# 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

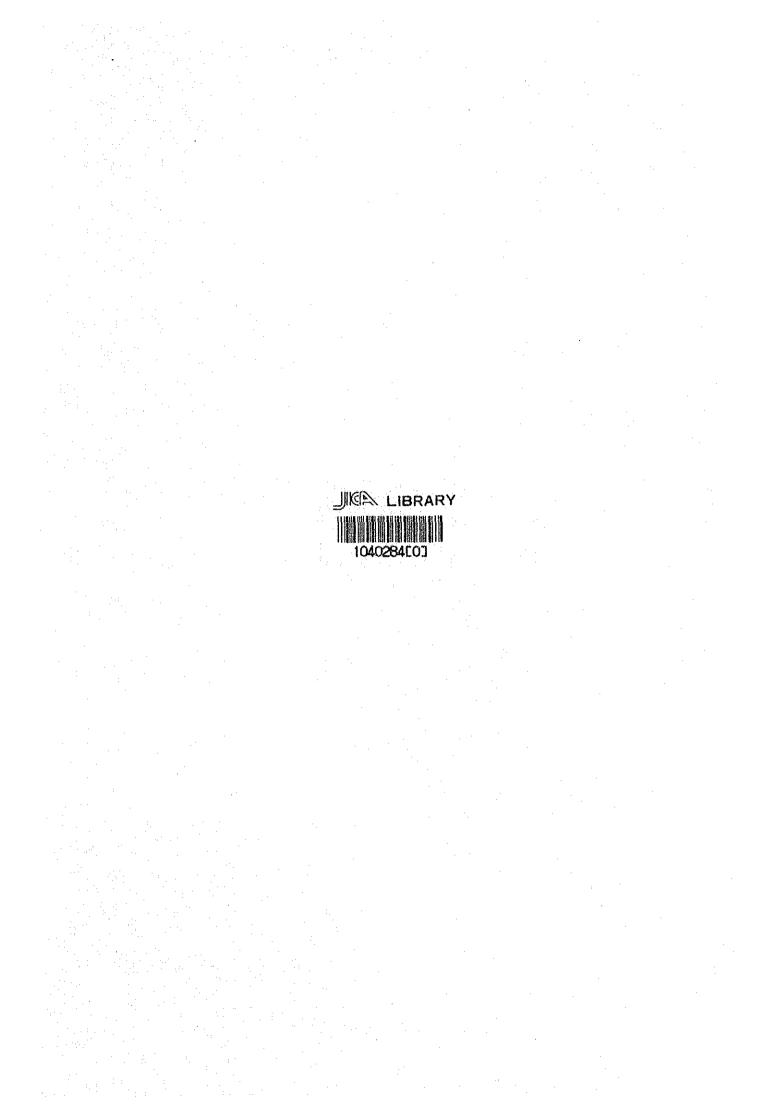
D. GROUNDWATER

E. LAND AND WATER USE

### MARCH 1986

JAPAN INTERNATIONAL COOPERATION AGENCY





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- C. HYDROGEOLOGY
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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 |
|             | <br>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  | <br>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  | <br>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<br>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)<br>30 40 50 60 70 |
|                              | Light brown to light gray silt with sand,<br>partly consolidated by carbonate material<br>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<br>fragments, the proportion of sand gradual<br>increase in order to the lower horizon. Th<br>shell crusts are included through whole he | ly Tall  |                                     |
|                              | •   | unutranta da la constructione de la constructi |                                     |
| SAND                         | Light grayish beach sand, medlum sand fac<br>with a few intercalation of marly clay.  | sies =   |                                     |
|                              |   |  |                                     |
| 22 = 6                       | Silt with sand and gravel, light yellow or<br>colored. The marly facles and sand/gravel<br>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<br>HORIZONTAL PERPENDICULAR  | FOREMAN  |  |
| LOCATION                                 | NEAR MUAZ SAGHIRAH  |   | LOGGED BY  | 1  |
| HOLE DIA.                                | 10 "  | COMPLETED   | CHECKED B  | Υ  |
| DEPTH<br>(m)<br>ELEVATION<br>(m)<br>DATE | LOG CLASSIFICATION  | DESCRIPTION AND STRUCTURES  |  | RILLING TIME (min/m)                         |
| (3) (3) (3) (3) (3) (3) (3) (3) (3) (3)  | 0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0   | Gravel with sand, dark brown gravel domi<br>facies, matrix filled by medium sand, cla<br>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<br>and clayey layers dirived from ophiolite.                         | last and and and a   |  |
| 72.24                                    | 0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0 | Brown gravel with clay, alternation facies of gravel and clay.  | university of the second s |  |
| rationalization in the second            | O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>O<br>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<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0<br>0   | Gravel and sand, sand dominant facies p<br>interbeded especially between 81 meters<br>83 meters,              | artly fund   |  |
| 87                                       | SAND  | Reddish brown sand, medium sand with a of carbonate material.   | Hittl  |  |
|  | O<br>O<br>C<br>C<br>O<br>O  | Gravel and sand, brown to black rounder<br>gravel made up of granule to pebble an<br>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<br>HORIZONTAL PERPENDICULAR   | FOREMAN   |   |
| LOCATION   | 10 KM DOWN STREAM   | COMMENCED  | LOGGED BY   |   |
| HOLE DIA.  | 10 "  | COMPLETED  | CHECKED B   | γ   |
| THICKNESS<br>(m)<br>DEPTH<br>(m)<br>ELEVATION<br>(m)<br>DATE   | LOG CLASSIFICATION  | DESCRIPTION AND STRUCTURES   |   | ILLING TIME (min/m)<br>0 30 40 50 60 70 , |
| 2)<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N<br>N  | GRAVEL<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G<br>G | Brown to light brown sand with silt and gra<br>silt dominant layer and much amount of gr<br>gravel interculate.at the upper horizon.<br>Granule gravel with sand and a few clayey<br>material.<br>Gray to light brown gravel layer, pebble to<br>granule with sandy matrix, the alternate fa<br>of pebble and granule. | avel<br>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<br>with sand and a few carbonate fragments.<br>brown to light brown colored facies.   |   |   |
