# THE GOVERNMENT OF SULTANATE OF OMAN

# HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST OF SULTANATE OF OMAN

# FINAL REPORT

### VOLUME 3

# SUPPORTING REPORT I

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 published 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 fromPre-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	The basement is made of dolomite,
Basement	limestone, quartzite, graywacke and
	 conglomerate.

#### **Triassic-Permian Formation**

Akhdar	Dolomite and dolomitic limestones
Dolomite	indicate the age ranging from Permian to
Andrewski star i star star star star star star star star	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	 Massive shelf limestones prevail, consisting of
Limestone	foraminiferal wackestone and packstone
	with subordinate skeleral grainstone.
:	Facies includes the shallow marine origin.

# Middle Cretaceous-Permian Formations

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

### Middle Cretaceous-Permian Formations

Hawasinah	Mainly pelagic sediments which are
Allochthonous	composed of 12 tectonical sub-units
Unit	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 assemblage consists	of
Ophiolite	the following rock facies:	
Nappe	1) Volcanic, extrusive rock	
	2) Subvolcanic feeder dike	
	3) Hypabyssal-gabbroid rock	
· · ·	4) Gabbro	
	5) Transitional rock between gabbro	

and periodotite

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  $10^{\circ}$  to  $20^{\circ}$  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.
	c

Sand and ----- Sandy flat plains remain between modern Gravel Flats 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-l

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

Ancient ---- Ancient wadi courses remain as topographical Channels 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 These are active wadi channels across the inter-fluvial plains. Facies are made of Beds 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 Medium sand to silty-sand flats overlie Sand 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, Occasionally saline facies of clay and granule. marine origin are included. Coastal Dune Self 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.

GE	OLOGICAL LOG OF WEI		
PROJECT HYDROLOGIC OBSERV	ATION 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	
DEPTH IN LOG CLASSIFICATION	DESCRIPTION AND STRUCTURES		LING TIME (min/m) 30 40 50 60 70
	Light brown to light gray silt with sand, partly consolidated by carbonate material and gravelly layer contained.	and anticularitien	
5 1 SAND	Sand with gravel, grayish sandy sediment made up of medium sand and granule grave	el.	
		ntanhuatan	
		turtur dan	
GRAVEL	Brownish gravel with sandand a few carbo fragments, the proportion of sand gradual increase in order to the lower horizon. Th shell crusts are included through whole he	ly Tall	
	•	unutranta da la constructione de la constructi	
SAND	Light grayish beach sand, medlum sand fac with a few intercalation of marly clay.	sies =	
22 = 6	Silt with sand and gravel, light yellow or colored. The marly facles and sand/gravel dominant facles interbeded.	angester	
		ulseritoritation durational	

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

Fig. C-2-1(1) Continued GEOLOGICAL LOG OF WELL HYDROLOGOC OBSERVATION PROJECT IN THE BATINAH COAST SITE WADE AHIN PROJECT ANGLE FROM HORIZONTAL FOREMAN HOLE NO. BA 1 PERPENDICULAR NEAR MIJAZ SAGHIRAH COMMENCED LOGGED BY LOCATION HOLE DIA COMPLETED CHECKED BY 10 " ELEVATION (m) DEPTH (m) THICKNES DRILLING TIME (min/m) CLASSIFICATION L06 DESCRIPTION AND STRUCTURES 9 40 50 ю 10 20 30 70  $^{\circ}$ 0 ò Gravel with sand, dark brown gravel dominant GRAVEL o r  $\circ$ 0 ó 36 Dark brown sand with a few carbonate-SAND 2 37 f ragnents. Light yellow orange clay with a little of carbonate material, partly change to the marly facies. CLAY n  $\circ$ o 0 GRAVEL Gravel and sand with carbonate fragments, dark brown to black, carbonate coated gravel o are included. Ó 0 o C o C o c C C C С 0 0 0 Light gray clay to marly clay with a few gravel. CLAY CLAY Light gray nearly clay with sandy material.

Fig. C-2-1(1) Continued

	GE	OLOGICAL LOG OF WE	LL	
PROJECT		TION PROJECT IN THE BATINAH COAST	SITE	WADI AHIN
HOLE NO.	BA 1	ANOLE FROM HORIZONTAL PERPENDICULAR	FOREMAN	
LOCATION	NEAR MUAZ SAGHIRAH		LOGGED BY	1
HOLE DIA.	10 "	COMPLETED	CHECKED B	Υ
DEPTH (m) ELEVATION (m) DATE	LOG CLASSIFICATION	DESCRIPTION AND STRUCTURES		RILLING TIME (min/m)
(3) (3) (3) (3) (3) (3) (3) (3) (3) (3)	0 0 0 0 0 0 0 0 0 0 0	Gravel with sand, dark brown gravel domi facies, matrix filled by medium sand, cla carbonate material.	nant -	<u>x</u> x x x x x x x x x x x x x x x x x x
68 5	SAND	Brown sand and clay, alternation of sand and clayey layers dirived from ophiolite.	last and and and a	
72.24	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Brown gravel with clay, alternation facies of gravel and clay.	university of the second s	
rationalization in the second	O O O O O O O O O O O O O O O O O O O	Dark gray to black gravel facies with a few carbonate and clayey material.	union la contraction de la contraction	
80 tr				
84 4	0 0 0 0 0 0 0 0 0 0 0	Gravel and sand, sand dominant facies p interbeded especially between 81 meters 83 meters,	artly fund	
87	SAND	Reddish brown sand, medium sand with a of carbonate material.	Hittl	
	O O C C O O	Gravel and sand, brown to black rounder gravel made up of granule to pebble an sorted clean sand layer.	direction p	

Fig. C-2-1(1) Continued GEOLOGICAL LOG OF WELL HYDROLOGIC OBSERVATION FOJECT IN THE ENTINHI COAST BA I ANGLE FROM HORIZONTAL PERPENDICUL PROJECT SITE WADL AHIN HOLE NO. FOREMAN PERPENDICULAR LOCATION NEAR MIJAZ SAGHIRAH COMMENCED LOGGED BY HOLE DIA. COMPLETED CHECKED BY 10 <sup>n</sup> THICKNESS (m) DEPTH L ELEVATION (m) DRILLING TIME (min/m) DESCRIPTION AND LOG CLASSIFICATION STRUCTURES 10 20 50 60 70 30 40 0 0  $\hat{}$ € GRAVEL -- Same as abave mentioned description --C C  $\hat{c}$ C 0 0 C 0 102

	GE	OLOGICAL LOG OF WE	LL	····
PROJECT		ION PROJECT IN THE BATINAH COAST	SITE	WADI BANI GHAFIR
HOLE NO.	JT 20 A	ANGLE FROM HORIZONTAL PERPENDICULAR	FOREMAN	
LOCATION	10 KM DOWN STREAM	COMMENCED	LOGGED BY	
HOLE DIA.	10 "	COMPLETED	CHECKED B	γ
THICKNESS (m) DEPTH (m) ELEVATION (m) DATE	LOG CLASSIFICATION	DESCRIPTION AND STRUCTURES		ILLING TIME (min/m) 0 30 40 50 60 70 ,
2) N N N N N N N N N N N N N	GRAVEL G G G G G G G G G G G G G G G G G G G	Brown to light brown sand with silt and gra silt dominant layer and much amount of gr gravel interculate.at the upper horizon. Granule gravel with sand and a few clayey material. Gray to light brown gravel layer, pebble to granule with sandy matrix, the alternate fa of pebble and granule.	avel anufariharihariharihariharihariharihariharih	
	O C C C C C C C C C C C C C C C C C C C	Much proportion of limestone granule grave with sand and a few carbonate fragments. brown to light brown colored facies.		
	CLAY	Reddish brown clay with a few granule gra		
	SAND	Medium to coase sand with gravel, light b colored facies.	rown -	
23	GRAVEL	Light brown gravel, much amount of pebble with carbonate fragments.	e e	
میں اور میں اور میں اور میں اور م	O GRAVEL O GRAVEL O C	Gray gravel, much amount of pebble with fine to medium sand.	في استار ساريت استار معاين باستار من استار من اس	

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

Fig. C-2-1(2) Continued

PROJECT     HYDROGIC OBSERVATION PROJECT IN THE BATINAH COAST     SITE     WADE BANK GIALIN.       HOLL NO.     IF 700A     TO DANI STREAM     COMMENCED     LOGGED BY       LOCATION     IO ANN DOWN STREAM     COMMENCED     LOGGED BY       INCLE DIA     IO     COMMENCED     CHECKED BY       INCLE DIA     IO     COMMENCED     CHECKED BY       INCLE DIA     IO     COMMENCED     DESCRIPTION AND STRUCTURES     DRILLING TIME (min/m)       INCLE DIA     IO     CRAVEL     Gray gravel, much assamt of pebble with first to medium smd.     IO       INCLE DIA     SILT     Light brown slit with gravel.     INCLE DIA     IO       INCLE DIA     SAND     Brows to light brown medium to corrst and, and, and structure to gravel, the first barrow and with slit end gravel, the first barrow and end to barrow and end to barrow and end to barrow and to			GE	OLOGICAL LOG OF WEL		
HOLE NO.     IT 20A     ANGL_REMONATE FOREMAN     PERPENDICULAR     FOREMAN       LOCATION     10 KM DOWN STREAM     COMMENCED     LOGGED BY       HOLE DIA.     10 "     COMPLETED     CHECKED BY       HOLE DIA.     10 "     COMPLETED     CHECKED BY       Image: State of the st	PROJECT	НҮ		PROJECT IN THE BATINAH COAST		WADI BANI GHAFIR
LOCK TION       Processor       Commencessor       Commencessor         HOLE DIA       10 *       0 *       COMPLETED       CHECKED BY         Image: Sort Sort Sort Sort Sort Sort Sort Sort	HOLE NO	).	JT 20A	ANGLE FROM PERPENDICULAR		
Image: Second		-FR	KM DOWN STREAM <del>9M-AL-HOUQAIN</del>			
33       10       GRAVEL       Gray gravel, much amount of pebble with fine to medium sand.         33       10       0       0         33       10       0       0         33       10       0       0         33       10       0       0         34       3       0       0         35       3       0       0         36       3       0       0         37       0       0       0         38       3       0       0         39       10       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         41       0       0       0         42       0       0       0         43       0       0       0         44       metres horizon.       0         45       0       0         46       0	HOLE DI	A.	10 "	COMPLETED	CHECKED BY	· · · · · · · · · · · · · · · · · · ·
33       10       GRAVEL       Gray gravel, much amount of pebble with fine to medium sand.         33       10       0       0         33       10       0       0         33       10       0       0         33       10       0       0         34       3       0       0         35       3       0       0         36       3       0       0         37       0       0       0         38       3       0       0         39       10       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         40       4       0       0         41       0       0       0         42       0       0       0         43       0       0       0         44       metres horizon.       0         45       0       0         46       0	EPTH (m) EVATION DATE (m)		CLASSIFICATION	DESCRIPTION AND STRUCTURES		·
35       3			1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 - 1996 -	Gray gravel, much amount of pebble with fine to medium sand.		
36       3       3       3         40       4       5       3       3         40       4       5       3       3         40       4       5       3       3         55       3       5       5       3       5         40       4       5       5       5       3         40       4       5       5       5       5         56       5       5       5       5       5       5         40       4       5       5       5       5       5         56       5       5       5       5       5       5       5         40       4       5       5       5       5       5       5       5         48       6       5						
36       3       3       3         40       4       5       3       3         40       4       5       3       3         40       4       5       3       3         55       3       5       5       3       5         40       4       5       5       5       3         40       4       5       5       5       5         56       5       5       5       5       5       5         40       4       5       5       5       5       5         56       5       5       5       5       5       5       5         40       4       5       5       5       5       5       5       5         48       6       5			A SILT	Light brown silt with gravel,	profile	
40       4         41       6         42       4         43       6         44       4         45       6         46       6         47       6         48       6         49       4         40       6         41       6         42       6         43       6         44 <td< td=""><td></td><td></td><td>۵ ۵</td><td></td><td></td><td></td></td<>			۵ ۵			
40       4       5         40       4       6         50       5         40       4         5       5         40       4         5       5         40       4         5       5         5       5         5       5         4       <	36 3		Δ			
40       4       5         40       4       6         50       5         40       4         5       5         40       4         5       5         40       4         5       5         5       5         5       5         4       <			Δ Δ		- The second sec	
SAND Light brown sand with slit and gravel, the intercalation of sandy layer at the 43 to 44 metres horizon.		uuduu d	A SAND			
SAND Light brown sand with slit and gravel, the intercalation of sandy layer at the 43 to 44 metres horizon.			۵ ۵		- Alar	
SAND Light brown sand with slit and gravel, the intercalation of sandy layer at the 43 to 44 metres horizon.	40 4	hantau	. A A		in the second	
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.						
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.		uluudu	× ×			
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.					niesita	
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.			× ×		- Participant	
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.		an hau lan	SAND	Light brown sand with slit and gravel, the intercalation of sandy layer at the 43 to 44 metres horizon.		
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.			*		andum	
48     A       A     A       A     MUDSTONE       MUDSTONE     Mudstone to marly mudstone with a few content of granule gravel.					lanta	
MUDSTONE Mudstone to marly mudstone with a few content of granule gravel.		uha ini	24 (A			
MUDSTONE Mudstone to marly mudstone with a few content of granule gravel.			Δ			
content of granule gravel.					ulaulu 1	
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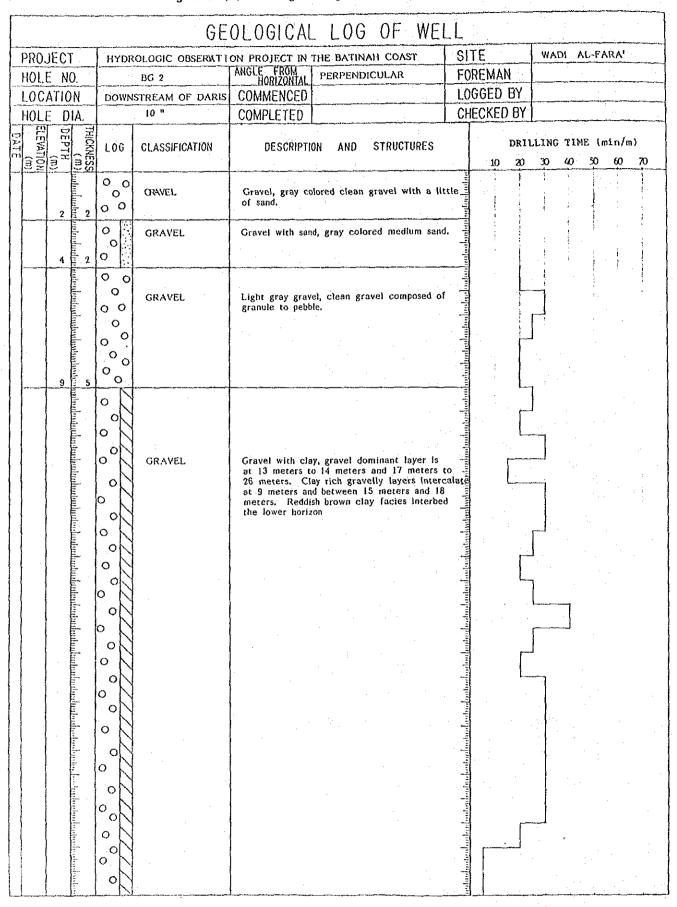
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Γ			<u> </u>	GE	OLOGICAL LOG OF WE	EL	<del></del>	*****								
F	PRO.	JECT	HYE		TION PROJECT IN THE BATINAH COAST	the second s	E		V	NAD	I AL	FAR	<u>A'</u>			
1		E NO.		BG I	ANGLE FROM HORIZONTAL PERPENDICULAR	FOR	REM/	NN .				····				
	LÓC	ATION	UPSTR	REAM OF AL-MUDA		LOG	GED	BY						·		
	HOL	E DIA.		10."	COMPLETED	CHE	CKE	D 8'	Y				· · · ·			
DATE	ELEVATION (m)	THICKNESS (m) DEPTH (m)	L06	CLASSIFICATION	DESCRIPTION AND STRUCTURES		DRILLING TIME (min/ 10 20 30 40 50 60									
	<u> </u>	y yangangan sa		SAND	Light gray sand with gravel, fine to very sand with rounded gravel	y fine instance										
		nahmhadrachaalaga 5	Δ 	SAND	Dark brown sand with gravel, poorly sort medium to coarse sand.	a p							in a substant da particular anno 1999 a substant	بوالم الم الم الم الم الم الم الم الم الم		
		11	Δ Δ	SILT	Links house on one offs with soud and a						-		. •			
		nhudnahndentendenden		312.1	Light brown to gray, silt with sand and g proportion of sand to silt is a like quanti	ity.										
		uuluuluuluu 11 6	A			سلساساس										
		mpulmu	4/4/	SAND	Gray to light gray sand with gravel, poor	e Ludaluuluu										
		ulanihunihunihunihunihunihunihunih	A/ A/		sorted sand with gravel, a few carbonate a clayey material,	and manufation			(		rik n waard dinamista		Anna a statement and	An ann an Ann an Ann		
			\$ X			राज्य का स्वार्ग						•				
			0	GRAVEL	Gray to white gravel with sand, and mucl					<u>}</u>			and the second			
		ահահանու			content of carbonate fragments included facies.	mbuduut				 :			*			
		22 4 1 24 2	0	SAND	Gray to white sand with gravel, abundant carbonate material .	t minuter							- 10 - 1998 - 10 Anna - 19 - 1 <sup>-1</sup> 10 (No. 1 <sup>-1</sup> )			
		tu he fued	0	GRAVEL	Gravel, clean gravely facles with a few s particles, carbonate fragments are commo through the whole horizon,	sandy an				•						
		29 5	0			لسأساساسهم					•			1		
			0	GRAVEL	Gravel with sand and carbonate material.		į	•	• • • • •		]	-				

