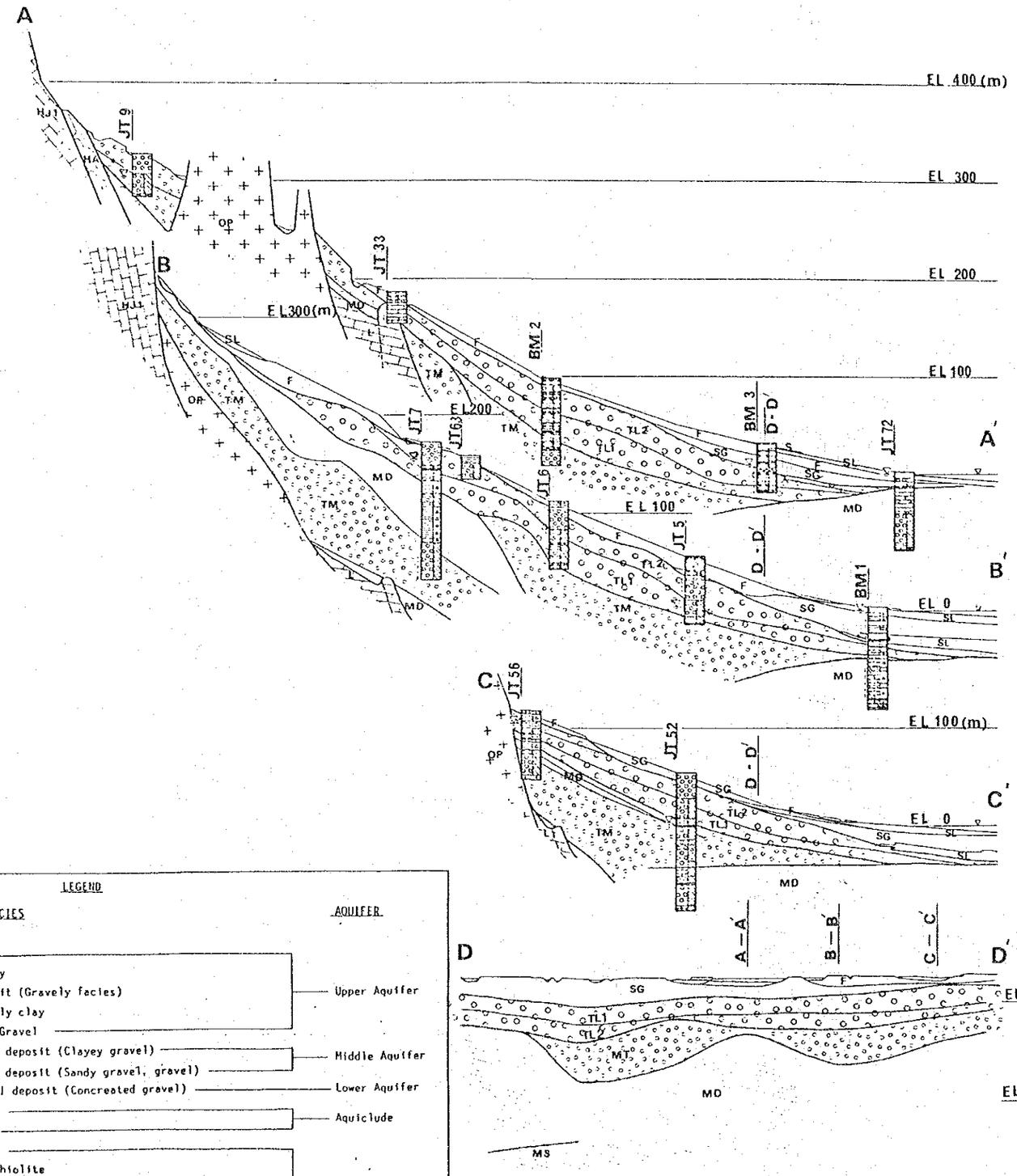


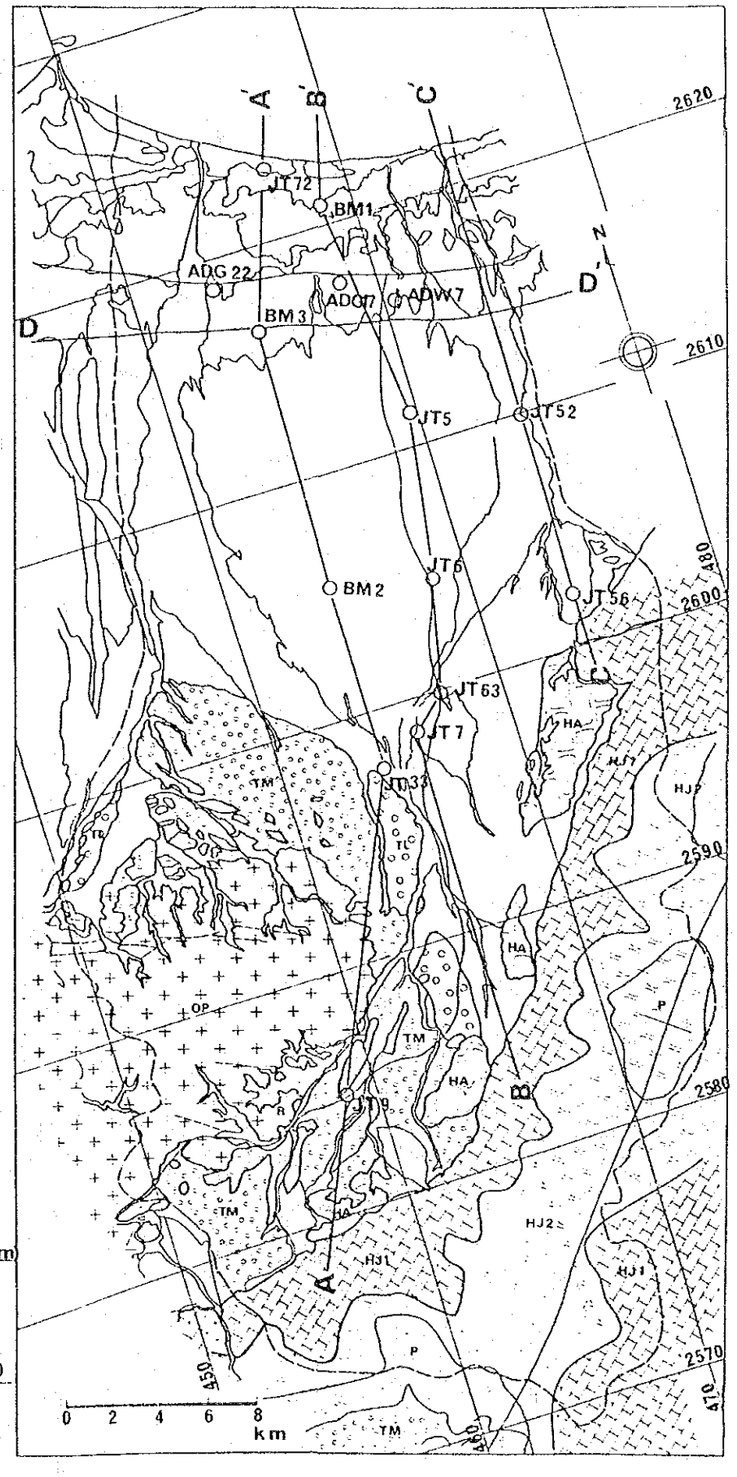


LEGEND

GEOLOGICAL FACIES		AQUIFER
S	Sand	Upper Aquifer
SL	Silt, Clay	
F	Fan deposit (Gravely facies)	
M	Marl, Marly clay	
SG	Sand and Gravel	
TL2	Terrace I deposit (Clayey gravel)	Middle Aquifer
TL1	Terrace I deposit (Sandy gravel, gravel)	
TM	Terrace II deposit (Concreated gravel)	Lower Aquifer
MS	Marlstone	Aquiclude
MD	Mudstone	
L	Limestone	Aquifuge
OP	Semail ophiolite	
HA	Hawasina complex (Chert, Sandstone, Limestone)	
HJ	Upper Hajar super GP. (Limestone, Marlstone)	
P	Pre-Permian metamorphics (Quartzite, Schist, Gneisses)	

Fig. Fig. C-2-2(5) Hydrogeological Map and Cross Section of Wadi Al-Ma'awil





LEGEND

GEOLOGICAL FACIES		AQUIFER
S	Sand	Upper Aquifer
SL	Silt, Clay	
F	Fan deposit (Gravely facies)	
M	Marl, Marly clay	
SG	Sand and Gravel	
TL 1	Terrace I deposit (Clayey gravel)	Middle Aquifer
TL 2	Terrace I deposit (Sandy gravel, gravel)	
TM	Terrace II deposit (Concreated gravel)	Lower Aquifer
MS	Marlstone	Aquiclude
MD	Mudstone	
L	Limestone	Aquifuge
OP	Semail ophiolite	
HA	Hawasina complex (Chert, Sandstone, Limestone)	
HJ1	Upper Hajar super GP. (Limestone, Marlstone)	
HJ2	Lower Hajar super GP (Dolomite)	
P	Pre-Permian metamorphics (Quartzite, Schist, Gneisses)	

2.2 Geo-resistivity Sounding

2.2.1 Outline of Survey

Geo-resistivity sounding surveys were conducted with OYO ESG2 type equipment, both for vertical and equi-depth soundings.