|  | CLAY  | Reddish brown clay with a few granule gra  |   |   |
|  | SAND  | Medium to coase sand with gravel, light b<br>colored facies.   | rown -  |   |
| 23   | GRAVEL  | Light brown gravel, much amount of pebble<br>with carbonate fragments.   | e<br>e  |   |
| میں اور میں اور<br>میں اور میں اور م | O GRAVEL<br>O GRAVEL<br>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<br>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<br><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<br>(m)<br>EVATION<br>DATE<br>(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<br/>۵</td><td></td><td></td><td></td></td<>  |                                       |            | ۵<br>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<br>Δ  |   | - The second sec |                                       |
| SAND<br>Light brown sand with slit and gravel, the<br>intercalation of sandy layer at the 43 to<br>44 metres horizon.   |                                       | uuduu d    | A SAND  |   |  |                                       |
| SAND<br>Light brown sand with slit and gravel, the<br>intercalation of sandy layer at the 43 to<br>44 metres horizon.   |                                       |            | ۵<br>۵  |   | - Alar   |                                       |
| SAND<br>Light brown sand with slit and gravel, the<br>intercalation of sandy layer at the 43 to<br>44 metres horizon.   | 40 4                                  | hantau     | . A<br>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<br>intercalation of sandy layer at the 43 to<br>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<br>(A  |   |  |                                       |
| MUDSTONE Mudstone to marly mudstone with a few content of granule gravel.   |                                       |            | Δ   |   |  |                                       |
| content of granule gravel.  |                                       |            |   |   | ulaulu<br>1  |                                       |
|   |                                       |            | 4 MUDSTONE  |   | <u>mbrid</u>   |                                       |
|   |                                       |            |   |   | <u>a</u> l-14  |                                       |
|   |                                       |            |   |   |  |                                       |
|   |                                       |            |   |   | laula<br>1   |                                       |
|   |                                       | -<br>      |   |   | नम्पन  |                                       |
|   |                                       | uluei.     |   |   | -<br>  |                                       |
|   |                                       |            |   |   |  |                                       |
|   |                                       |            |   |   | an line  |                                       |
|   |                                       | - abude    |   |   | - Internet   |                                       |
|   |                                       | uluulu     |   |   | 40.00  |                                       |
|   |                                       | <u>1</u>   |   |   |  |                                       |

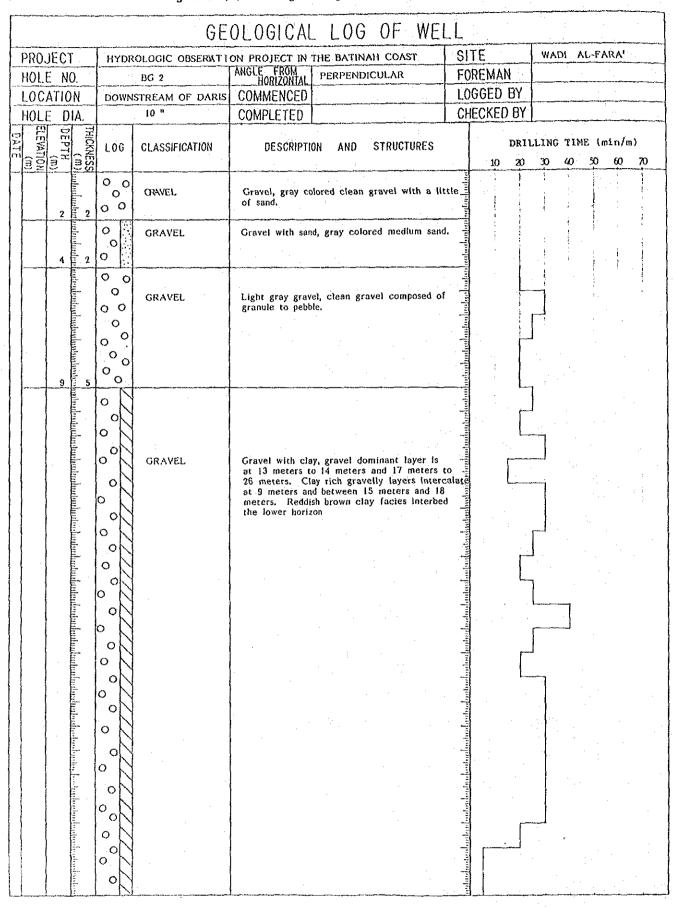
·····

| 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<br>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<br>(m) | THICKNESS<br>(m)<br>DEPTH<br>(m)   | L06      | CLASSIFICATION  | DESCRIPTION AND STRUCTURES  |  | DRILLING TIME (min/<br>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<br>5             | Δ<br>    | SAND            | Dark brown sand with gravel, poorly sort<br>medium to coarse sand.  | a<br>p   |  |       |           |          |                       |      | in a substant da particular anno 1999 a substant   | بوالم الم الم الم الم الم الم الم الم الم |  |  |