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

Fig. C-2-1(3) Continued

					GE	OLOGICAL LOG OF WI	ELL	
		)JEC		HYD	ROLOGIC OBSERVAT	TION PROJECT IN THE BATINAH COAST	SITE	WADI AL-FARA'
		OLE NO. BG I				ANGLE FROM HORIZONTAL PERPENDICULAR	FOREMAN	
· ·		CATIC		UPSTI	REAM OF AL-MUDA		LOGGED BY	-
			IA. F	<u>i</u>	10 "	COMPLETED	CHECKED BY	
UALE	(E) (E)		(m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES	DR1 10 20	LLING TIME (min/m) 30 40 50 60 70
		31	ահու	0	GRAVEL	same as above mentioned description		
		34	mparananananana 3		SAND	Light gray sand, medium to coarse sand with much amount of carbonate materia	d nitro	
			mhaqaadaa	A . A . A	SAND	Light gray sand with gravel, a few clay		
-			hadredundenden	(A) (A)		fine sand, abundant carbonate material a contained.	are The second s	
-	   	42	8 antershurden un				almethan and an	
			ne series in the second		SAND	Sand, a few clay and much quantity of carbonate fragments and very fine sand are also included.	sinulanianinat 	
		46	4 4	4 . 4 .	SAND	Sand with gravel, abundant carbonate fragments.	diminut	
	 	50	uluelu: 4	2				
			an partantia da construction de la construcción de la construcción de la construcción de la construcción de la La construcción de la construcción d	$\sim$	SAND	Sand, clean fine to medium sand, well s and facies seems to be beach sand.	sorted	
	 	53	3 ստահաշիդութ-իսսկցակունը։					
			dansholoylarda				<u> den den den de</u>	
			oring drau (1994) or t				undredendari	



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

Fig. C-2-1(4) Continued

	<u></u> ;			GE	OLOGICAL LOG OF WE	LL		<b>.</b>					
P	PRO	JECT			ION PROJECT IN THE BATINAH COAST	SIT	E	WA	DI AL	-FAF	A'		
	IOLI	e no.		BG 2	ANGLE FROM HORIZONIAL PERPENDICULAR	HORIZONIAL PERPENDICULAR PORCIMAN							
		ATION	DOWN	STREAM OF DARIS			GED BY						
		E DIA.	<u>.</u>	10 <sup>, #</sup>	COMPLETED	CHE	CKED BY						
DATE	EVATION	THICKNESS (m) DEPTH (m)	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES		DR1 10 20	LLING 30	TIM 40	E (m 50		) 07	
		32 m 23	0000	GRAVEL	Same as above mentioned description	under and series					ι. ·		
		101401 34		SAND	Light gray to light brown sand composed medium sand	of human				1	•		
		uthus hundred and hundred and hu	0 0 0 0	GRAVEL	Gravel with clay and sand, light gray to light brown colored granule to pebble.	<u> ماسا میا میا مارم</u>				•			
		39 u	。 。			       							
		ահաման 41 ա	۵ ۵	CLAY	Brown clay with gravel	लाज्यान्यव			-				
		43 u		CLAY	Brown clay with a few gravel	արական							
		44 H	å	CLAY	Brown clay with granule to pebble	Internet	<b>L</b> .						
		44 <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u> <u>1</u>	0000	GRAVEL	Gravel with clay, light gray to light brow gravelly facies.	c							
		nınınlarılınılınılınılını 50	0 0 0 0 0 0 0	GRAVEL	Light gray to white gravel, consolidated f filled up of carbonate material.	acies in the standard						·	
		50 4	0		· · · · · · · · · · · · · · · · · · ·	120040							
		n hundundu	0	GRAVEL	Gravel with clay, brown to reddish brown consolidated facles.	नुम्यातम्ब		-1					
		ulealada	0			-tatilization	ſ						
		lanter let				hunana	نــــــــــــــــــــــــــــــــــــ						
		57 7	0 0										
		nulunhundun		CLAY	Clay with sand and a few granule gravel, brown colored facies.	Lighterror and			·				

	GE	OLOGICAL LO	G OF WE	LL					
PROJECT H	YDROLOGIC OBSERVAT	ION PROJECT IN THE BAT	TINAH COAST	SITE	WADI AL	-FARA'			
HOLE NO.	BG 2	ANGLE FROM HORIZONTAL PERPE	NDICULAR	FOREMAN					
LOCATION	WNSTREAM OF DARIS	COMMENCED		LOGGED BY					
HOLE DIA.	10 "	COMPLETED		CHECKED BY					
ELEVATION	CLASSIFICATION	DESCRIPTION ANI	D STRUCTURES	DR1 10 20	RILLING TIME (min/m				
m)	CLAY	Light brown clay with	sand and a few gra		30 40	50 60	70		
65 8	CLAY	Reddish brown clay, a are contained.	little of granule gra	avel					
	CLAY	Light brown to reddish sandy particles are of v	brown clay with so very fine to fine sa	Ind, Ind, Ind, Ind, Ind, Ind, Ind, Ind,					
		White to light gray mar upper facies seems to i carbonate matrix, the l consist of maristone wi from ophiolite.	oe a conglomerate ower horizon mainly	ived mining and the second sec					
				urturd on to observe the dama transferration of an element of the dama transferration of the					

Fig. C-2-1(4) Continued

[		-		GE	DLOGICAL LOG OF WELL
		JECT	HYD	ROLOGIC OBSERVAT	ION PROJECT IN THE BATINAH COAST SITE WADI AL-FARA'
		<u>e no.</u>		BG 2	HORIZONTAL PERPENDICULAR FOREMAN
		ATION	DOW	NSTREAM OF DARL	
	HOL	E DIA.		10 "	COMPLETED CHECKED BY
DATE	LEVATION (m)	THICKNESS (m) (m) (m)	L06	CLASSIFICATION	DESCRIPTION AND STRUCTURES
_	· .	91 2		MARL	same as above mentioned desdription
	- <sup>14</sup> -	landard			
		uniunianta			
		ebududa			
		Sinlantaut			
	-	minudundan			
		hunturshuets			
1 1	tala Le	ահարհո			
		dun lun l			
		Ē	•		
		man			
		սիսվուլ			
		հութովումը			
	t P				
		hondourde .			
		den Austhauthauthauthen treaken ten beitreeken ten beitreeken ten beschen ten beschen ten beschen ten beitreek			
		- 			

			GE	OLOGICAL	LOGO	F WEL			<del></del>						
PROJ	JECT	HYDE					SITE			ŴA	DI AI	<u>FA</u>	RA'		
HOLE NO. BF 1				ANGLE FROM Horizontal	PERPENDICU	ÄR	FORE				<u>.</u>				
1	ATION	NEAR	THE AL-MUSANA		·		LOGO								
HOLE		·	10 *	COMPLETED	. <u> </u>		CHEC			ING TIME (min/m)					
LEVATION (m) DATE	THICKNESS (m) DEPTH (m)	LOG	CLASSIFICATION	DESCRIPTI	DESCRIPTION AND STRUCTURES			DR 10	20	NG T 30	1ME 40	(min 50		70 ·	
	untur furtur 3 3		SILT	Light gray san	dy slìt.		terlindinateralised				A CALL AND	* * *	:		
	4	! :	SILT	Light gray silt	with send.			:				:			
	6 2		SILT	Light gray sem sandy material	il-consolidated s	ilt with a fer	* unter-fronten			•	-	·	:		
	7		SAND	Light gray to	gray sand, fine	to medium s	and I								
	8 1	0	GRAVEL	Light gray to content of gra	gra y gravel wit nule gravel.	h sand, much	1 III 1 III			· .		1.			
	10 2		SILT	Light gray silt peoble.	with granule gr	avel and a f	ewinning					· · ·	•		
	ահամաս	0 0 0 0	GRAVEL	Light gray to clayey materia	gray gravel with !.	sand a lew	านของเป็นสายเป็นสาเป็สสาเป็สสสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตส	•		• • •	 		,	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	
	in the second	Δ	SAND	Light gray to g medium sand gr	ray sand and gr anule gravel,	ave), fine to	անակարութութական			•		:			
		0 0 0 0	GRAVEL	Light gray to g granule gravel	ray gravel with with a few sand	sand, subrou y particles,	ndedimina								
	nutunhatharheim	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	GRAVEL	Light grav of granule grav	el with sand, m el.	uch proportia	u trutiminchartaulaatuu						· · ·		
	ليومنهم ليعظمه فيميليهم						<u>անտետիակական</u>				•				
	29 8	0					hord and real real		£ .					<u> </u>	

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

Fig. C-2-1(5) Continued

		GE	OLOGICAL	LOG OF	WELL			<u> </u>			ontint		
PROJECT	HYDROGIC		PROJECT IN TH	E BATINAH COAST		ITE		WA	DI AL	-FAR	۸		
HOLE NO.	BF 1		ANGLE FROM HORIZONTAL	PERPENDICULAR	F	OREMA	N						
LOCATION	NEAR THE	AL-MUSANA'	COMMENCED			OGGED							
HOLE DIA.		<u>Он</u> .	COMPLETED		C	HECKEL							
DEPTH DEPTH (m) DEPTH (m) DATE	LOG CLA	SSIFICATION	DESCRIPTIO	ON AND STRUCT	URES		DRILL	.1NG 30			n/m) 60 70		
B) (B) (B) (B) (B) (B) (B) (B) (B) (B) (		SAND		h gravel and carbon lium to coase sand. vith sand, much amo and a few carbona	unt of ate fragment		20	30	40	50			
42 million for the second seco		SAND	Gray colored material .	fine to medium sand	with merly		•						
54 54		SAND		medium sand. medium sand with ti of marly material.	he	ախուհունունունունունունունունունունու		•					
		· · · · · · · · · · · · · · · · · · · ·				undruction de contraction de contrac				: 			