The vertical soundings were performed by the Wenner method along five observation lines with seventy nine observation points aligned along wadi courses around proposed project well sites. The observations were carried out at about two kilometre intervals along the observation lines, and the observation lines were determined by the courses that passed through the spots such as existing observation wells and proposed project wells which were expected to provide clear geological information for successful analysis.

Equi-depth sounding was carried out along five observation lines in the littoral area within four kilometres from the seacoast, consisting of two lines (ESH-1, 2), near Barka, three lines (ESH-3, 4, 4') in Sur Al-Bu Khamis near Abu Abali, one line (ESH-7) in Wadi Batha near Al-Suwaiq and two lines (ESH-5, 6) near Saham. The observations were conducted by both Wenner and Estlan arrangements in order to clarify sea water wedge which was supposed to intrude inland in the littoral area. (Location map is given in Fig. C-2-3).

2.2.2 Method of Analysis

The vertical soundings were conducted by the Wenner's four electrode method and the Sundberg standard method was adopted to analyse the observed sounding curves in case of conformable matching to the standard curve. For other cases where sounding curves were straight and had inflection points, the direct matching method was applied. Furthermore, these methods were also used to decide the boundary of deep geological formation.

Equi-depth Soundings were carried out by the two arrangements: Wenner and Eslan method, taking the unit separation of 10metres. This sounding method, the so-called $\rho a - \rho u$ method, presumes that the underground structure along sounding lines would have a mass of the unit volume with a resistivity of ρu. The specific resistivity values calculated by this hypothesis were plotted on an equi-resistivity map.

Once the patterns of resistivity distribution were drawn, the geological structure or the shape of seawater wedges was outlined.

2.2.3 Vertical Sounding

The vertical soundings on gravel plain were conducted to the depth of 100 m in order to clarify geological structure which consisted of gravel layers, which are favourable for aquifers, and the basement rocks. And other soundings near proposed project wells were surveyed for the acquisition of geological information in preparation of well drillings. As shown in Table C-2-1, the observed resistivity values could be classified into four to seven resistivity layers, based on presumed properties of the geological stratigraphy in wadi deposits.

The basement rocks are composed of Palaeozoic and/or Mesozoic formation such ophiolites and carbonate rocks, which outcrop on the mountain side surroundings wadi plain. According to the analysed profiles (Fig. C-2-4), the basement rocks are correlated with a very low resistivity layer, and seem to dip downstream steeply, therefore, the wdi basin underlain by these basement rocks may tend to extend to the littoral area.

The upper classic formation consists of recent wadi gravels, terrace deposits and tertiary deposits, and fills up the wadi basin. The relation between each layer is of overlapping structure, in which tertiary deposits are covered by terrace deposits and terrace deposits are overlain by the recent gravels. Also the distribution of these layers indicates that the upper layer may be located nearer to the littoral strip.

2.2.4 Equi-depth Sounding

The equi-depth soundings were carried out at the littoral strip within 4 km inland from the seacoast in order to clarify the shape of sea-water wedges.

The specific resistivity, i.e. ρu value is low and below 100 ohm-m over the whole observation lines as shown in the equi-depth resistivity maps (Fig. C-2-5). At the top formation along observation lines, which is made of fine materials, the resistivity values are variable between the coast and the inland of cultivated area. Resistivity values below 10 ohm-m were measured in the surface layers along coastside line, i.e. ESH-1, ESH-3, and they are attributed to the high salinity of groundwater.

The second resistivity layer is overlain by the surface low resistivity layer. The thickness of this layer is presumed to be 10 m to 20m according to the resistivity pattern of equi-resistivity maps. These resistivity values are possibly due to the semiconsolidated shore deposits which are made of the alternation of sand, gravel and clay, and these formations are traced horizontally at a about 50 m depth.

Through the classification of resistivity pattern, the interface between fresh and saltwater has been outlined at Barka line (ESH-1):
The observation line of Barka is located at 1.4 km to 1.9 km from the seacoast, where the 3.5 ohm-m contour line has been correlated with the interface at about 50 m depth.

Table C-2-1 Classification of Resistivities by Vertical Method

ESH-1 (Wadi Ahin Line)

Geographical Unit / Geological Unit	Upstream	Gravel Plain	Coastal Strip
Wadi Gravel Deposit I	-- (ohm-m)	320 - 3950 (ohm-m)	1000 (ohm-m)
Wadi Gravel Deposit II	--	68 - 638	60
Terrace Deposits	2950	140 - 465	31
Tertiary Deposits I	--	11 - 52	--
Tertiary Deposits II	--	205 - 300	--
Bed Rock	--	93	--

ESH-2 (Musana'ah - Jamma' Line)

Geographical Unit / Geological Unit	Upstream	Gravel Plain	Coastal Strip
Wadi Gravel Deposits I	-- (ohm-m)	340 - 29000 (ohm-m)	-- (ohm-m)
Wadi Gravel Deposits II	--	82 - 2700	1 - 70
Terrace Deposits	--	12 - 270	--
Tertiary Deposits I	--	28 - 510	--
Tertiary Deposits II	--	7 - 27	--
Tertiary Deposits III	--	24 - 38	--
Bed Rock	--	75 - 267	--

ESH-3 (Barka - Muslimat Line)

Geographical Unit / Geological Unit	Upstream	Gravel Plain	Coastal Strip
Wadi Gravel Deposits	29 - 4500 (ohm-m)	8 - 540 (ohm-m)	8 - 30 (ohm-m)
Terrace Deposits	--	9 - 250	--
Tertiary Deposits	--	1 - 19	5
Bed Rock	--	--	--

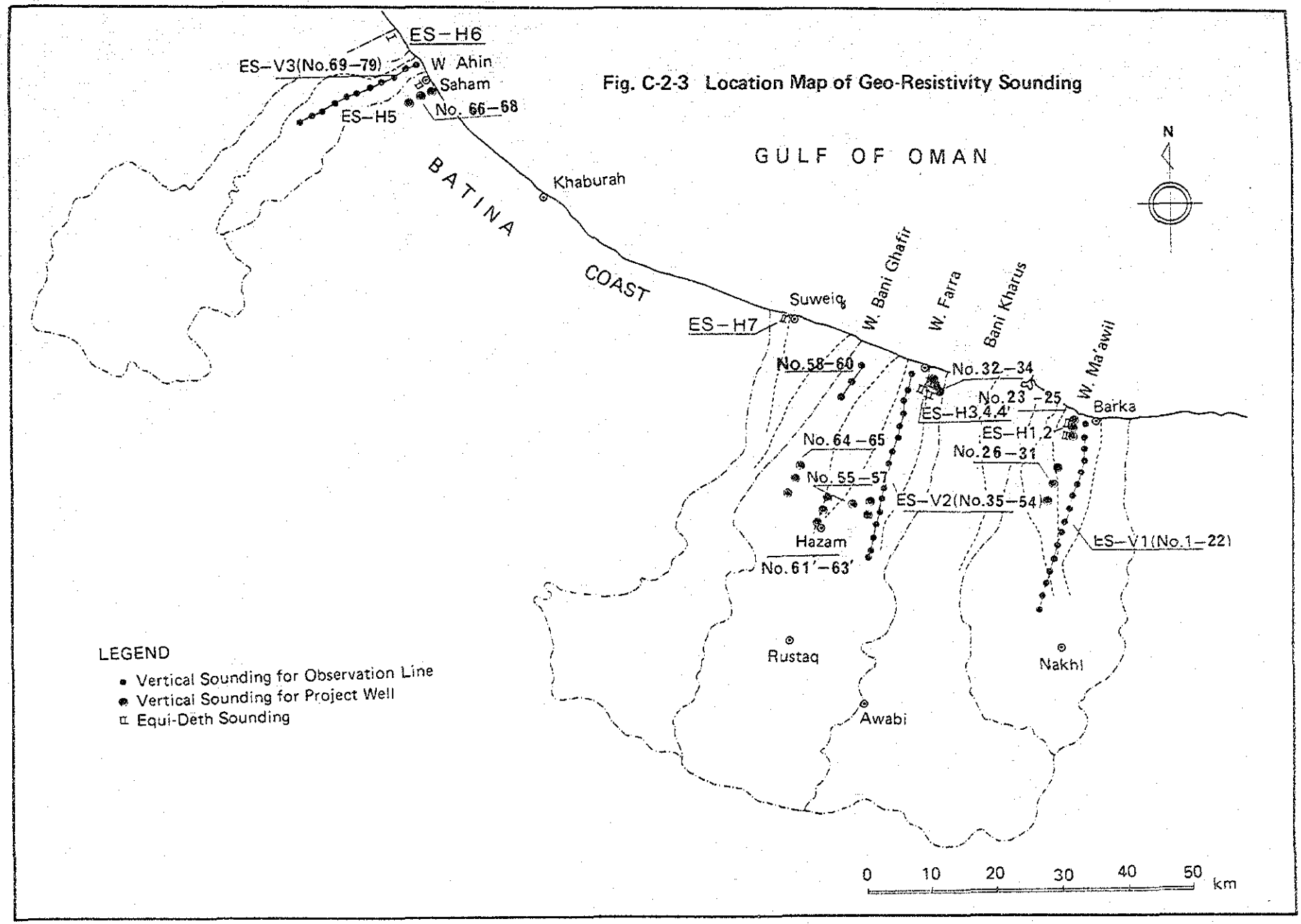
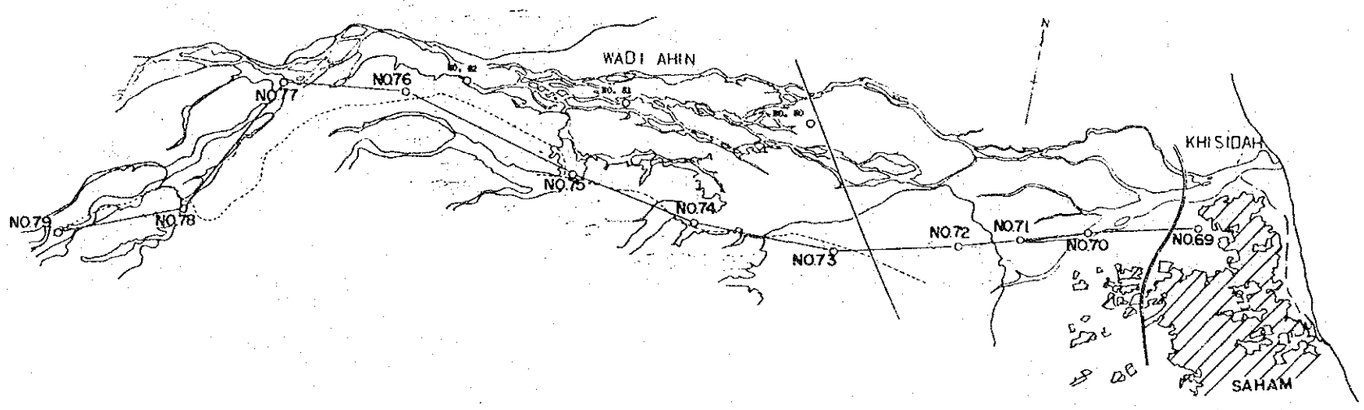