|      |                  | 11                                 | Δ<br>Δ   | SILT            | Links house on one offs with soud and a   |  |  |       |           |          | -                     |      | . •  |   |  |  |
|      |                  | nhudnahndentendenden               |          | 312.1           | Light brown to gray, silt with sand and g<br>proportion of sand to silt is a like quanti                            | ity.   |  |       |           |          |                       |      |  |   |  |  |
|      |                  | uuluuluuluu<br>11 6                | A        |                 |   | سلساساس  |  |       |           |          |                       |      |  |   |  |  |
|      |                  | mpulmu                             | 4/4/     | SAND            | Gray to light gray sand with gravel, poor   | e<br>Ludaluuluu  |  |       |           |          |                       |      |  |   |  |  |
|      |                  | ulanihunihunihunihunihunihunihunih | A/ A/    |                 | sorted sand with gravel, a few carbonate a<br>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<br>facies.  | mbuduut  |  |       |           | <br>:    |                       |      | *  |   |  |  |
|      |                  | 22 4<br>1<br>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<br>particles, carbonate fragments are commo<br>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<br>HORIZONTAL PERPENDICULAR  | FOREMAN  |                                      |
| · ·  |            | CATIC        |  | UPSTI     | REAM OF AL-MUDA  |   | LOGGED BY  | -                                    |
|      |            |              | IA.<br>F   | <u>i</u>  | 10 "             | COMPLETED   | CHECKED BY   |                                      |
| UALE | (E)<br>(E) |              | (m)  | LOG       | CLASSIFICATION   | DESCRIPTION AND STRUCTURES  | DR1<br>10 20   | LLING TIME (min/m)<br>30 40 50 60 70 |
|      |            | 31           | ահու   | 0         | GRAVEL           | same as above mentioned description   |  |                                      |
|      |            | 34           | mparananananana<br>3   |           | SAND             | Light gray sand, medium to coarse sand<br>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<br>contained.  | are The second s |                                      |
| -    | <br> <br>  | 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<br>   |                                      |
|      |            | 46           | 4<br>4   | 4 . 4 .   | SAND             | Sand with gravel, abundant carbonate<br>fragments.  | diminut  |                                      |
|      | <br>       | 50           | uluelu: 4  | 2         |                  |   |  |                                      |
|      |            |              | an partantia da construction de la construcción de la construcción de la construcción de la construcción de la<br>La construcción de la construcción d | $\sim$    | SAND             | Sand, clean fine to medium sand, well s<br>and facies seems to be beach sand.                   | sorted   |                                      |
|      | <br>       | 53           | 3<br>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<br>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<br>(m)<br>DEPTH<br>(m)  | LOG           | CLASSIFICATION    | DESCRIPTION AND STRUCTURES   |                                   | DR1<br>10 20                          | LLING<br>30 | TIM<br>40 | E (m<br>50 |         | )<br>07 |  |
|      |           | 32 m 23   | 0000          | GRAVEL            | Same as above mentioned description  | under and series                  |                                       |             |           |            | ι.<br>· |         |  |