Fig. C-2-1(5) Continued

	GE	OLOGICAL LOG OF WEI	_L	
PROJECT	HYDROLOGIC OBSERVAT	ION PROJECT IN THE BATINAH COAST	SITE	WADI AL-FARA'
HOLE NO.	BF 1	ION PROJECT IN THE BATINAH COAST ANGLE FROM HORIZONTAL PERPENDICULAR	FOREMAN LOGGED BY	
	NEAR AL-MUSANA'AH	COMMENCED		
HOLE DIA.		COMPLETED	CHECKED BY	
THICKNESS (m) DEPTH (m) ELEVATION (m) DATE	LOG CLASSIFICATION	DESCRIPTION AND STRUCTURES	DRIL 10 20	LING TIME (min/m) 30 40 50 60 70
61 7	SAND	,	traefi ny	
C C C	0	Carbonate coated old gravelly facies, dark brown to gray granule / pebble with sand and carbonate fragments. The sandy horize intercalated between 63 and 66 meters; and between 67 and 70 meters.	ng halandari	
			aalissi kuntenduntun kuntun kuntun kuntun kuntun kun	
			<u>սիսիսիստիստիսի</u>	
			entre funte	
	O GRAVEL	Grey to dark brown gravel and sand with carbonate fragments, much content of gra to pebble and moderate proportion of me to coarse sand.	umunu anules diumaaaaa	
79 uu				
	MARL	Dark brown marl with sand, medium to co sand drived from ophiolite and hard calcar clayey layer. The alternate facies of s and marl at the 54 to 61 meters horizon.	ious	
			ution tradition tradition to the second s	
	I     I       I     I       I     I       I     I       I     I	White to light gray marl with sandy layer and a few granule gravel,		

Fig. C-2-1(5) Continued GEOLOGICAL LOG WELL 0F HYDROLOGIC OBSERVATION PROJECT IN THE BATINAH COAST SITE PROJECT WADI AL-FARA ANGLE FROM HORIZONTAL FOREMAN HOLE NO. BF 1 PERPENDICULAR COMMENCED LOGGED BY LOCATION NEAR AL-MUSANA'AH COMPLETED CHECKED BY HOLE DIA. 10 " DEPTH (m) ELEVATION (m) DRILLING TIME (min/m) HICKNES CLASSIFICATION LOG DESCRIPTION AND STRUCTURES 3 30 40 50 60 70 10 20 i MARL Same as above mentioned description --94 Dark brown to light gray sand with clay SAND and a little of granule to pebble. 99 Ś 0  $\mathbf{c}$ Dark brown gravel with sand and carbonate fragments, carbonate coated old gravel with GRAVEL  $^{\circ}$ coarse sandy matrix.  $\mathbf{C}$ 0 O 0 105 6

p	ROJ	IECI		HYDE	OLOGIC OBSERVAT	ION PROTECT IN 1	HE BATINAH COAST	SIT		WAL	N AL	-FA	'A'	
H	OLE	N	).		ВМЕТ	ANGLE FROM HORIZONTAL	HE BATINAH COAST PERPENDICULAR		EMAN					<u>.</u>
L	OCA	ATIO	N		ULADDAH	COMMENCED			GED BY					
H	IOLE DIA. 10 "		10 <sup>n</sup>	COMPLETED		CHE	CKED BY							
			THICKNESS	LOG	CLASSIFICATION	DESCRIPTIO	N AND STRUCTURES	S		LING		E (m 50		
		2	2		SANDY SILT	Light gray unco	nsolidated sandysilt	<del>nalisaka da</del> n					·. ·	
		4	nutundure.htm	۵ ۵	SAND	Sand with granu contains carbona	le and silt, occasionally ite fragments.							
			antoalmah	00	GRAVEL	clay varies each	I with clay, the proport horizon, example for at neters intercaltes clay la	( <del>-</del>	:			•		
			בי ישוניתנותנית מתומישישישים בי ני ישוניתניתנית	0				<u> باساساس</u>		•		1	· .	
		9 10			CLAY	Light gray sem	-consolidated to consolid	lated		·				÷.,
			or hard material to		CLAY	Light gray clay to consolidate c	with gravel, semi-conso lay with granule to pebb	lidated le.		·. ·				
		13		• • • • • • • • • • • • • • • • • • • •	GRAVEL.	Light gray grave clay with granu	el with clay, semi-consol le to pebble.	idated international and					:	
					CLAY		l, semi-consolidated claya ttle proportion of gravel 1 in diameter.							:
								<u> </u>				• • •		
		24	2 191   e 131   e 111   1	F			۰ ۱۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰	ութանություն	:		· ·			
			adamtanlanten he				e e su constanta Seconda	<u> </u>		•	• •			
								n-mil.						

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

 1	nnö	ICOT		HYDD		EOLOGICAL LOG OF WELL	 1
		JECT E NO.			BM I	ANGLE FROM L DEDDENDICULAD FODEWAN	<u>ь</u>
		ATION	:	в	ARKA	COMMENCED LOGGED BY	
	HOL	E DIÁ		•	10 <sup>-н</sup>	COMPLETED CHECKED BY	
I DATE	ELEVATIO	DEPTH (m)	THICKNE	LOG	CLASSIFICATION	DESCRIPTION AND STRUCTURES DRILLING TIME (min/m	
-		77) m)	SS		SILT	Silt, light gray to light brown silt with a little of sand.	70
		entrutustadustentratustustati	5		SAND	Sand with granule and silt, light gray to light brown semi-consolidated silt with gravelly intercalation.	
		10	5	,     	SAND	Light gray clean sand.	
		13 ամյանանական անություն	1		SAND	Light gray sand with clay.	
		18 18 19 19 19 19 19 19 19 19 19 19 19 19 19	5	4	SAND	Light gray sand with gravel.	
		20 e	2		SAND	Light gray sand with clay,	
		uluuluudanlaulee 25			SAND	Light gray to light brown coarse sand.	
-		26	1	·	SILT	Light gray calcarious silt,	
		28	2		SAND	Light gray sand with calcarious clay.	
	l	29	1	 	SILT	Light gray silt.	
					SAND	Light gray medium sand.	

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

				GE	OLOGICAL LOG	G OF WEL			÷			
PRÓ	JECT		HYDR		TION PROJECT IN THE BATI	······································	SITE		WADI	AL-MA	AWIL	,
	E NO.			BM 1	T THAT FRANCE	DICULAR	FOREN	IAN				
LOC	ATION			BARKA	COMMENCED		LOGGE					
HOL	E DIA	۱.		10 "	COMPLETED		CHECK	ED BY				
ELEVAIIO	DEPTH (m)	THICKNES	LOG	CLASSIFICATION	DESCRIPTION AND	STRUCTURES		DRII 10 20	LLING T 30 40			) 70
	31			SAND	Light gray medium sand.						1	
	32		······	SILT	Light gray silt with sand.	·					ł	
	34			SAND	Light gray to light brown	: :	rules lester					
	35		···· ۵	SAND	Light gray to gray sand	with granule gravel.	un un			:		
	36	1		SAND	Light gray medium sand.	· · · · · · · · · · · · · · · · · · ·	111			;		
	37	,		SILT	Light brown silt to sand.		1000		× .			
	unhunternfundumfund 40	3		SAND	Light gray fine sand with carbonate fragments.	i clay and a few	adjurteduchudan		· · · · · · · · · · · · · · · · · · ·			
i:	41			SILT	Light gray silt, semi-cons	olidated calcarious						
	43			SAND	facies. Light gray fine to mediu material.	m sand with carbor	nate					
	44	1	0	SAND	Light gray sand with gra	vei.	and the		]	· · ·		
	45			SAND	Light gray to light brow	n sand with clay an	nd E		<b></b>			i
	2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2		۵ ۵	SAND	-carbonate fragments, Gray sand with granule g 48 meters much amount	gravel, especially a						
	48 48 48 48 48 48 48 48 48 48 48 48 48 4	3	0 0 0 0	SAND	Gray gravel with carbon	ate particles.	dan ada a a a a a a a a a a a a a a a a		]			
 	52 <sup>-11</sup>	4	0				ruduu si me		 · _	) 1. 21	i.	
	նդրիստիստիզդիգրի։	•		MARL	Light brown to white ma of granule gravel.	ristone with a little	ախուհավարերու անություն	[			:	
	ահականութ	-					atrofootan Barto					
	nganghardar dar						manna			· · · · · · · · · · · · · · · · · · ·		

Fig. C-2-1(7) Continued GEOLOGICAL LOG OF WELL PROJECT HYDROLOGIC OBSERVATION ROJECT IN THE BATINAH COAST SITE WADE AL-MAIAWE ANGLE FROM HORIZONTAL BM 1 PERPENDICULAR HOLE NO. FOREMAN LOCATION BARKA COMMENCED LOGGED BY COMPLETED HOLE DIA CHECKED BY 10 " m DEP THICKNES LEVATION (m) DRILLING TIME (min/m) L06 **CLASSIFICATION** DESCRIPTION AND STRUCTURES je ÷ **9**. 10 30 40 50 ю 20 70 61 MARL -- Same as above mentioned description --MARL Light gray to white marl with sand, facies is rather soft than the above marly horizon. 70 Light gray to white marlstone with gravel, sandyclay layers partly intercalated. MARLSTONE 85 15 Light gray to white marlstone with sandy material. MARLSTONE MARLSTONE Light gray to white marlstone with gravel.

Fig. C-2-1(7) Continued

		GE	OLOGICAL	LOG OF WE				
PROJECT	HYDR	OLOGIC OVSERVATI	ON PROJECT IN TH	IE BATINAH COAST	SIT		WADI A	L-MA'AWIL
HOLE NO.		BM I			REMAN			
LOCATION	. 	BARKA	COMMENCED			GED BY		
HOLE DIA.		10. <sup>#</sup>	COMPLETED			CKED BY		
THICKNESS (m) DEPTH (m) ELEVATION (m) DATE	LOG	CLASSIFICATION	DESCRIPTI	ON AND STRUCTURES		DRIL 10 20	LING TIM	E (min/m) 50 60 70
93 <sup>1</sup> 93		MARLSTONE	Same as ab	ove mentioned description -	i nutuulenkeetee			
	HR	MARLSTONE	Lightgray to w	white maristone with clay.	a fia			
94 <u>EE 1</u>		MARLSTONE		white maristone with grave	- Budunlandandandandan			
	E				inter T		1.	
	Ele	MARLSTONE	Light gray to	white maristone with clay	and			
			gravel.		1	: [ ]		
					mp			
102 4								
		MARLSTONE	Light gray to	white maristone with granu	ile. internation			
արգինությունը արտանությունը արտանությունը ունեները ունեները ունեները ունեները ունեները ունեները ունեները ունենե					ագերջերությունը գերելու հայեսով առիսով առիսոկում առիսոկում առիսոկում առիսոկում առիսոկում			
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1					historiadan		,	

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ſ				GE	OLOGICAL	LOG OF WE	 [_ [_	
	HOL	JECT E NO.	HYD	ROLOGIC OBSERVAT BM 2	TION PROJECT IN ANGLE FROM HORIZONTAL	THE BATINAH COAST PERPENDICULAR	SITE FOREMAN	WADLAL-MA'AWIL
-	HOLI	ATION E DIA.	NOR	TH OF AL WASIT	COMMENCED COMPLETED		LOGGED BY CHECKED BY	
						L		LING TIME (min/m)
1	VATION (III)	DEPIN (m)	LOG	CLASSIFICATION	DESCRIPTIO	ON AND STRUCTURES	10 20	30 40 50 60 70
		2	0	GRAVEL	Gravel with sil facies, and cla the lower hori:	t, white to light gray colore y dominant layer is much a	ed T	
		and hushers	0 0 0 0	GRAVEL		ith a few fine sand	imfaatonkaetur	
		nuluuluuluuluu 7					uniteritania.	
		antur de de de due ka	00000	GRAVEL	Gravel with fin material, the l in matrix.	ne sand and a little of clay lower facies contain medium	i sand	
		durden den der					loului louluuluulu	
		14 14 14 14 14 14 14 14 14 14 14 14 14 1		GRAVEL	Gray gravel with	sand.	in the second	
		undunden benit	0000	GRAVEL	Gravel with si	It and sand.	ulnalaatuu taatuu taatuu	
		20	00	· · · · · · · · · · · · · · · · · · ·				
		1	00	GRAVEL	Gravel with sa	and.		
		trolous house of	0000	GRAVEL	Light gray to little of sand.	gray gravel with silt and a	limburli altantaria	
·   ·   ·		և սիսությությունը	0					: 
		durdan antradi	0					
		29	800					
. [			Pol	GRAVEL	Gravel withsilt	and carbonate fragments		