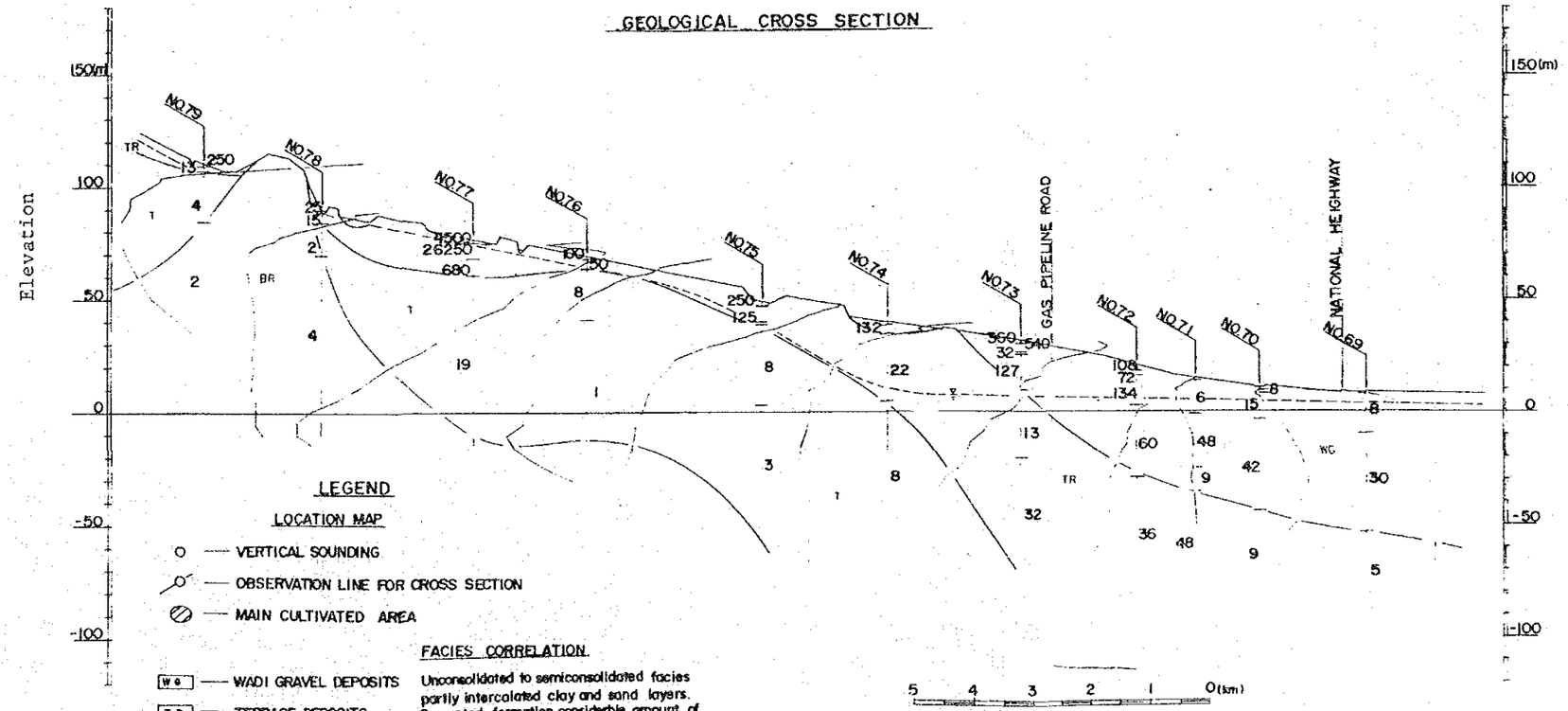
Fig. C-2-3 Location Map of Geo-Resistivity Sounding

Fig. C-2-4(1) Vertical Geo-Resistivity Soundings, Wadi Ahin Line

LOCATION MAP OF VERTICAL SOUNDING (WADI AHIN LINE)



GEOLOGICAL CROSS SECTION



LEGEND

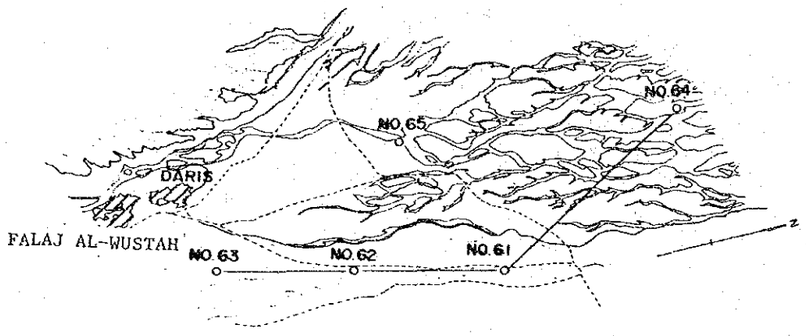
LOCATION MAP

- VERTICAL SOUNDING
- OBSERVATION LINE FOR CROSS SECTION
- MAIN CULTIVATED AREA

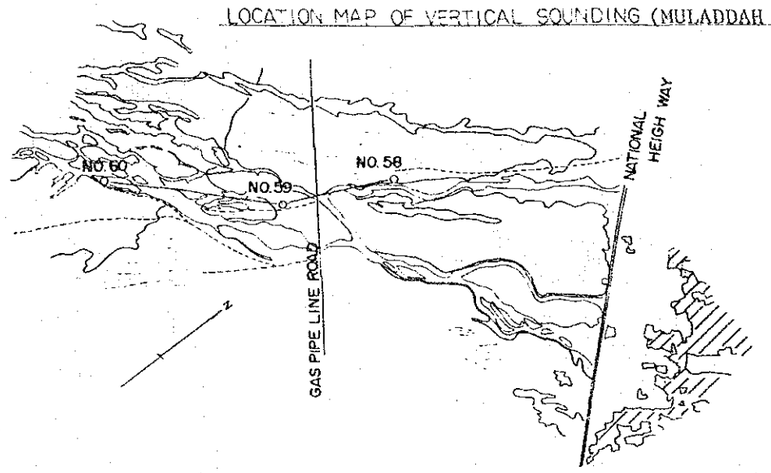
		FACIES CORRELATION.
WG	WADI GRAVEL DEPOSITS	Unconsolidated to semiconsolidated facies partly intercalated clay and sand layers.
TR	TERRACE DEPOSITS	Cemented formation, considerble amount of clay materials.
T	TERTIARY DEPOSITS	Marly mudstone or mudstone intercalated gravel dominant layers.
BR	BASEMENT ROCKS	Gabbros, serpentinized peridotites and basic extrusives.
▽	WATER TABLE	