|      |           | 101401<br>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<br>light brown colored granule to pebble. | <u> ماسا میا میا مارم</u>         |                                       |             |           | •          |         |         |  |
|      |           | 39 u  | 。<br>。        |                   |  | <br> <br> <br> <br>               |                                       |             |           |            |         |         |  |
|      |           | ահաման<br>41 ա  | ۵<br>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><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u><br><u>1</u> | 0000          | GRAVEL            | Gravel with clay, light gray to light brow gravelly facies.                        | c                                 |                                       |             |           |            |         |         |  |
|      |           | nınınlarılınılınılınılını<br>50   | 0 0 0 0 0 0 0 | GRAVEL            | Light gray to white gravel, consolidated f<br>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<br>0        |                   |  |                                   |                                       |             |           |            |         |         |  |
|      |           | nulunhundun   |               | CLAY              | Clay with sand and a few granule gravel,<br>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<br>HORIZONTAL PERPE  | NDICULAR                                   | FOREMAN  |                     |        |    |  |  |
| LOCATION  | WNSTREAM OF DARIS  | COMMENCED   |  | LOGGED BY  |                     |        |    |  |  |
| HOLE DIA. | 10 "               | COMPLETED   |  | CHECKED BY   |                     |        |    |  |  |
| ELEVATION | CLASSIFICATION     | DESCRIPTION ANI   | D STRUCTURES                               | DR1<br>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<br>are contained.   | little of granule gra                      | avel   |                     |        |    |  |  |
|           | CLAY               | Light brown to reddish sandy particles are of v   | brown clay with so<br>very fine to fine sa | Ind, Ind, Ind, Ind, Ind, Ind, Ind, Ind,  |                     |        |    |  |  |
|           |                    | White to light gray mar<br>upper facies seems to i<br>carbonate matrix, the l<br>consist of maristone wi<br>from ophiolite. | oe a conglomerate<br>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<br>(m)   | THICKNESS<br>(m)<br>(m)<br>(m)   | L06 | CLASSIFICATION   | DESCRIPTION AND STRUCTURES                          |
| _      | · .               | 91 2   |     | MARL             | same as above mentioned desdription                 |
|        | - <sup>14</sup> - | landard  |     |                  |   |
|        |                   | uniunianta   |     |                  |   |
|        |                   | ebududa  |     |                  |   |
|        |                   | Sinlantaut   |     |                  |   |
|        | -                 | minudundan   |     |                  |   |
|        |                   | hunturshuets   |     |                  |   |
| 1<br>1 | tala<br>Le        | ահարհո   |     |                  |   |
|        |                   | dun lun l  |     |                  |   |
|        |                   |  |     |                  |   |
|        |                   | Ē  | •   |                  |   |
|        |                   | man  |     |                  |   |
|        |                   | սիսվուլ  |     |                  |   |
|        |                   | հութովումը   |     |                  |   |
|        | t<br>P            |  |     |                  |   |
|        |                   | hondourde .  |     |                  |   |