# 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-MAXAVIL.       NOLE NO.     INM 2     ANDI AL-MAXAVIL.     PERPENDICULAR     FOREMAN       LOCATION NORTH OF AL-WAST     COMPLETED     CHECKED BY     UGGED BY       HOLE DIA     10 *     COMPLETED     CHECKED BY       HOLE DIA     10 *     COMPLETED     CHECKED BY       STATE     GRAVEL     - Same as above mentioned description     ID     D<							Fig.	C-2-1(8)	Con	tinu
HOLE       NO.       DM 2       ANGLE FROM       PERPENDICULAR       FOREMAN         LOCATION       NORTH OF AL-WASIT       COMMENCED       LOGGED BY         MOLE       DIA       10 *       COMPLETED       CHECKED BY         MOLE       DIA       10 *       COMPLETED       CHECKED BY         MOLE       DIA       10 *       COMPLETED       CHECKED BY         MOLE       DIA       0 *       CAMPLE       DESCRIPTION AND STRUCTURES       DRILLING TIME (mLn/m)         B       0 *       O       CRAVEL       Same as above mentioned description       0 *		·····		······	,		<u></u>			
LOCATION       NORTH OF AL-WASIT       COMMENCED       LOGGED BY         HOLE DIA       10 *       **       COMPLETED       CHECKED BY         IDE       COMPLETED       CHECKED BY       DESCRIPTION AND STRUCTURES       DRILLING TIME (min/m)         IDE       CO       CHAVEL       Sume as above mentioned description       10 20 30 40 50 60 70         IDE       CO       CRAVEL       Gravel with sand and clay, gray colored fackes       IDE         IDE       CO       CRAVEL       Gravel with sandyclay and carbonate fragments         IDE       O       CRAVEL       Gravel with sandyclay.         IDE       O       CRAVEL       Gravel with sandyclay and carbonate fragments.         IDE       O       CRAVEL       Gravel with sandyclay.         IDE       O       CRAVEL       Gravel with sandyclay.         IDE       O       CRAVEL       Gravel with sandyclay.         IDE       O       CRAVEL       Gray gravel with sandyclay.         IDE       O       CRAVEL       Gray gravel with sand, clay and carbonate         IDE       O       CRAVEL       Gray gravel with sand, clay and carbonate         IDE       O       CRAVEL       Gray gravel with sand and clay.         IDE			HYDR		TION PROJECT IN THE BATINAH COAST			WADL AL	<u>-MA'AU</u>	Ш. <u> </u>
HOLE       DIA       10 **       COMPLETED       CHECKED BY         Image: Structure Structur	~~									·····
State       State       LDG       CLASSIFICATION       DESCRIPTION       AND       STRUCTURES       DRILLING TIME (min/m)         33       3       0       CRAVEL       Same as above mentioned description       10       20       30       40       50       60       70         33       4       0       CRAVEL       Same as above mentioned description       10       20       30       40       50       60       70         33       4       0       CRAVEL       Gravel with sand and clay, gray colored factes       10       20       30       40       50       60       70         34       1       0       GRAVEL       Gravel with sandyclay and cerbonate fragments       10       20       30       40       50       60       70         35       1       0       GRAVEL       Gravel with sandyclay       10       20       10       20       10			NORT							·
31       2       0       CRAVEL       Same as above mentioned description         31       2       0       CRAVEL       Gravel with sand and clay, gray colored facies         35       4       0       GRAVEL       Gravel with sandyclay and carbonate fragments         31       1       0       GRAVEL       Gravel with sandyclay and carbonate fragments         31       1       0       GRAVEL       Gravel with sandyclay.         0       0       GRAVEL       Gray gravel with sand, clay and carbonate         41       11       0       Gray gravel with sand, clay and carbonate         42       0       GRAVEL       Gray gravel with sand and clay.         52       0       GRAVEL       Gray gravel with sand and clay.         54       2       0       GRAVEL       Gray gravel with sandyclay.         55       1       0       GRAVEL       Gray gravel with sandyclay.         55       1       0       GRAVEL       Gray gravel with sandyclay.         55 <td< td=""><td></td><td></td><td>L06</td><td></td><td></td><td></td><td>DRILLI</td><td></td><td></td><td></td></td<>			L06				DRILLI			
a       0       0       GRAVEL       Gravel with sand and clay, gray colored facles         35       4       0       0       Gravel with sandyclay and carbonate fragments         35       1       0       GRAVEL       Gravel with sandyclay and carbonate fragments         0       0       GRAVEL       Gravel with sandyclay.         0       0       GRAVEL       Gray gravel with sandyclay.         0       0       0       0         0       0       Gray gravel with sandyclay.       0         0       0       Gray gravel with sand, clay and carbonate fragments.       0         40       2       0       Gray gravel with sand, clay and carbonate fragments.       0         40       2       0       Gray gravel with sandyclay and carbonate fragments.       0         32       0       Gray to light gray gravel with sandyclay and carbonate fragments.       0       0         54       2       0       Gray	3	I E	10 1	GRAVEL	Same as above mentioned description ~				<u>~~~</u>	
36       1       0       GRAVEL       Gravel with sandyclay and cerbonate fragments         0       0       0       GRAVEL       Gravel with sandyclay.         0       0       0       GRAVEL       Gravel with sandyclay.         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         0       0       0       0       0         10       0       0       0       0         40       2       0       0       0         10       0       0       0       0         10       0       0       0       0         110       0       0       0       0         10       0       0       0       0         10       0 <td< td=""><td></td><td>er duralination</td><td>00000</td><td>GRAVEL</td><td>Gravel with sand and clay, gray colored f</td><td>facies</td><td></td><td></td><td></td><td>:</td></td<>		er duralination	00000	GRAVEL	Gravel with sand and clay, gray colored f	facies				:
and       1       0       0         and       0       0       0       0       0			ON	GRAVEL	Gravel with sandyclay and carbonate frage	ments			1 	
47       11       0         47       11       0         47       11       0         47       11       0         47       11       0         47       0       GRAVEL         49       2       0         52       3       0         52       3       0         54       2       0         54       2       0         54       2       0         55       1       0         6       0       GRAVEL         55       1       0         55       1       0         6       0       GRAVEL         55       1       0         6       0       GRAVEL         55       1       0       0         6       0       GRAVEL       Gravel, clean gravel with sandyclay and carbonate fragments.         55       1       0       0         6       0       GRAVEL       Gravel, clean gravel included large sized gravet         6       0       GRAVEL       Brown sand and clay with a little of granule.			0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	GRAVEL	Gray gravel with sandyclay.	العباسا يعالمه المباسا يسابع المباليما يسابعه المعالمين				
52     3     0       52     3     0       52     3     0       52     3     0       52     3     0       54     2     0       54     2     0       55     1     0       6     0     GRAVEL       55     1     0       6     0       55     1       7     0       6     Gravel, clean gravel included large sized gravel       6     0       7     0		47 11 11	000000	GRAVEL	Gray gravel with sand, clay and carbonate fragments.	» ساسطىساساسا سامىلىساسىلىيىلى				
54     0     GRAVEL     Gray to light gray gravel with sandyclay and carbonate fragments.       54     2     0     GRAVEL       55     1     0     O       55     1     0       CLAY     Brown sand and clay with a little of granule.		2) 1991 1991 1991 1991 1991 1991 1991 19	0000	GRAVEL	Gray gravel with sand and clay.	und nu den nu den nu				
55 I O O GRAVEL. Gravel, clean gravel included large sized gravel CLAY Brown sand and clay with a little of granule.	-	54 2		GRAVEL	Gray to light gray gravel with sandyclay and carbonate fragments.	mintentun				
CLAY Brown sand and clay with a little of granule,		55 1	000	GRAVEL	Gravel, clean gravel included large sized	gravet				
				CLAY	Brown sand and clay with a little of gran	nule, <u>u</u>				

Fig. C-2-1(8) Continued

			· ·		OLOGICAL LOG OF	······································				
PROJ			HYD	BM 2	TION PROJECT IN THE BATINAH COA ANGLE FROM HORIZONIAL PERPENDICULAR		ITE	WADI	AL-M	A'AWIL
HOLE				H OF AL-WASIT	COMMENCED		OREMAN			<u>.</u>
LOCA			NORT	10 "						· · · · · · · · · · · · · · · · · · ·
HÓLE	히	A ===					HECKED BY			
ELEVATION	EPTH (m)	THICKNESS	L06	CLASSIFICATION	DESCRIPTION AND STRUCT	URES	DRILL 10 20	אוד זאנ דוא 30 40		n/m) 60 70
			0 0 0 0 0	GRAVEL	Gray gravel with sandysilt and carbo material.	onate	harden begrunden die er		· · · · · · · · · · · · · · · · · · ·	
			00000	GRAVEL	Gray gravel with carbonate material sized gravel are contained.	l, the large				
		-	0 0 0 0 0 0 0			- - -				
				GRAVEL	Light gray gravel with sand and car material, facies is concreated by ca matrix.	bonate arbonate	landmilianhanhanhan			
			°	GRAVEL	Light gray gravel with silt and a f	lew sand.				
			° 0 0 0 0 0 0							
				GRAVEL	Dark gray gravel, facies is compose amount of large sized gravel.	sed of muc			:	
							doordood oo doordood and an			
							set as least a			
			0 0 0 0				uderlandaulandau		<b>.</b>	

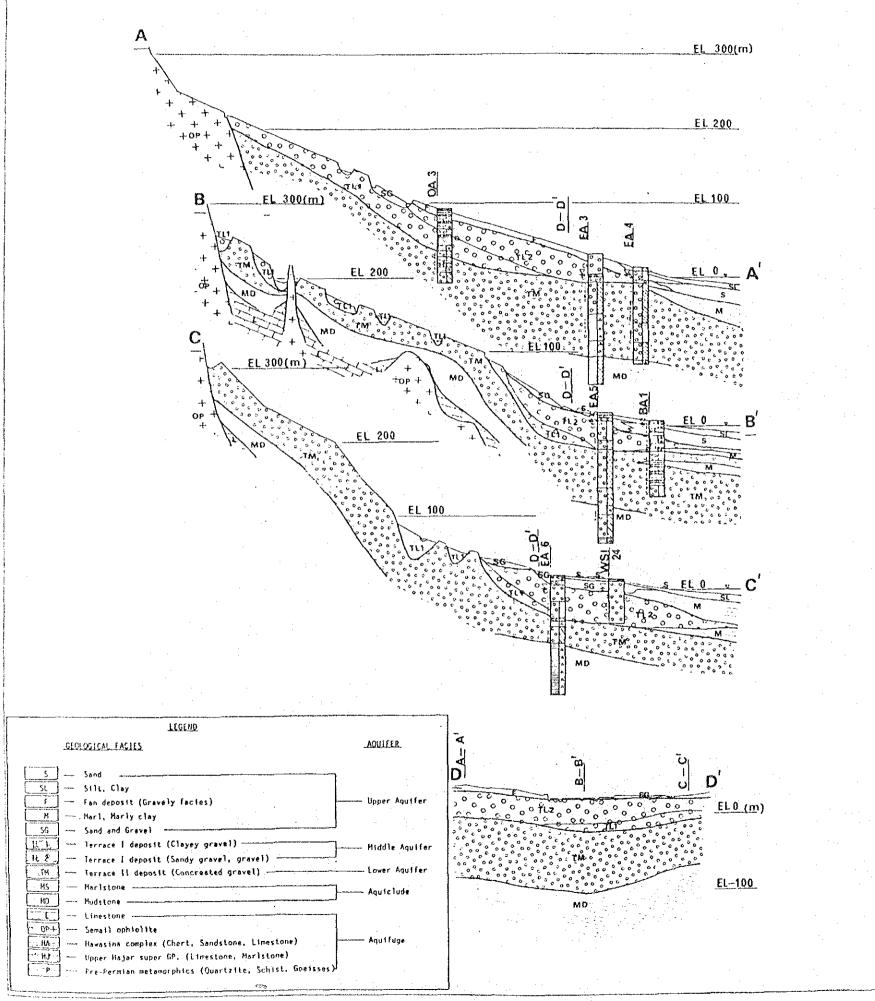
		GE	OLOGICAL LOG OF WEI	LL		 - -					
PROJECT	НҮД		TION PROJECT IN THE BATINAH COAST		TE		W	ADI A	LM	A'AWI	L
HOLE NO.		BM 3	ANGLE FROM HORIZONIAL FOREMA						· · · · · · · ·		-
LOCATION	UPST	REAM OF HIFRI	COMMENCED	LC	)GGED	BY					
HOLE DIA.	DIA. 10 " COMPLETED CHECKED B			<u>d By</u>							
THICKNESS (m) DEPTH (m) ELEVATION (m) DATE	L06	CLASSIFICATION	DESCRIPTION AND STRUCTURES					TIME			70
มปมะ	۵ ۵	SAND	Reddish brown sand with granule and a few silt.				1	•		•	
		CLAY	Clay with sandy partcles, light gray colore calcarlous sediments.	antenlentee							- -
andandaradaran 6	0 0 0	GRAVEL	Gray gravel with sand and carbonate fragm	ents							
	o	GRAVEL	Gray gravel with clay.	und nu							
	0	•		-lanta de	т. 1						·
		GRAVEL.	Gray gravel with sand and clay.	իսերերերոնու					•		
12 5	0			and and and and			•.				
	000	GRAVEL	Gravel with clay, gray to light gray color gravelly layer filled up clayey matrix.	eq bulantan bulantan							
uduudau								:			
1912 7	°oN			իտնու				•.			
20 1		SAND	Gray to light gray sand with much content clayey_matrix.	01							
inut and a second	0 0 0 0	GRAVEL	Gravel and sand with much amount of clay.	նակությունորի։		·	÷ .		·	·	
25 5				وساسطيم			·				
27 2	000000	GRAVEL	Gravel, gray colored clean gravel with a fe sand.	*			:	- - - -	* ****		
	0 0 0 0	GRAVEL	Gray to light gray gravel with much conter clayey material.	nt of			· .				
	ం	GRAVEL	Gray gravel layer made up of granule grave	el.			Ì		<u> </u>		· · · · · · · · · · · · · · · · · · · ·