Fig. C-2-4(2) Vertical Geo-Resistivity Soundings, Hazam Line – Muladdah Line

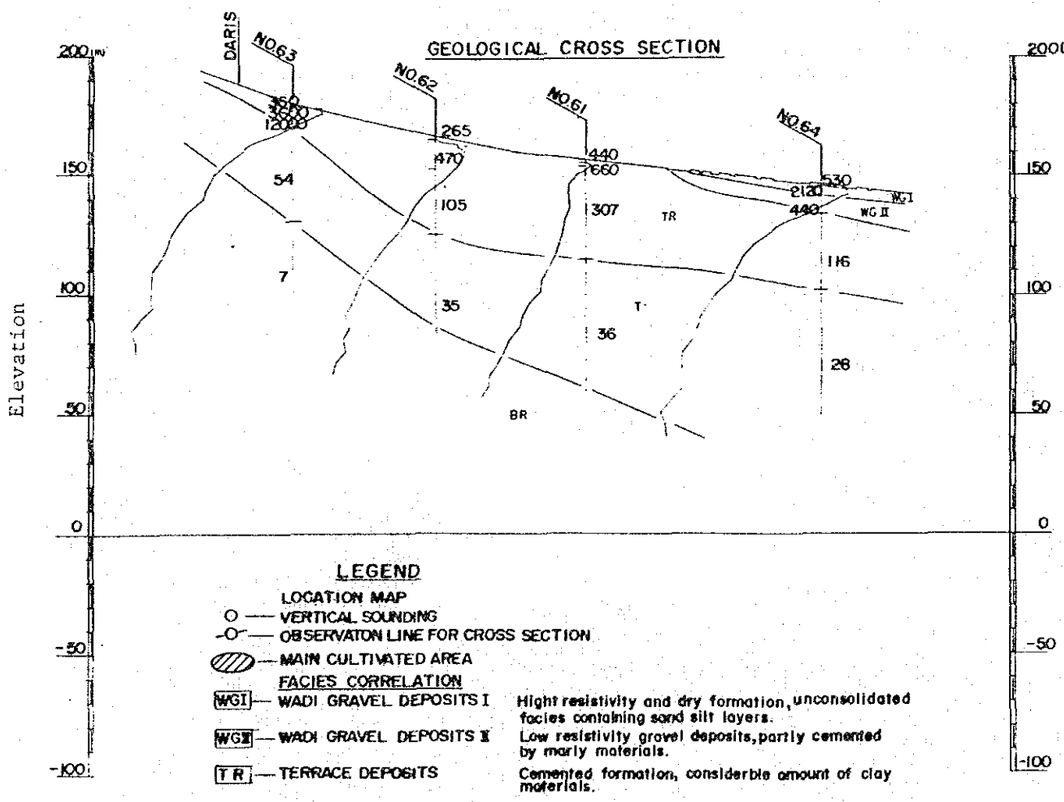
LOCATION MAP OF VERTICAL SOUNDING (HAZAM LINE)



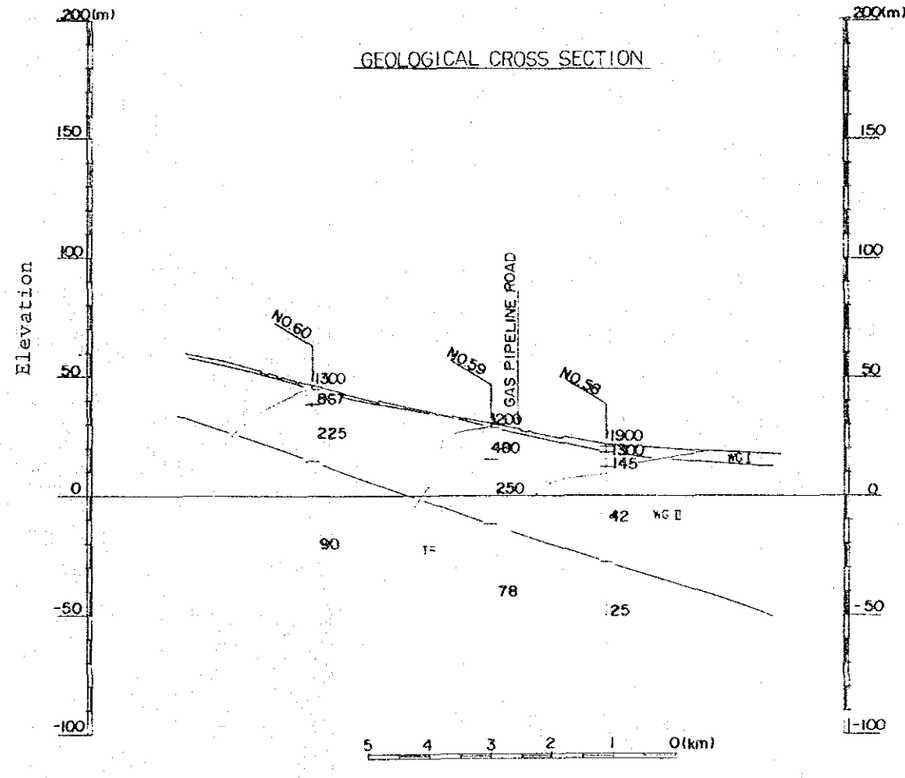
LOCATION MAP OF VERTICAL SOUNDING (MULADDAH LINE)



GEOLOGICAL CROSS SECTION



GEOLOGICAL CROSS SECTION



LEGEND

LOCATION MAP

O — VERTICAL SOUNDING

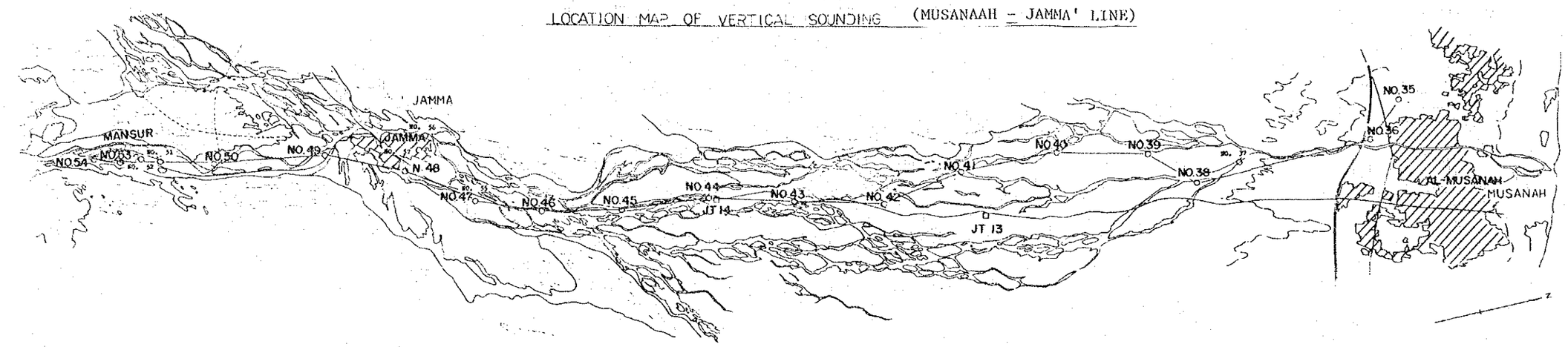
-O- — OBSERVATON LINE FOR CROSS SECTION

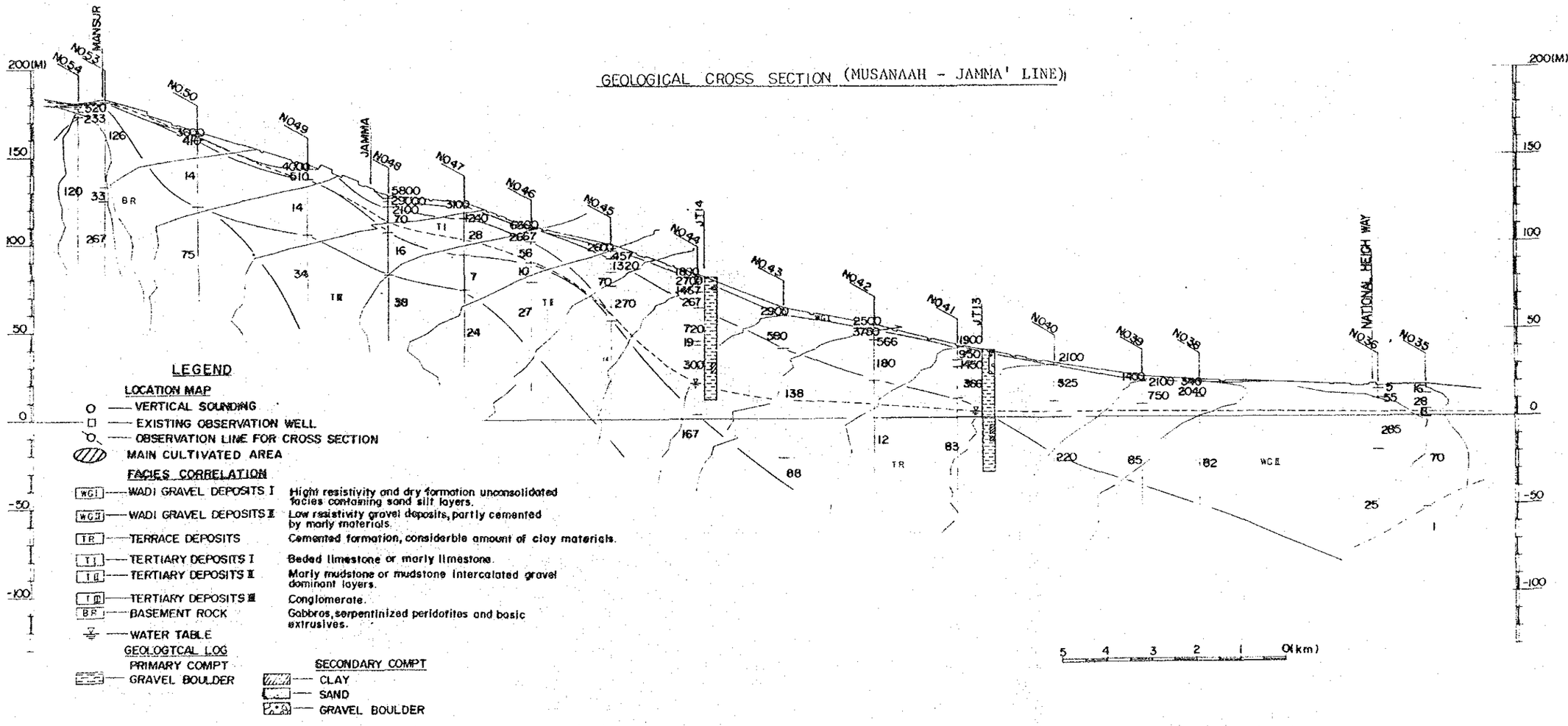
▨ — MAIN CULTIVATED AREA

FACIES CORRELATION

WGI	WADI GRAVEL DEPOSITS I	Hight resistivity and dry formation, unconsolidated facies containing sand silt layers.
WGII	WADI GRAVEL DEPOSITS II	Low resistivity gravel deposits, partly cemented by marly materials.
TR	TERRACE DEPOSITS	Cemented formation, considerble amount of clay materials.
T	TERTIARY DEPOSITS	Marl or marly limestone.
BR	BASEMENT ROCKS	Gabbros, serpentinized peridotites and basic extrusives.