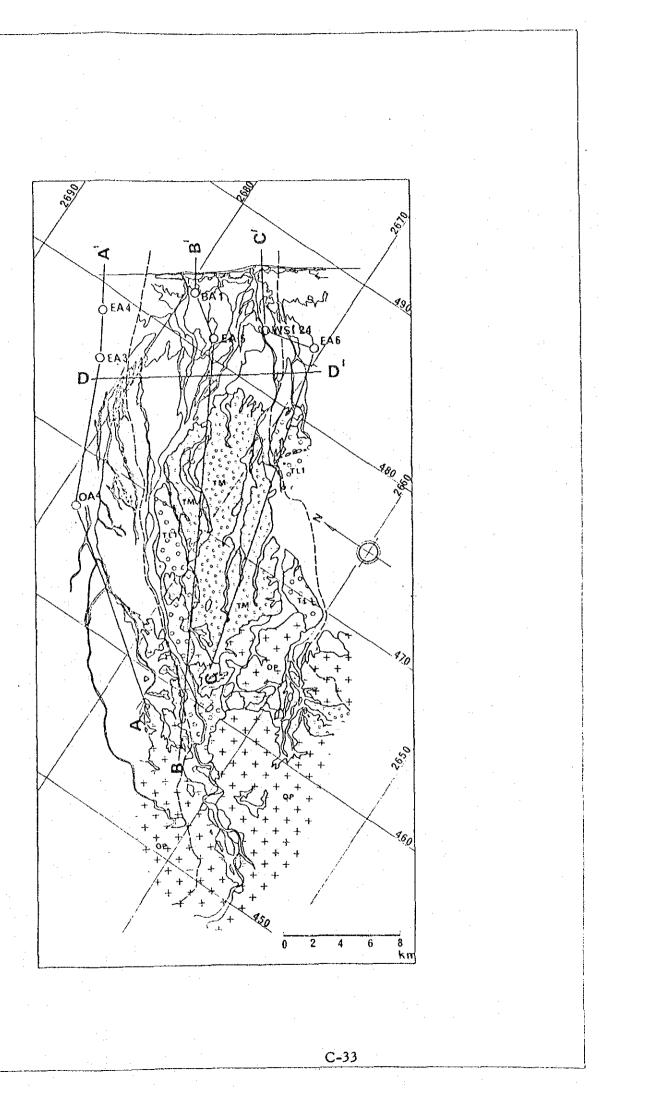
## Fig. C-2-1(9) Geological Log of Observation Well, BM3

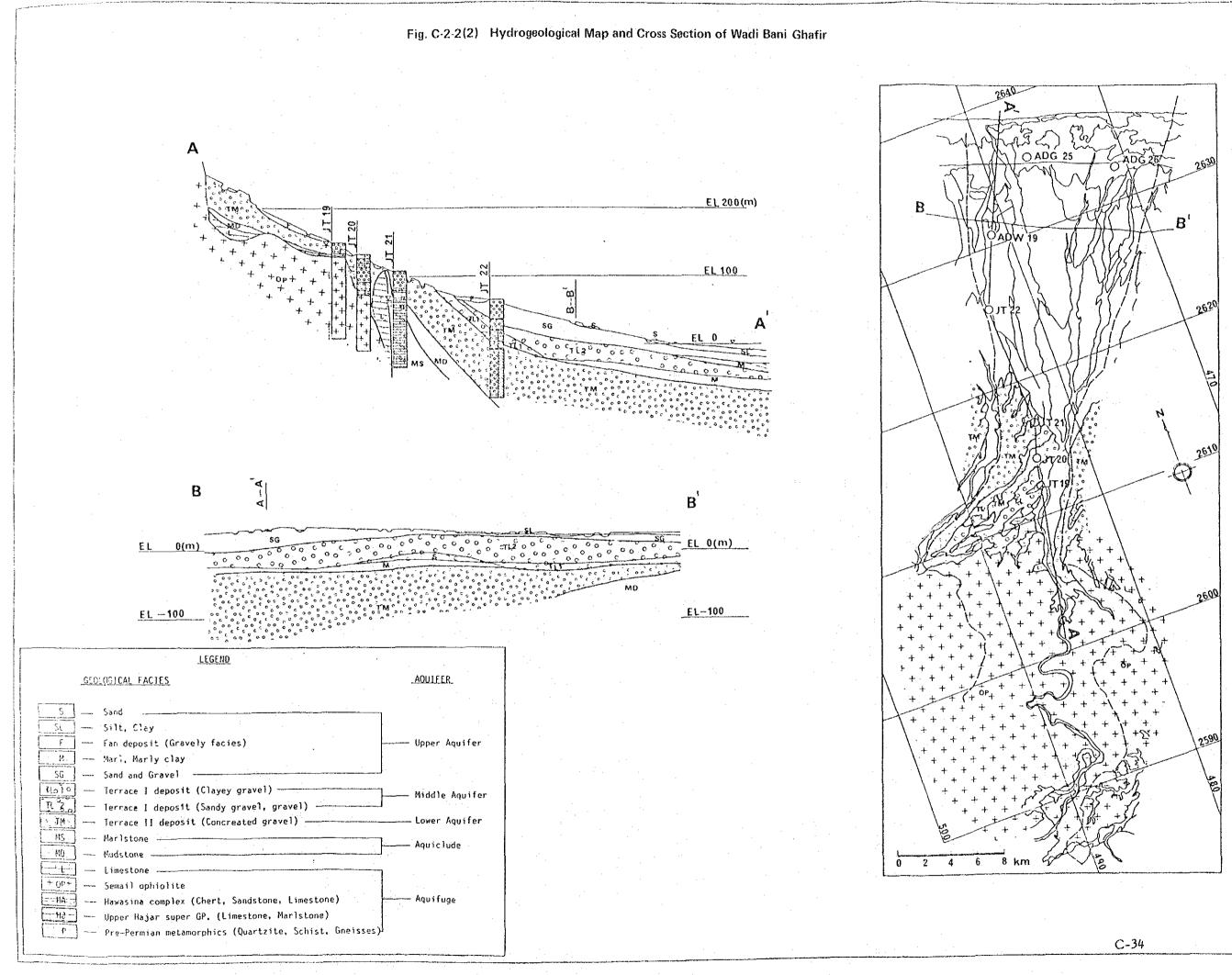
Fig. C-2-1(9) Continued

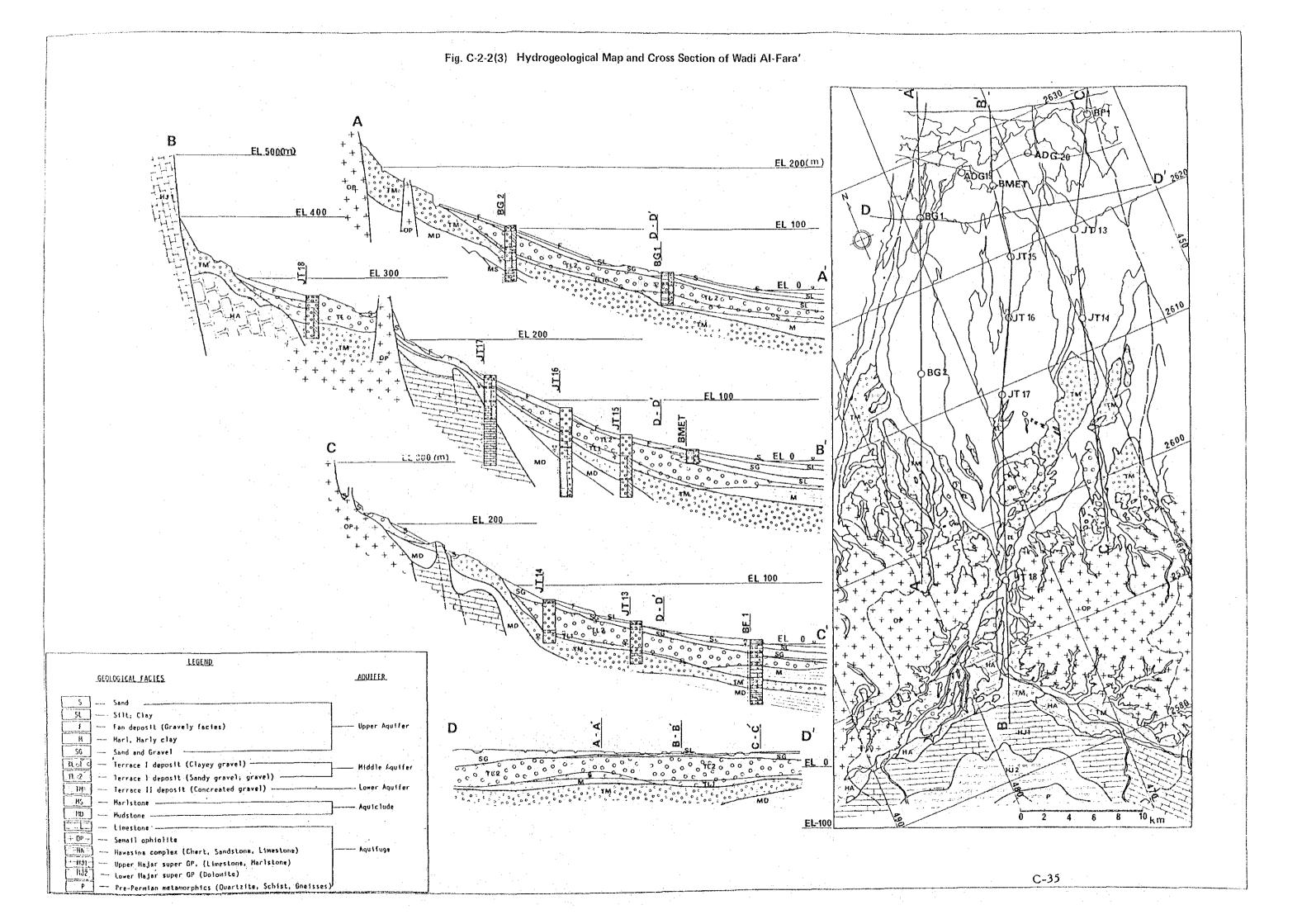
PR0	JECT	TYD	ROLOGIC OBSERVA		THE BATINAH COAST	SITE		WADI	AL MA'AWIL
HOL	E NO.		BM 3	ANGLE FROM HORIZONTAL	PERPENDICULAR	FORE	EMAN		
	ATION	UPSTREAM OF HIFRI		COMMENCED		}	GED BY		
HOL	E DIA.	<u></u>	10 "	COMPLETED C		CHEC	CKED BY		
ELEVATION	THICXNESS (m) DEPTH (m)	LOG	CLASSIFICATION	DESCRIPTIO	N AND STRUCTURES		DRIL 10 20	LING TIM 30 40	E (min/m) 50 60 70
<u> </u>	31	00	GRAVEL	same as abov	e mentioned description				
	restanduminn bandundun burdun bandun directu	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	GRAVEL	Gravel and sand gravel dominant beded, carbonate the whole horize	, gray sand rich facies and layer are alternately inter e fragments are rare throu on.	⊶. ' waadaa hadaa hadaa ahaa hadaa had		a de conservante de la conservante de l	
	landandanlan bankan 42					بسامينكسا سباسيا		and and the second s	
	anturshadenshaden-husterilandas	0 0 0 0 0	GRAVEL	Brownish gray g fragments.	ravel with sand and carbor	ate and a fundamenta		a press, c. constrained and a set of	
	48 W								
	51		CLAY	Brownish gray c calcarious sedi	lay with sand and granule, ments are contained.	التقاصلينا بتنابينا		* • • •	
	uniondantion feederate				N	يمنكبه أيبدل يتدايد التداير			
	n landar hardera badar.					անտեսունունու			
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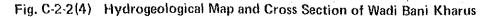


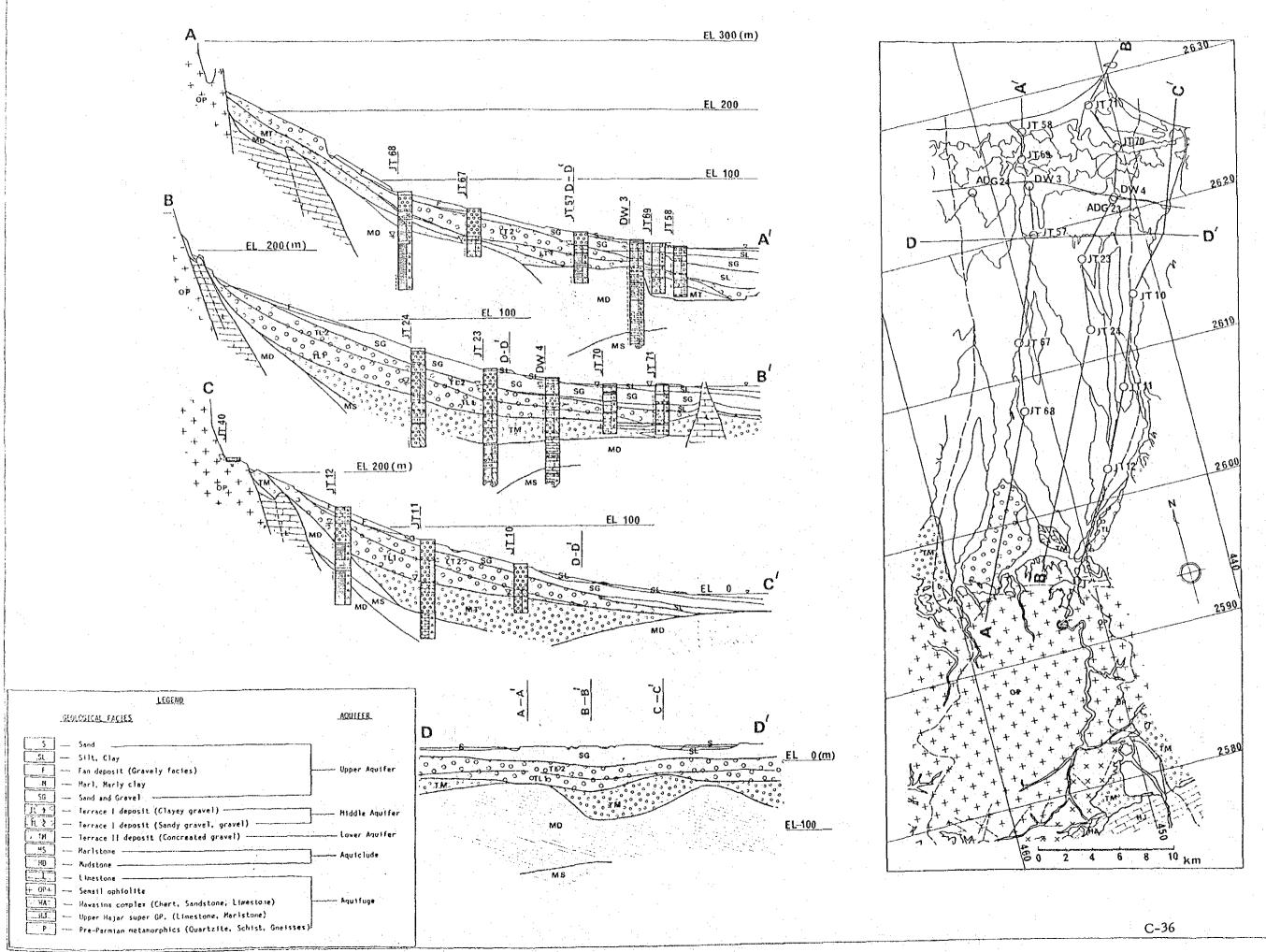


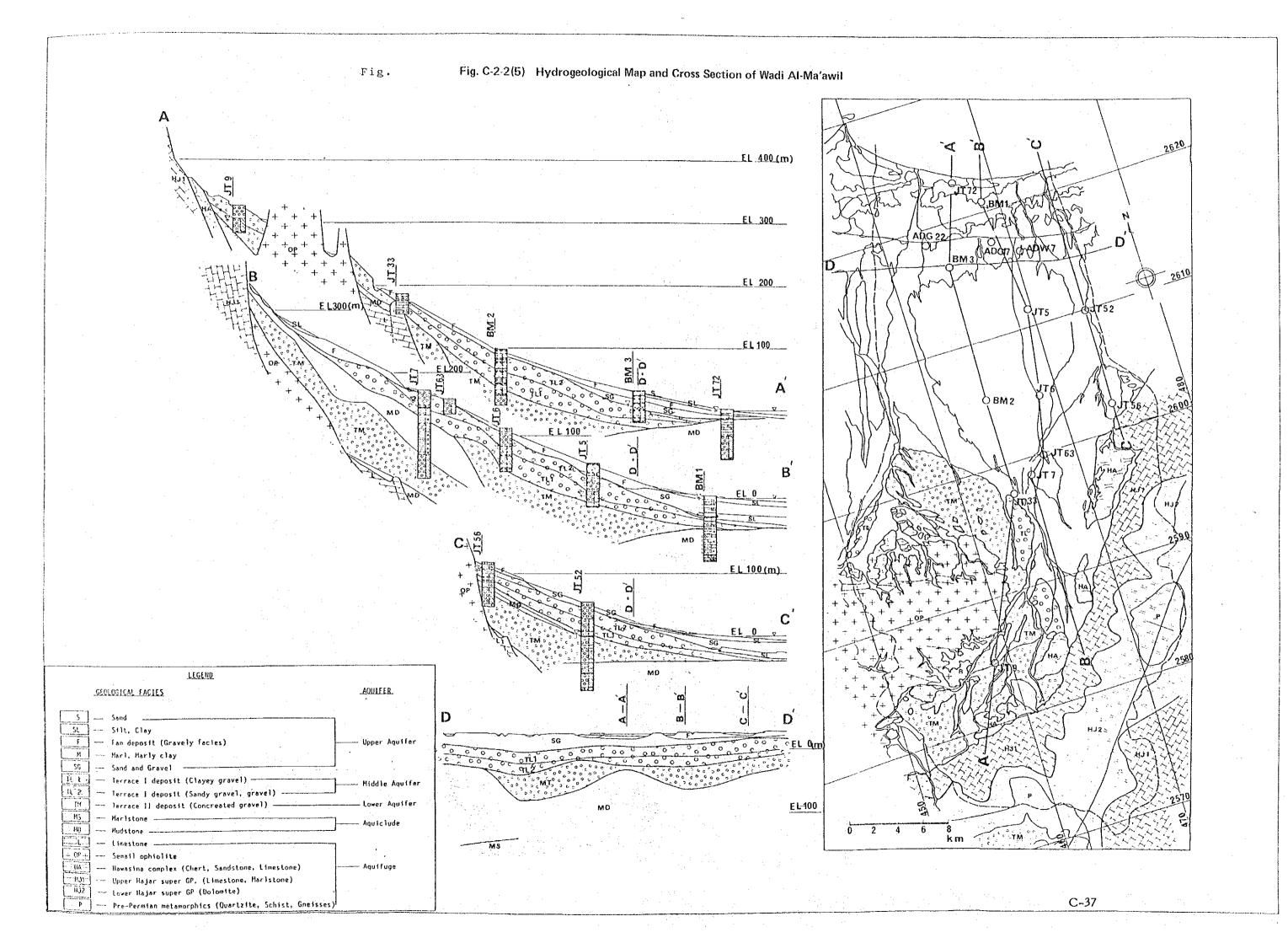












#### 2.2 Geo-resistivity Sounding

#### 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  $\beta a - \beta u$  method, presumes that the underground structure along sounding lines would have a mass of the unit volume with a resistivity of  $\beta u$ . 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. Pu 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

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	
<u></u>	• • • • • • • • • • • • • • • • • • •	<b>5.</b> <u></u>	5 <u></u>

ESH-1 (Wadi Ahin Line)

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	graph Water	82 - 2700	1 - 70
Terrace Deposits	<b></b>	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			

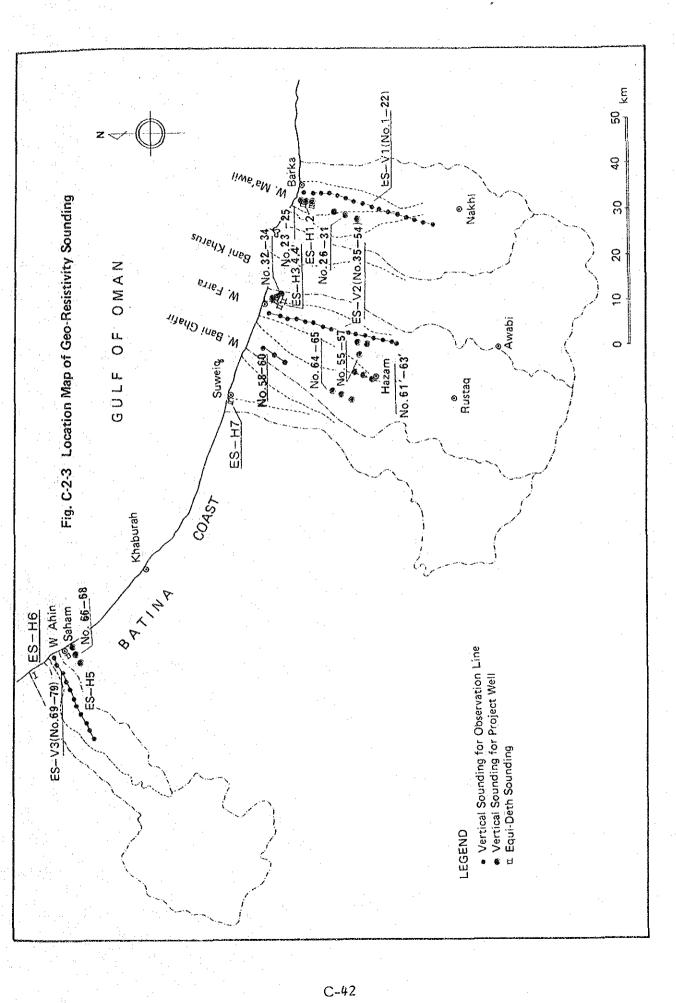
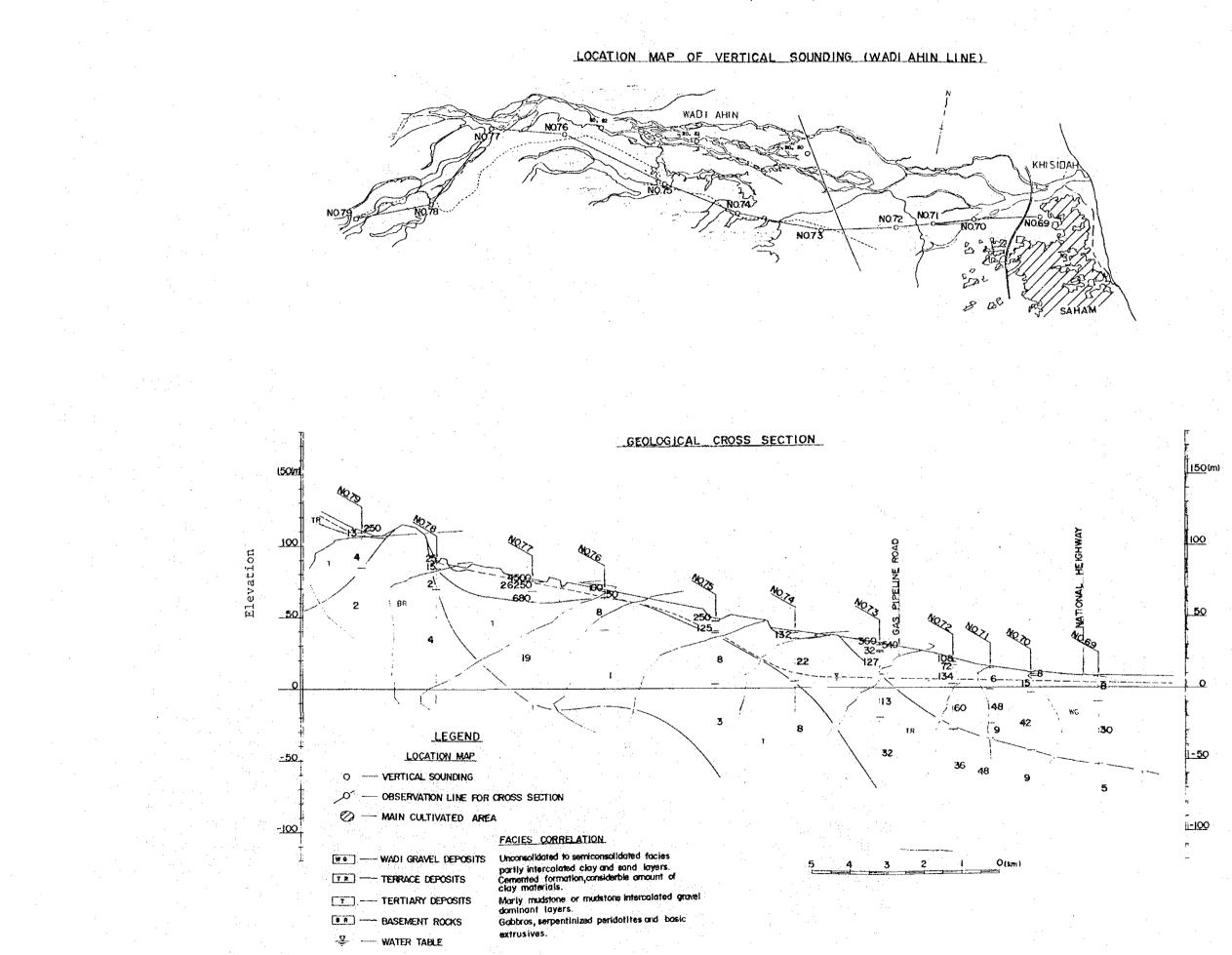
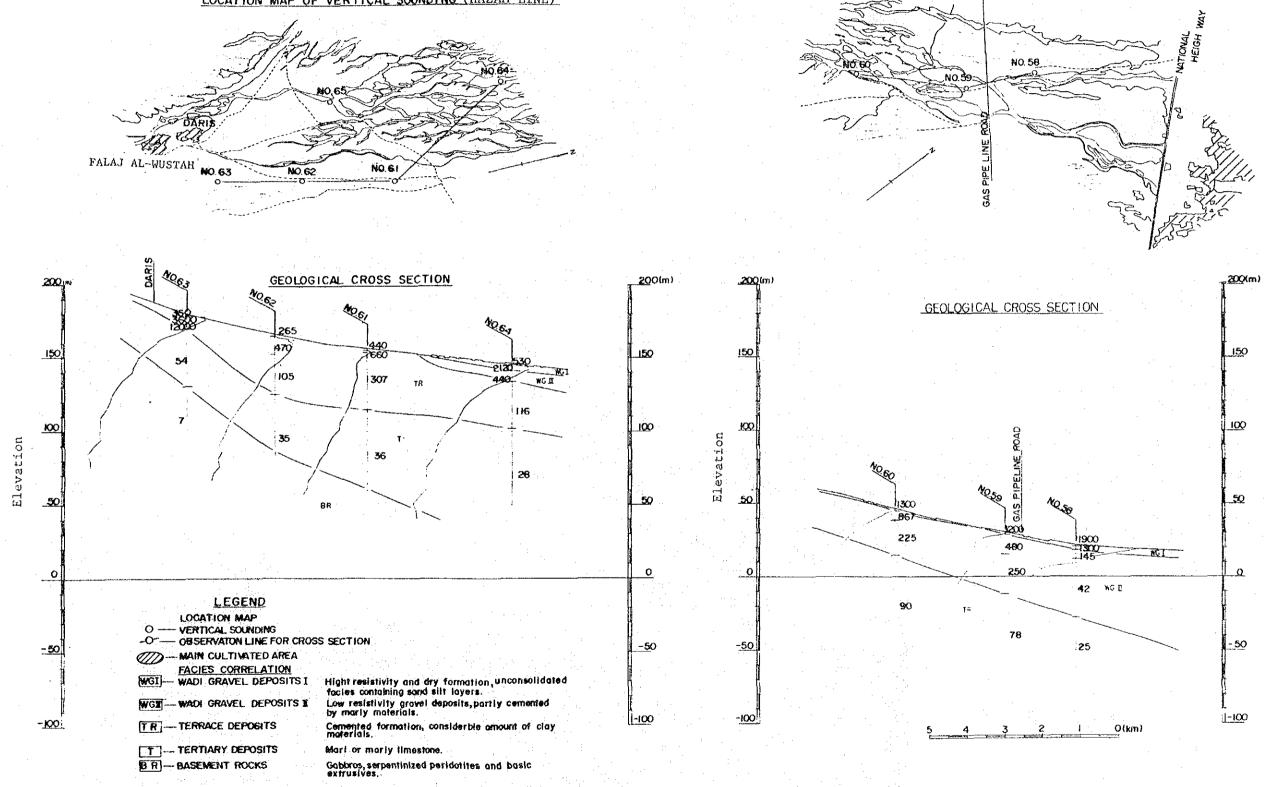