Fig. C-2-4(3) Vertical Geo-Resistivity Soundings, Musana'ah – Jamma' Line





LEGEND

LOCATION MAP

- VERTICAL SOUNDING
- EXISTING OBSERVATION WELL
- OBSERVATION LINE FOR CROSS SECTION
- MAIN CULTIVATED AREA

FACIES CORRELATION

WGI	WADI GRAVEL DEPOSITS I	Hight resistivity and dry formation unconsolidated facies containing sand silt layers.
WGII	WADI GRAVEL DEPOSITS II	Low resistivity gravel deposits, partly cemented by marly materials.
TR	TERRACE DEPOSITS	Cemented formation, considerble amount of clay materials.
TI	TERTIARY DEPOSITS I	Beded limestone or marly limestone.
TII	TERTIARY DEPOSITS II	Marly mudstone or mudstone intercalated gravel dominant layers.
TIII	TERTIARY DEPOSITS III	Conglomerate.
BR	BASEMENT ROCK	Gabbros, serpentinized peridotites and basic extrusives.

- WATER TABLE

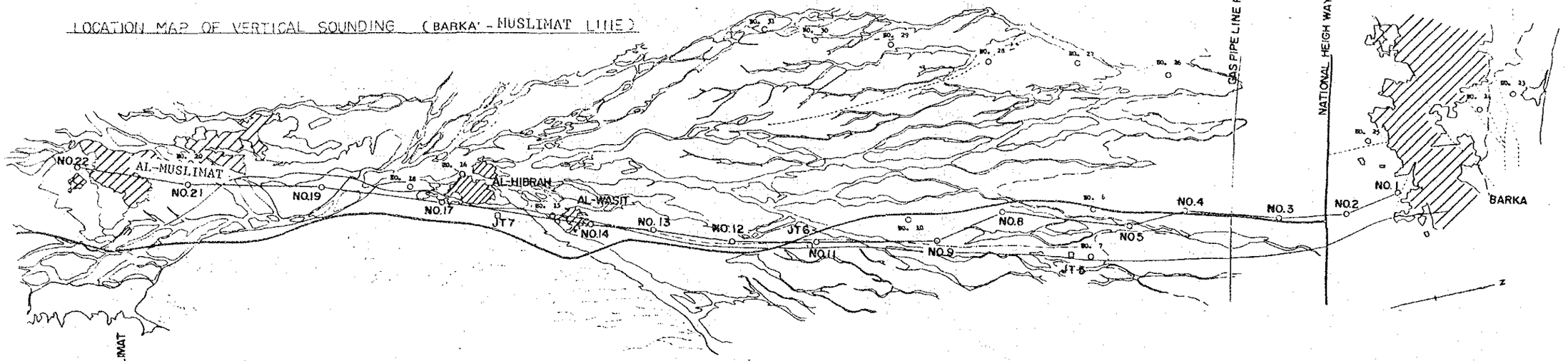
GEOLOGTCAL LOG

PRIMARY COMPT
- GRAVEL BOULDER

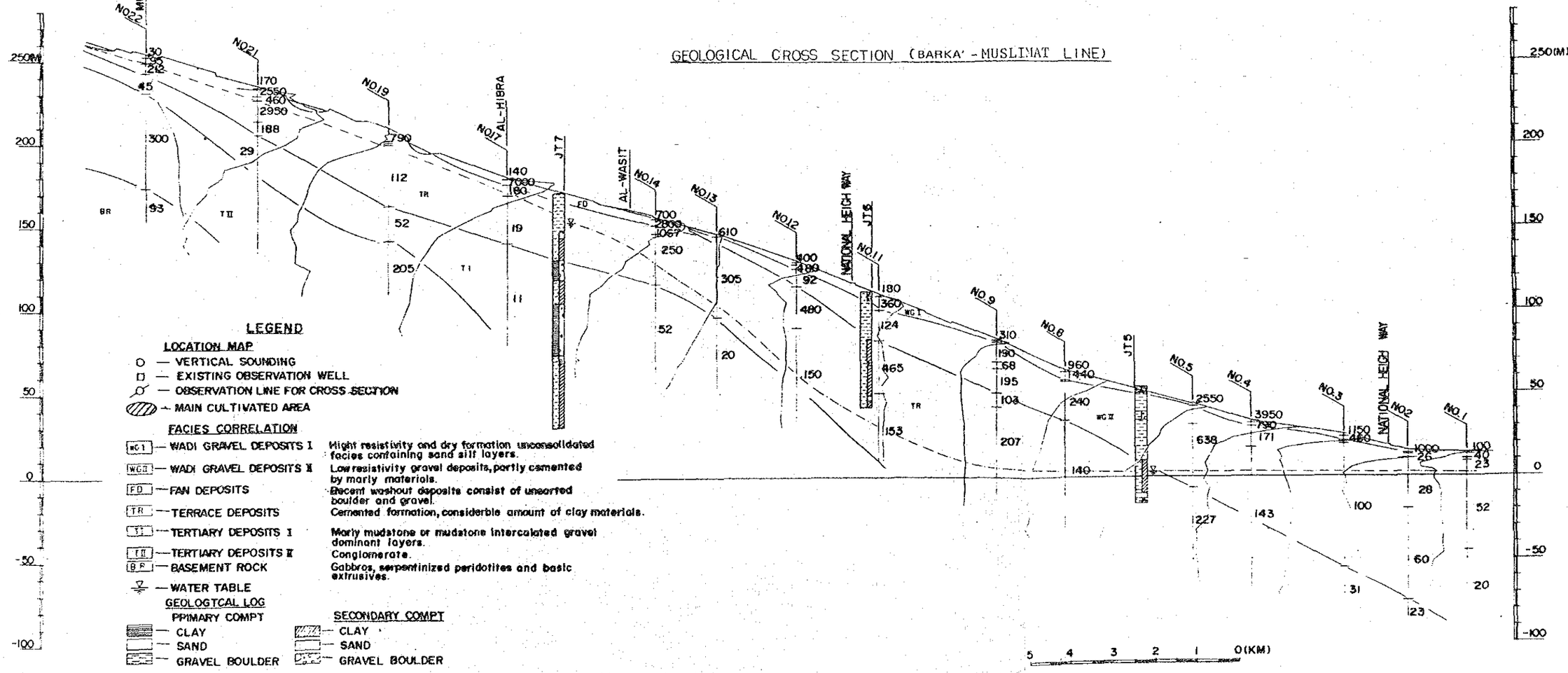
SECONDARY COMPT
- CLAY
- SAND
- GRAVEL BOULDER

Fig. C-2-4(4) Vertical Geo-Resistivity Soundings, Barka' — Muslimat Line

LOCATION MAP OF VERTICAL SOUNDING (BARKA' - MUSLIMAT LINE)



GEOLOGICAL CROSS SECTION (BARKA' - MUSLIMAT LINE)



LEGEND

LOCATION MAP

- O — VERTICAL SOUNDING
- □ — EXISTING OBSERVATION WELL
- — OBSERVATION LINE FOR CROSS SECTION
- — MAIN CULTIVATED AREA

FACIES CORRELATION

WG I	— WADI GRAVEL DEPOSITS I	Hight resistivity and dry formation unconsolidated facies containing sand silt layers.
WG II	— WADI GRAVEL DEPOSITS II	Low resistivity gravel deposits, partly cemented by marly materials.
FD	— FAN DEPOSITS	Recent washout deposits consist of unsorted boulder and gravel.
TR	— TERRACE DEPOSITS	Cemented formation, considerble amount of clay materials.
T I	— TERTIARY DEPOSITS I	Marly mudstone or mudstone intercalated gravel dominant layers.
T II	— TERTIARY DEPOSITS II	Conglomerate.
B R	— BASEMENT ROCK	Gabbros, serpentinized peridotites and basic extrusives.