Fig. C-2-4(1) Vertical Geo-Resistivity Soundings, Wadi Ahin Line

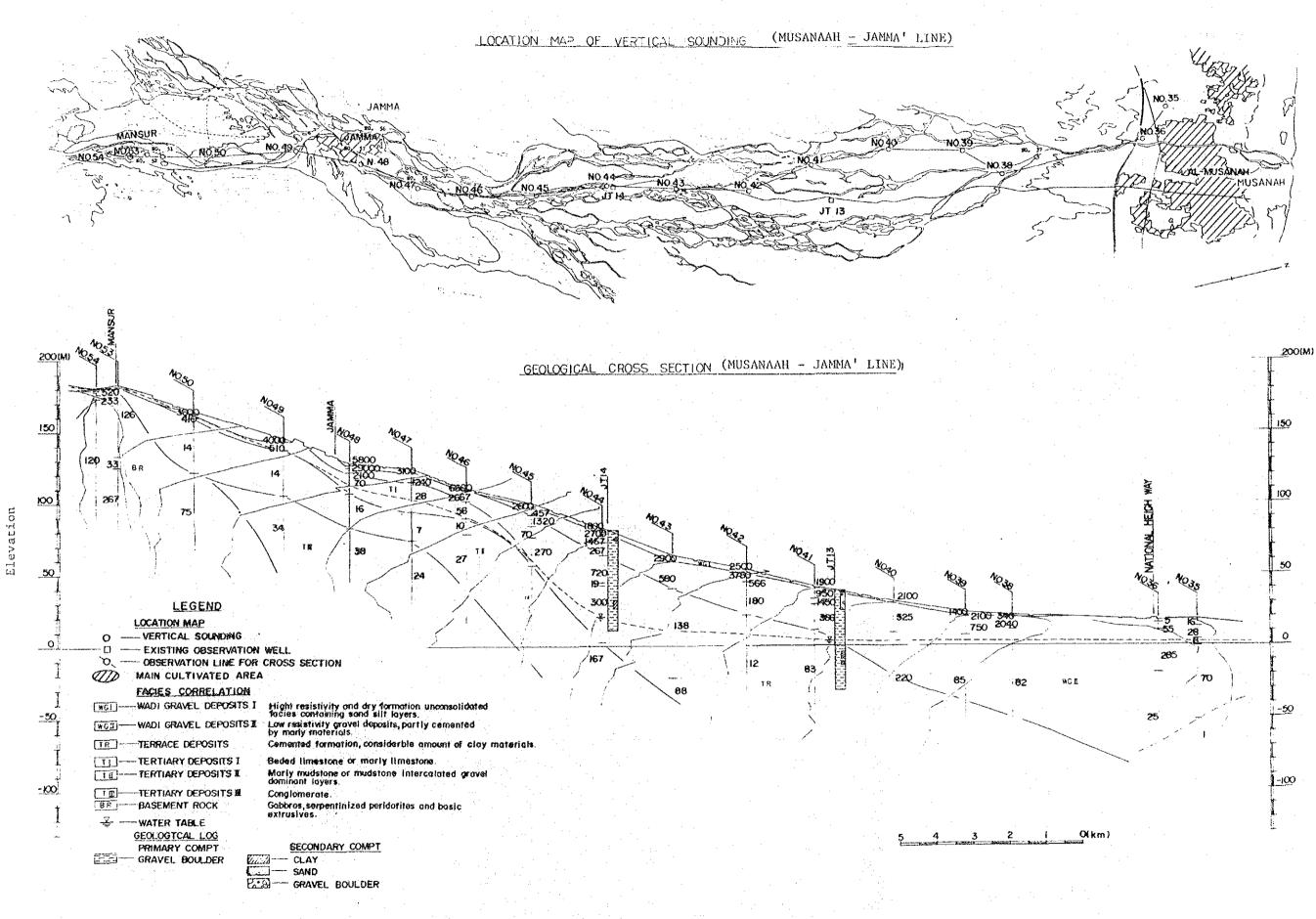


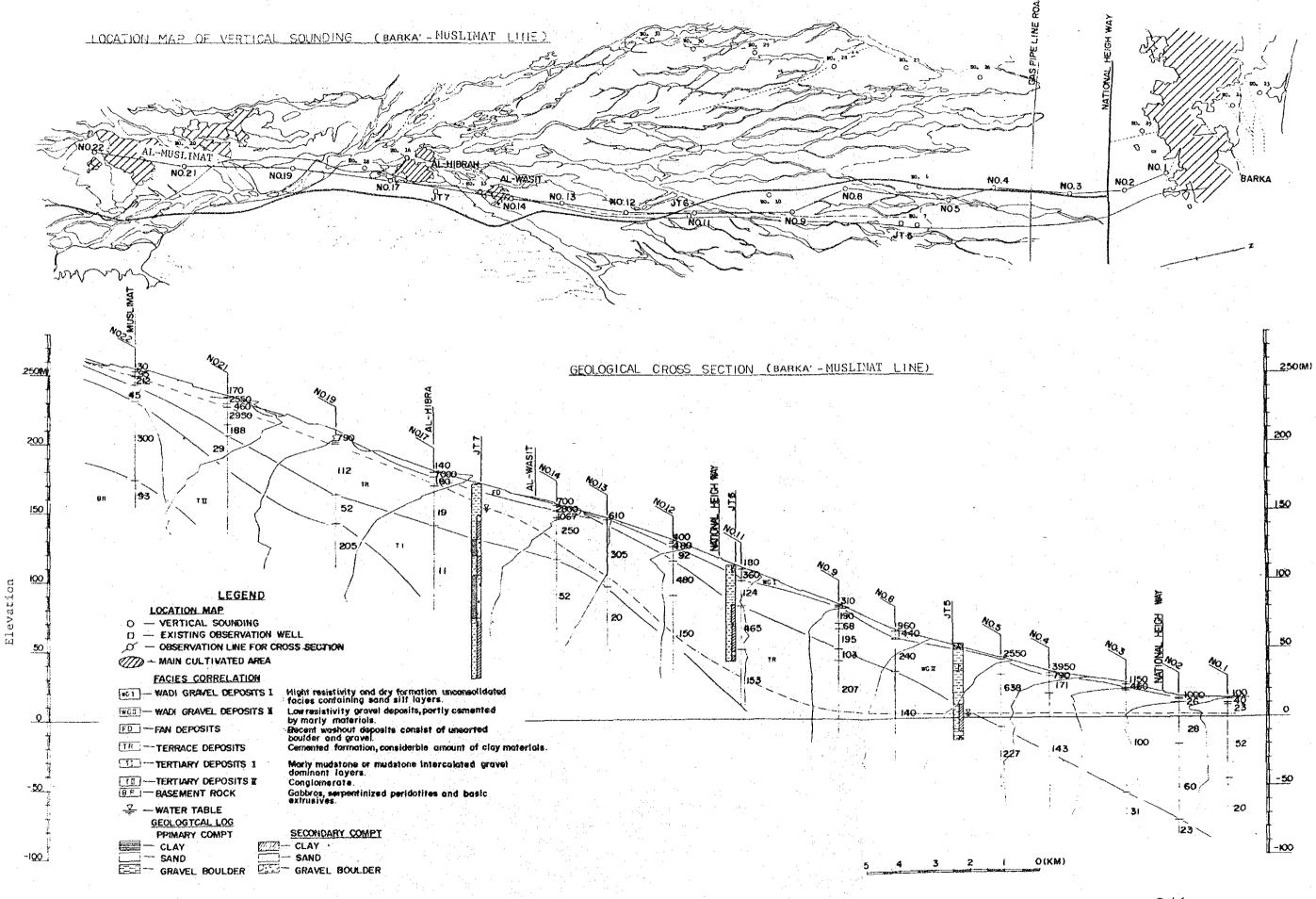


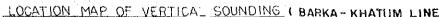
LOCATION MAP OF VERTICAL SOUNDING (HAZAM LINE)

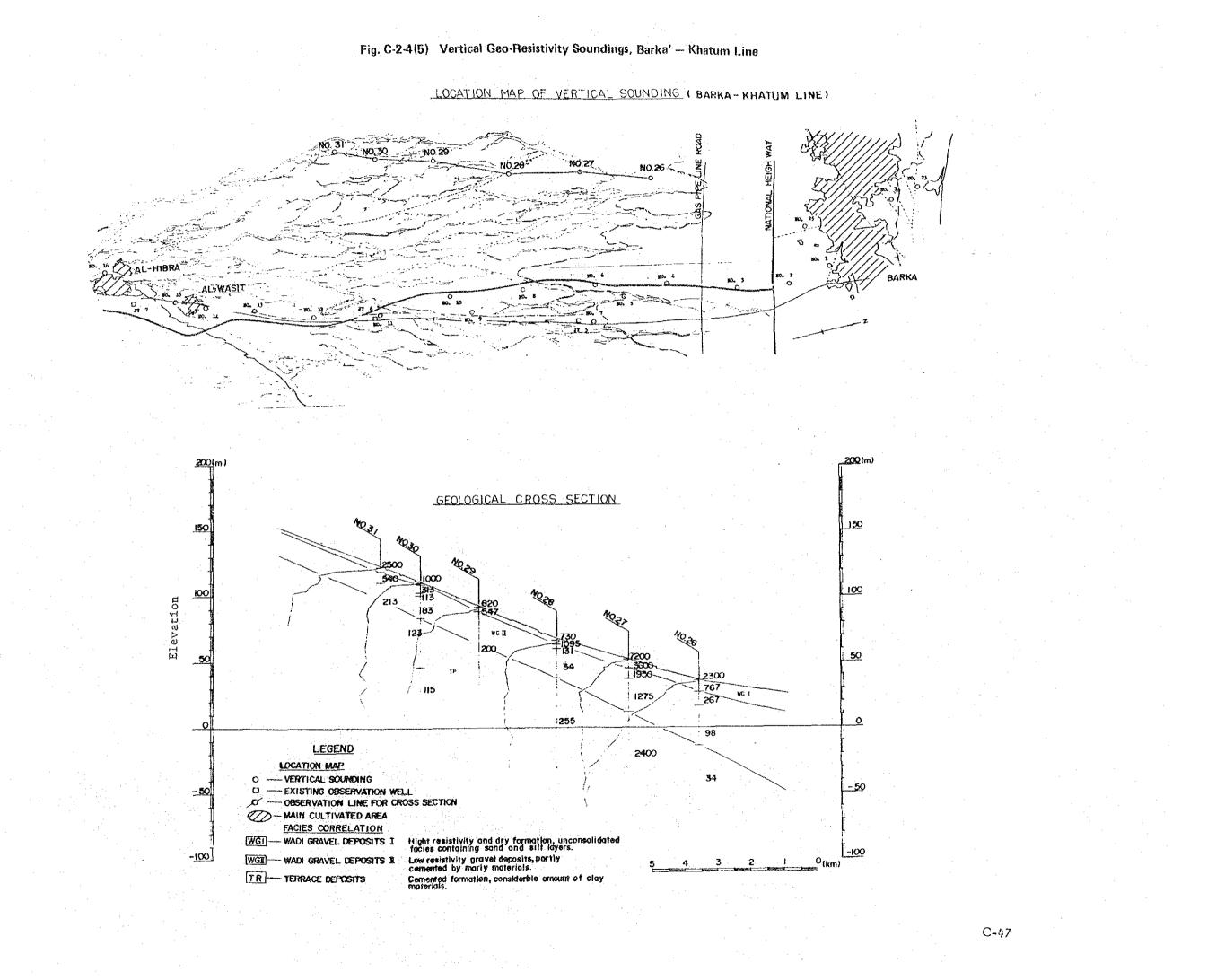
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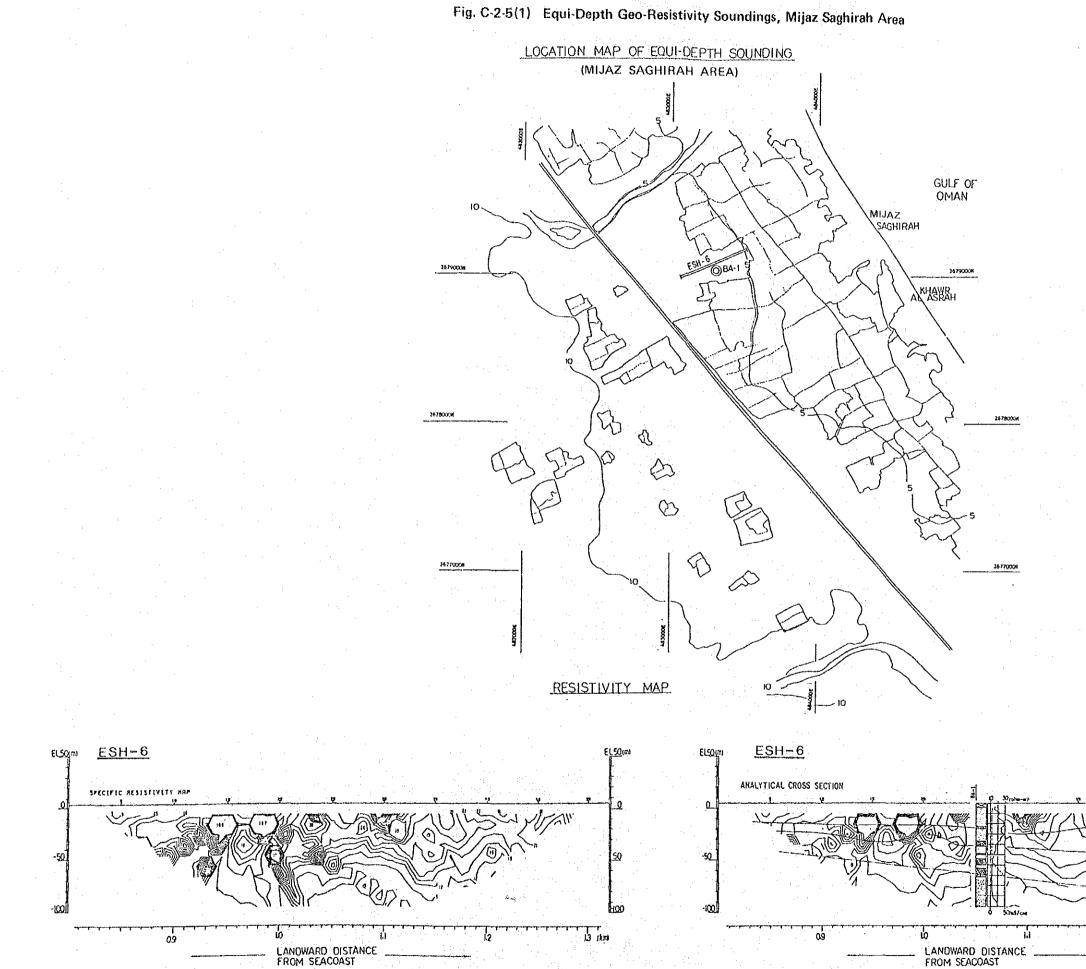
#### LOCATION MAP OF VERTICAL SOUNDING (MULADDAH LINE)

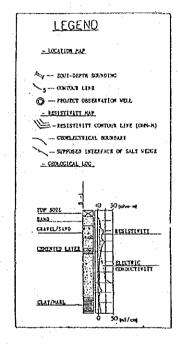


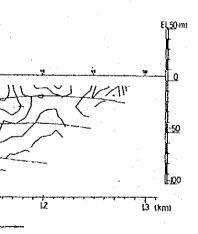












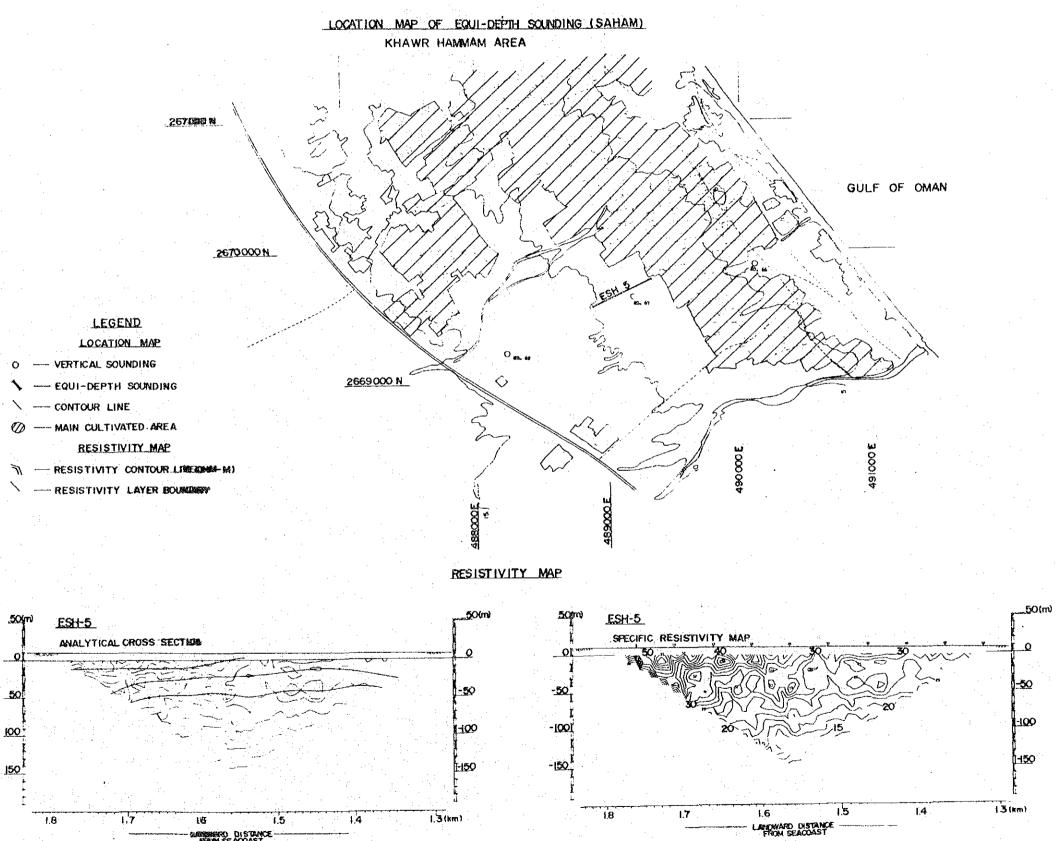
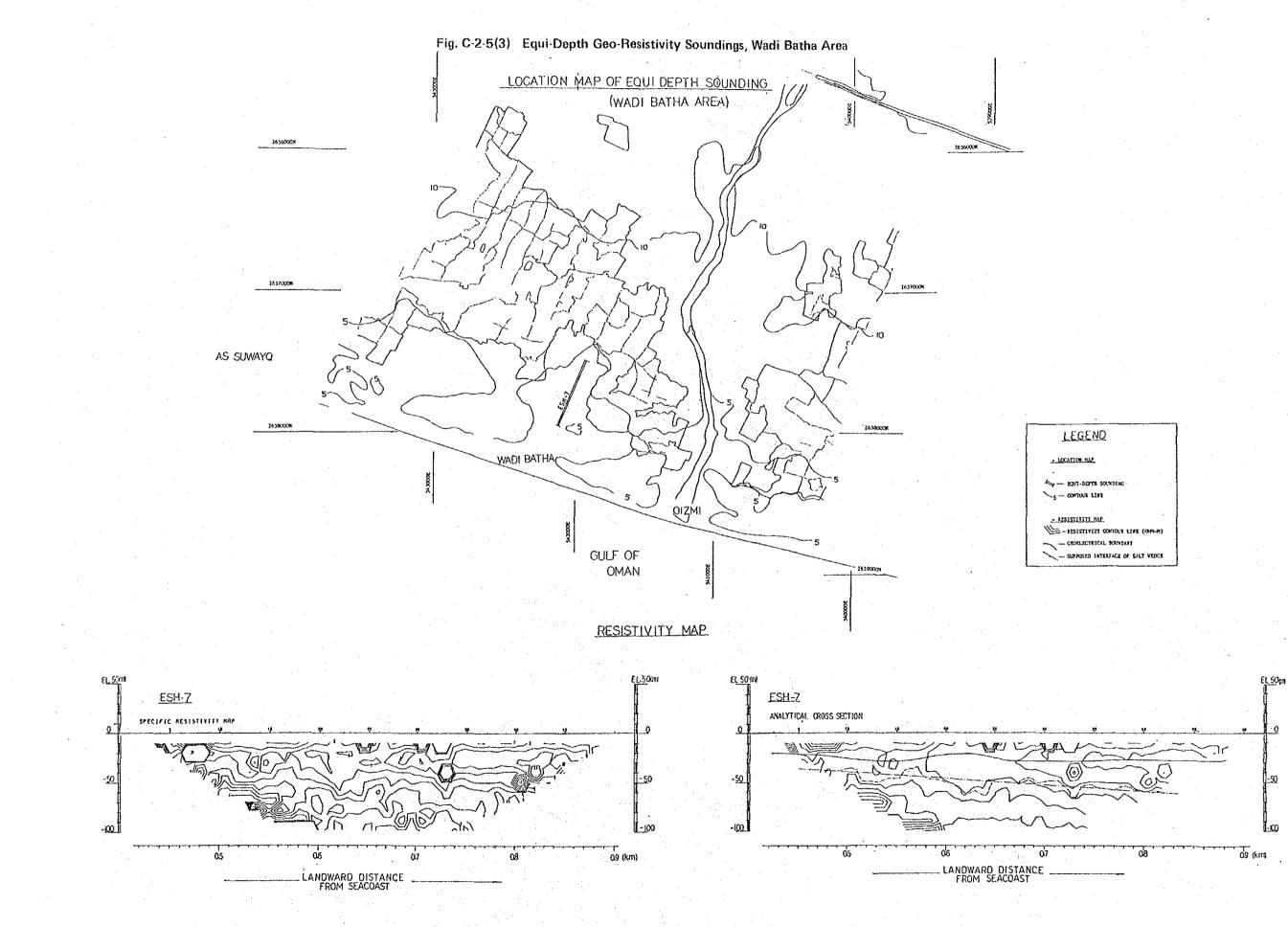


Fig. C-2-5(2) Equi-Depth Geo-Resistivity Soundings, Khawr Hammam Area

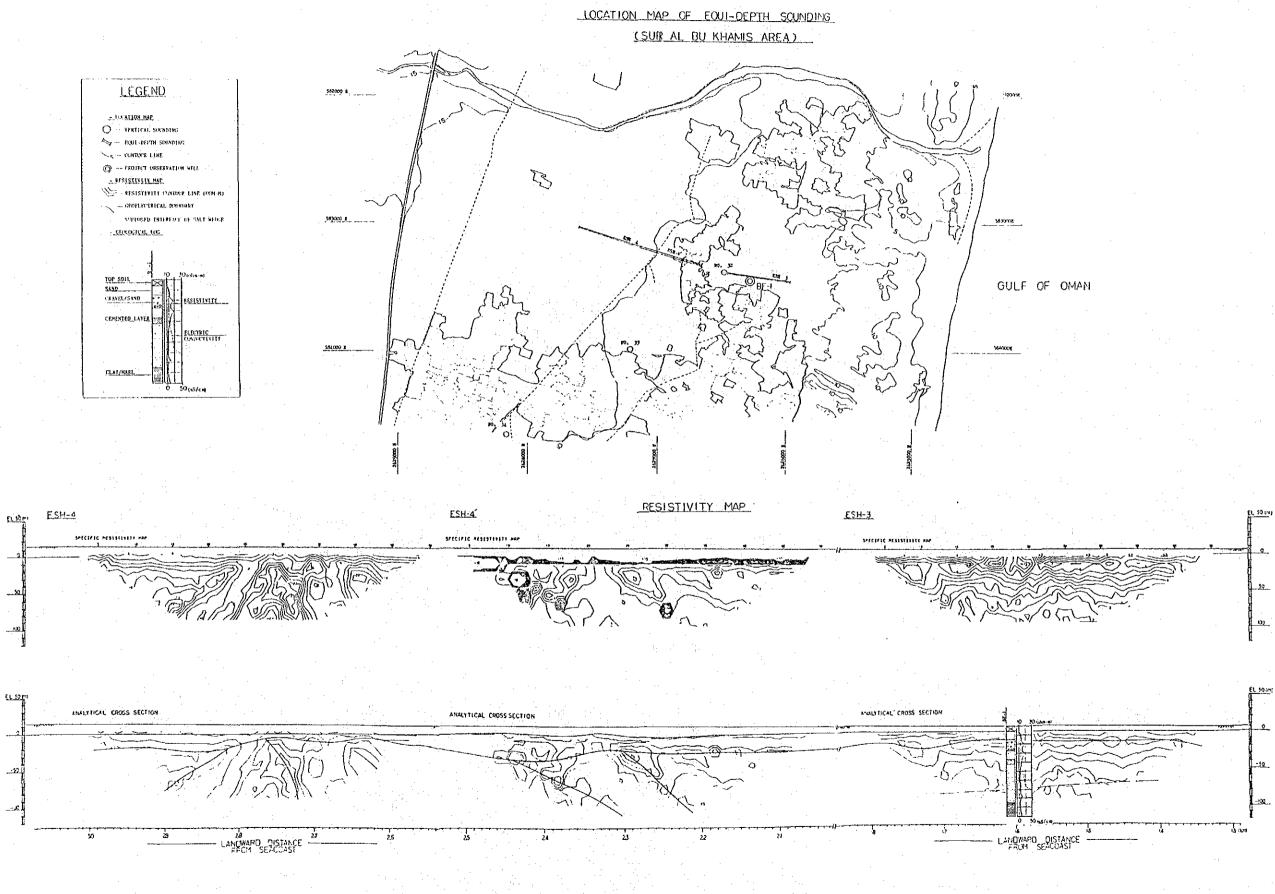
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## Fig. C-2-5(4) Equi-Depth Geo-Resistivity Soundings, Sur Al Bu Khamis Area



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