▽ — WATER TABLE

GEOLOGTCAL LOG

PRIMARY COMPT	SECONDARY COMPT
— CLAY	— CLAY
— SAND	— SAND
— GRAVEL BOULDER	— GRAVEL BOULDER

Fig. C-2-4(5) Vertical Geo-Resistivity Soundings, Barka' — Khatum Line

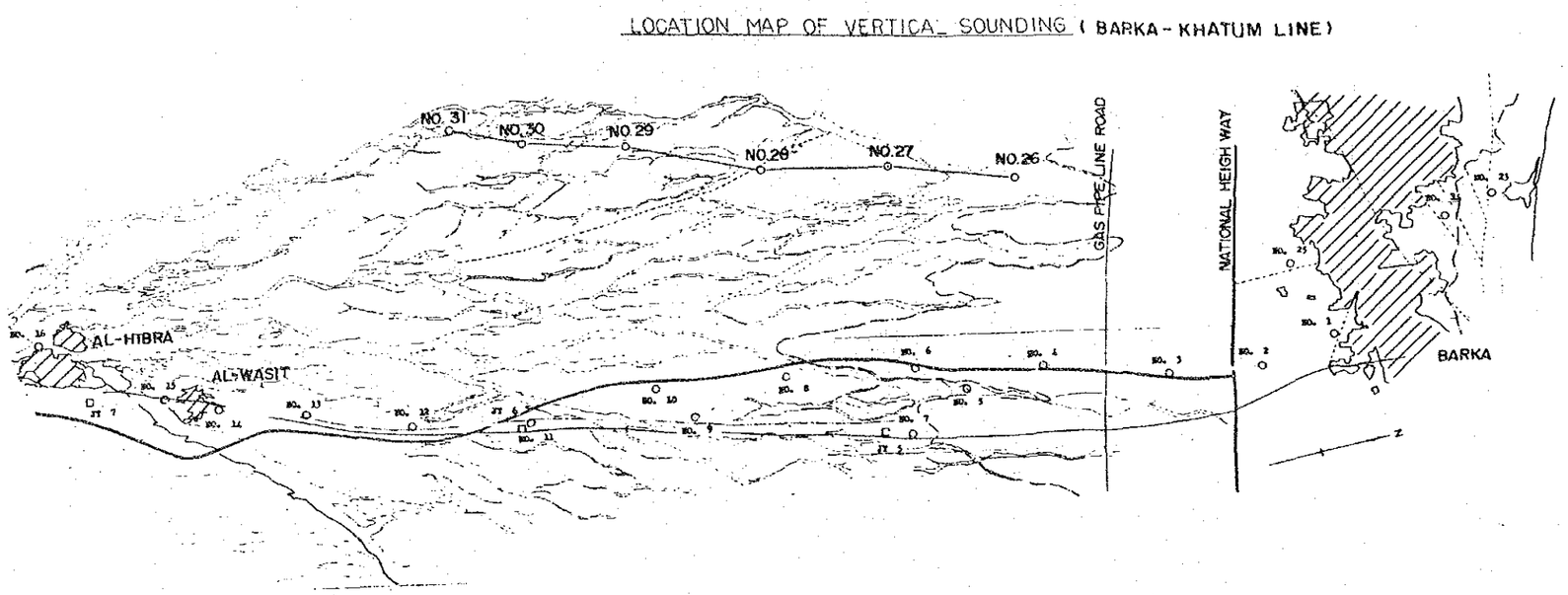
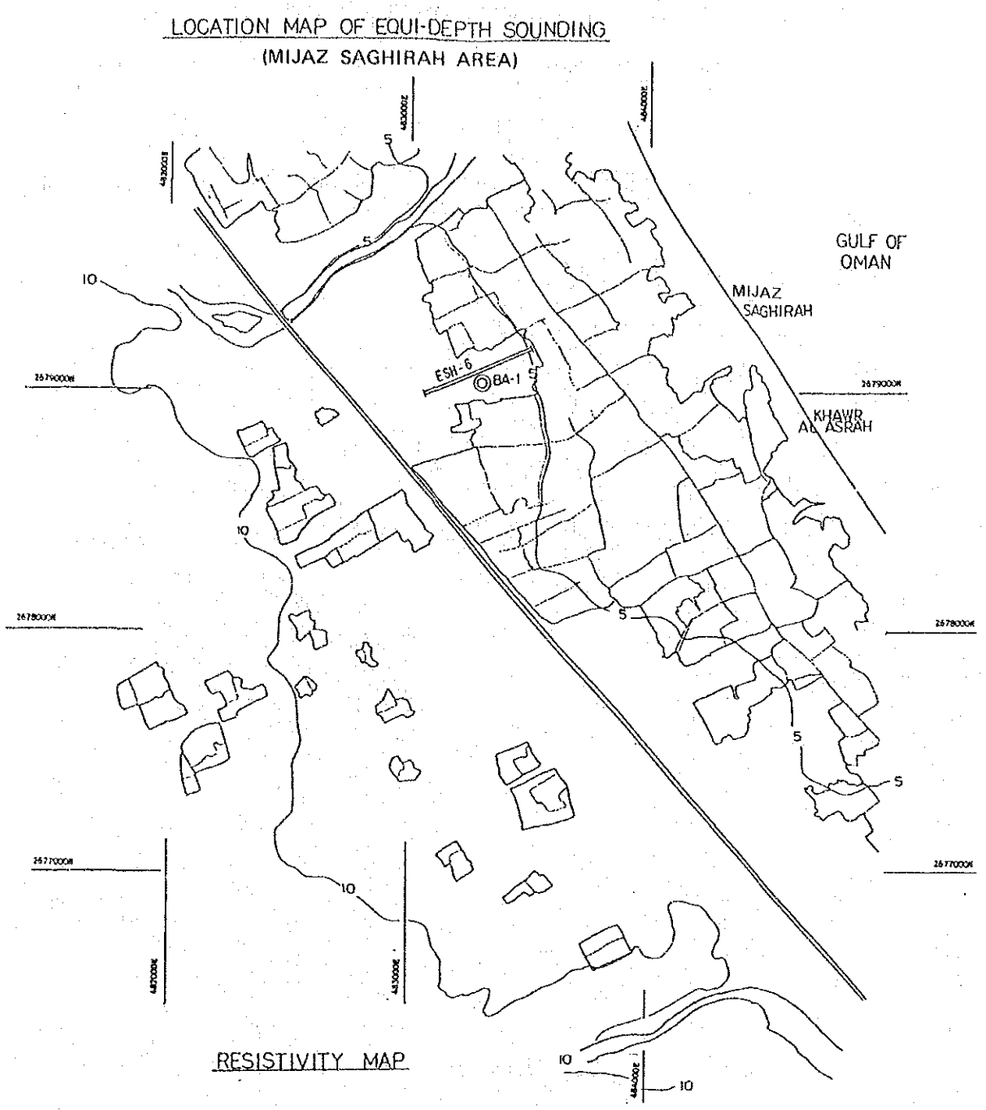
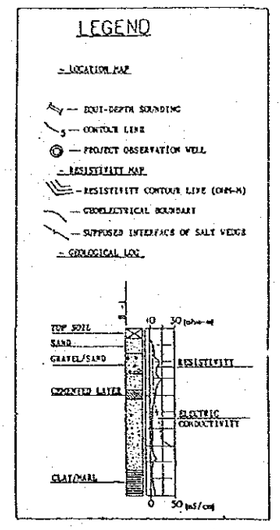
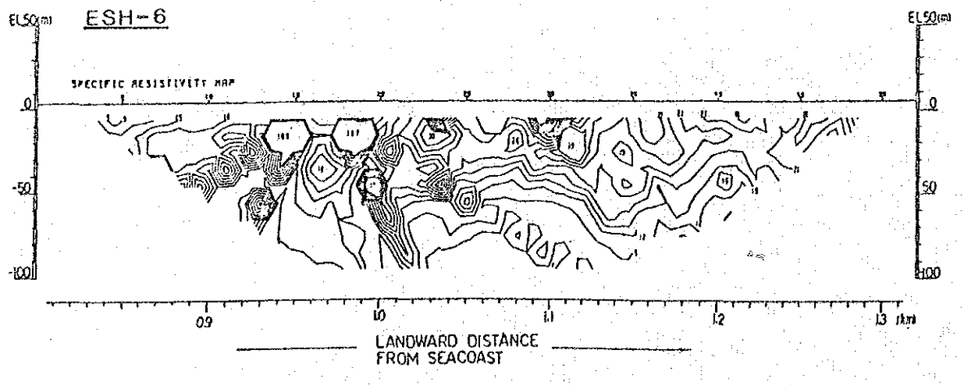


Fig. C-2-5(1) Equi-Depth Geo-Resistivity Soundings, Mijaz Saghirah Area







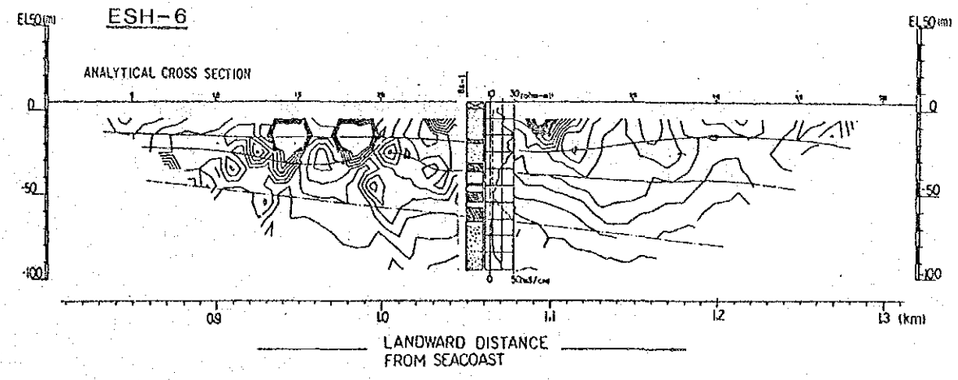
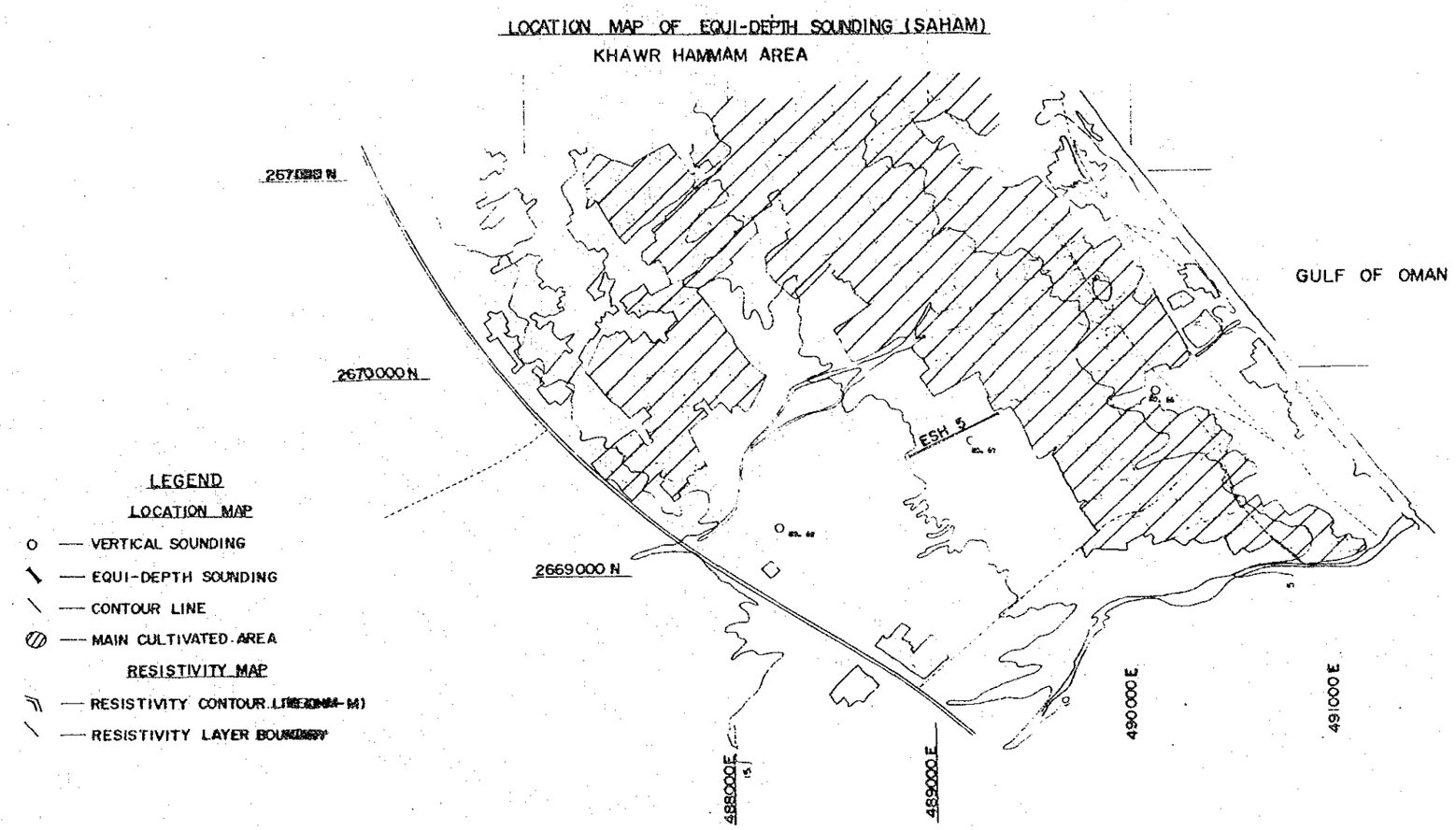
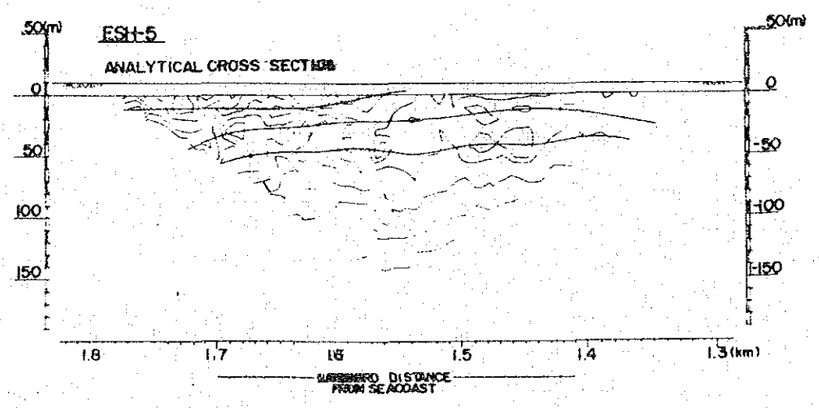


Fig. C-2-5(2) Equi-Depth Geo-Resistivity Soundings, Khawr Hammam Area



RESISTIVITY MAP



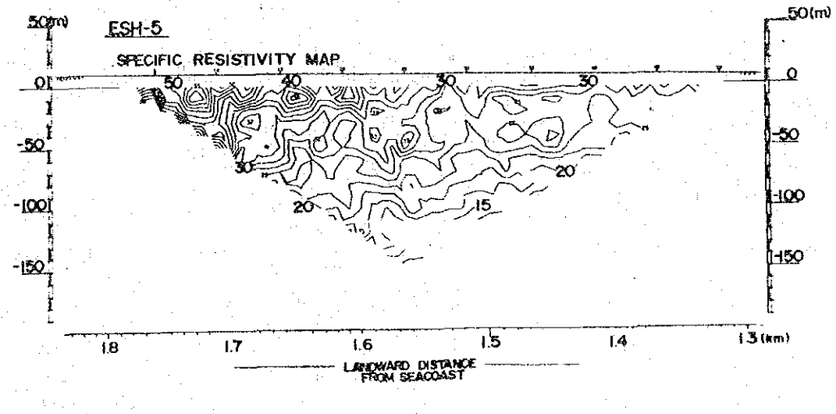
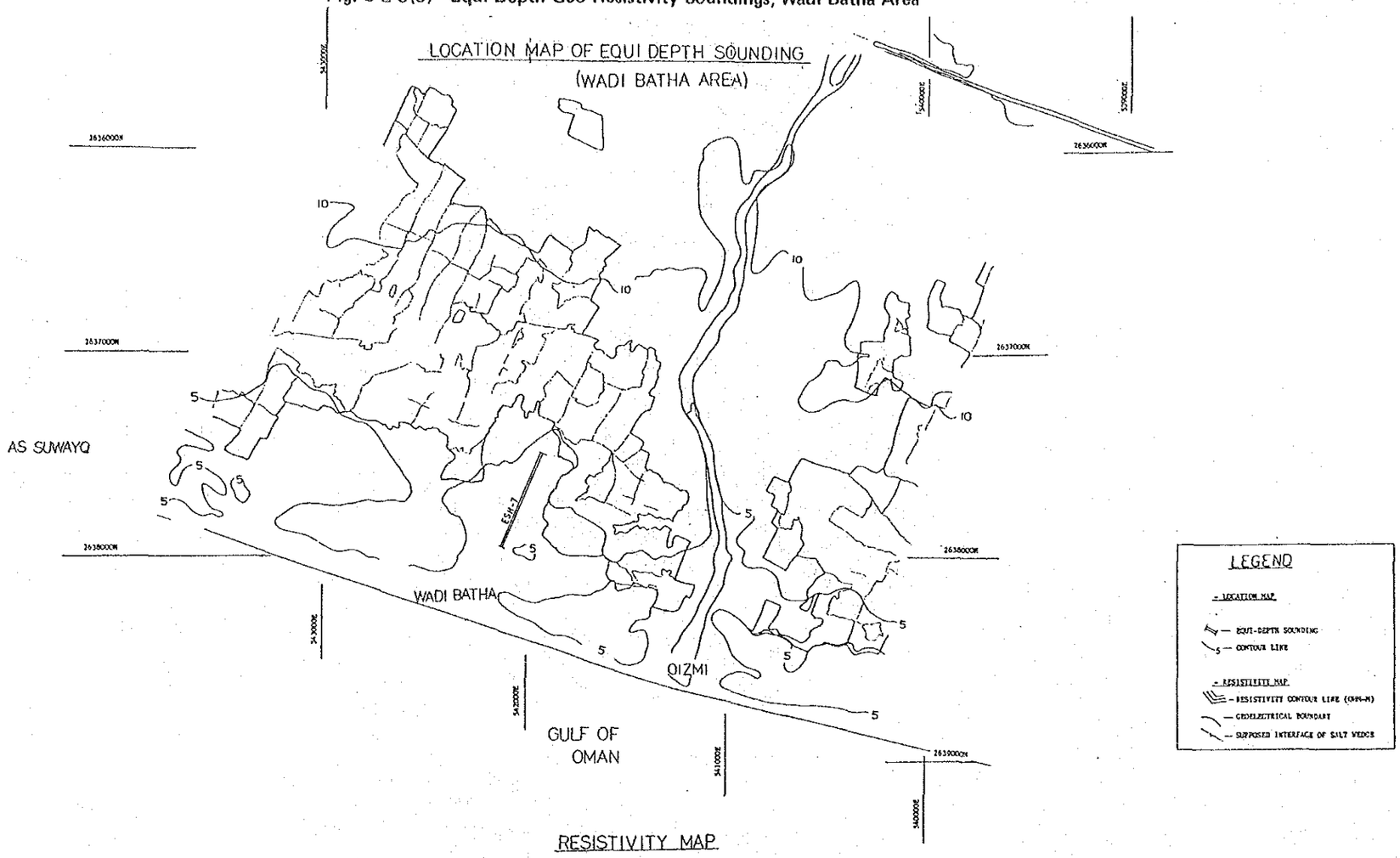
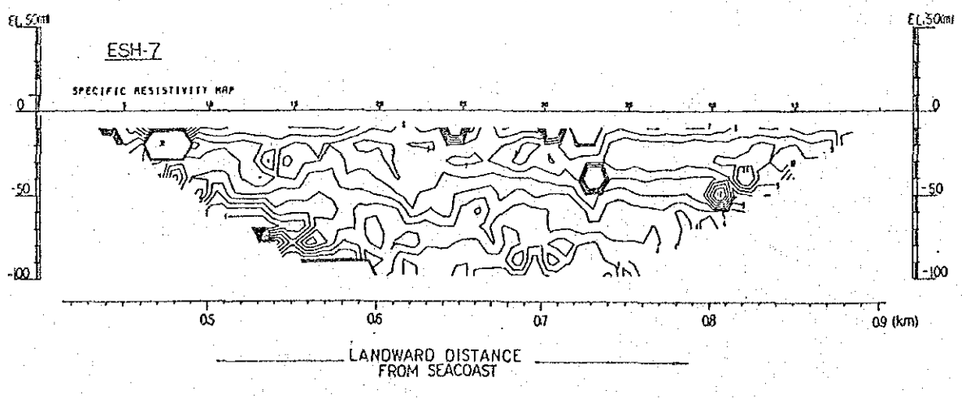


Fig. C-2-5(3) Equi-Depth Geo-Resistivity Soundings, Wadi Batha Area



RESISTIVITY MAP



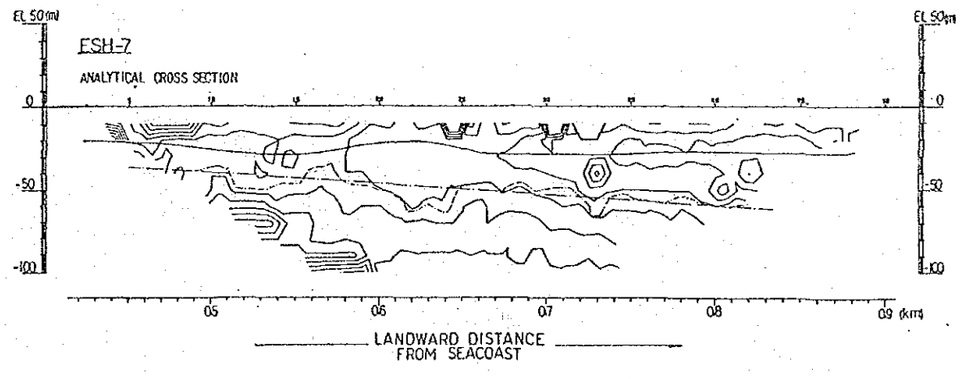
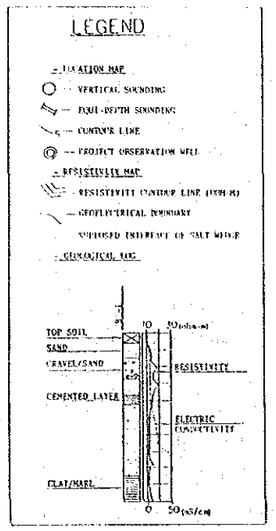
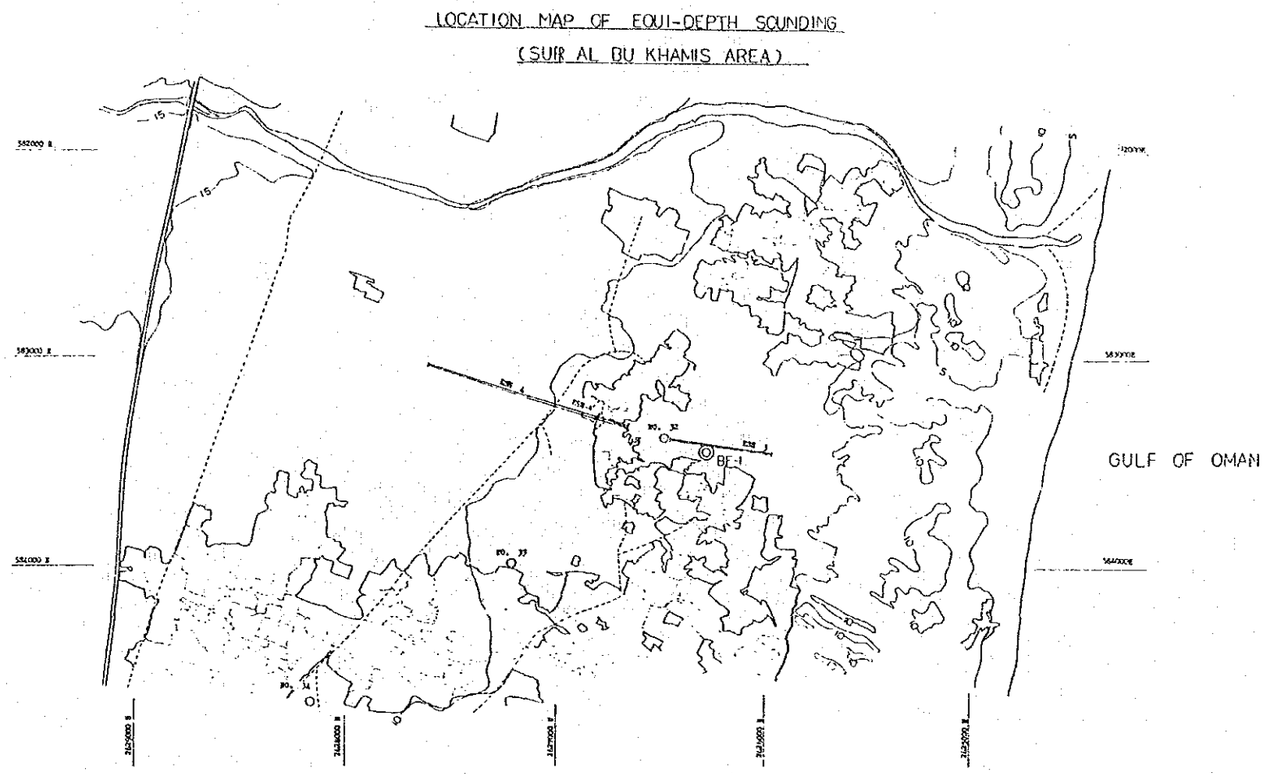


Fig. C-2-5(4) Equi-Depth Geo-Resistivity Soundings, Sur Al Bu Khamis Area





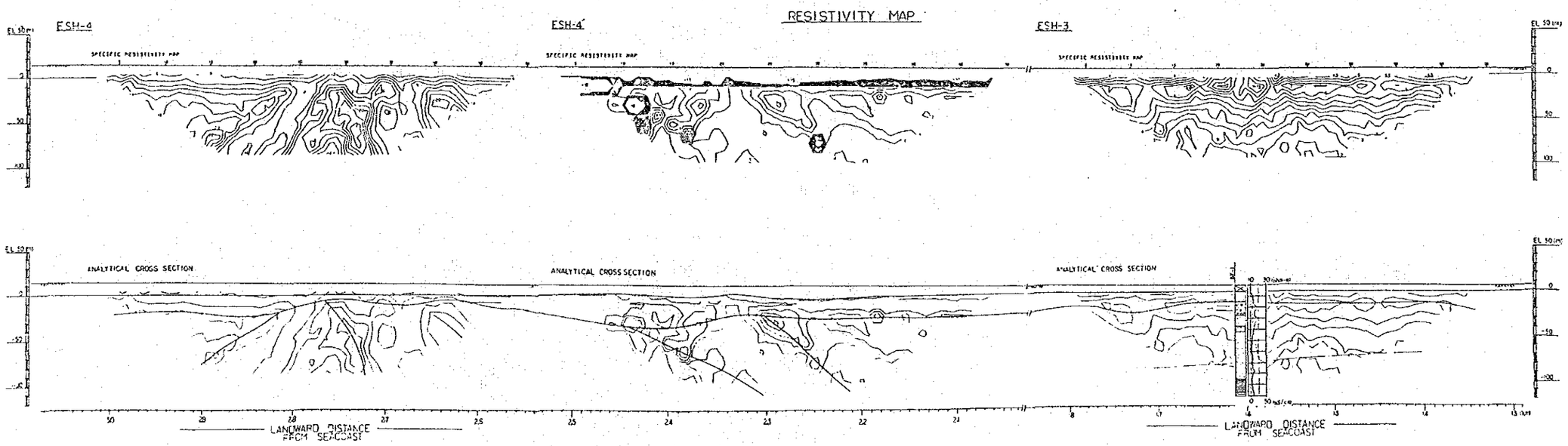


Fig. C-2-5(5) Equi-Depth Geo-Resistivity Soundings, Barka' Area