|        |                   | den Austhauthauthauthen treaken ten beitreeken ten beitreeken ten beschen ten beschen ten beschen ten beitreek |     |                  |   |
|        |                   | -<br>  |     |                  |   |

|                         |   |   | GE             | OLOGICAL                          | LOGO                               | F WEL                        |  |          | <del></del> |                  |   |             |       |   |  |
|-------------------------|---|---|----------------|-----------------------------------|------------------------------------|------------------------------|--|----------|-------------|------------------|---|-------------|-------|---|--|
| PROJ                    | JECT  | HYDE                                    |                |                                   |                                    |                              | SITE   |          |             | ŴA               | DI AI   | <u>FA</u>   | RA'   |   |  |
| HOLE NO. BF 1           |   |   |                | ANGLE FROM<br>Horizontal          | PERPENDICU                         | ÄR                           | FORE   |          |             |                  | <u>.</u>  |             |       |   |  |
| 1                       | ATION   | NEAR                                    | THE AL-MUSANA  |                                   | ·                                  |                              | LOGO   |          |             |                  |   |             |       |   |  |
| HOLE                    |   | ·                                       | 10 *           | COMPLETED                         | . <u> </u>                         |                              | CHEC   |          |             | ING TIME (min/m) |   |             |       |   |  |
| LEVATION<br>(m)<br>DATE | THICKNESS<br>(m)<br>DEPTH<br>(m)  | LOG                                     | CLASSIFICATION | DESCRIPTI                         | DESCRIPTION AND STRUCTURES         |                              |  | DR<br>10 | 20          | NG T<br>30       | 1ME<br>40   | (min<br>50  |       | 70 ·  |  |
|                         | untur furtur 3<br>3   |   | SILT           | Light gray san                    | dy slìt.                           |                              | terlindinateralised  |          |             |                  | A CALL AND | *<br>*<br>* | :     |   |  |
|                         | 4   | ! :                                     | SILT           | Light gray silt                   | with send.                         |                              |  | :        |             |                  |   | :           |       |   |  |
|                         | 6 2   |   | SILT           | Light gray sem<br>sandy material  | il-consolidated s                  | ilt with a fer               | *<br>unter-fronten   |          |             | •                | -   | ·           | :     |   |  |
|                         | 7   |   | SAND           | Light gray to                     | gray sand, fine                    | to medium s                  | and I  |          |             |                  |   |             |       |   |  |
|                         | 8 1   | 0                                       | GRAVEL         | Light gray to<br>content of gra   | gra y gravel wit<br>nule gravel.   | h sand, much                 | 1 III<br>1 III   |          |             | · .              |   | 1.          |       |   |  |
|                         | 10 2  |   | SILT           | Light gray silt<br>peoble.        | with granule gr                    | avel and a f                 | ewinning   |          |             |                  |   | · · ·       | •     |   |  |
|                         | ահամաս  | 0<br>0<br>0<br>0                        | GRAVEL         | Light gray to<br>clayey materia   | gray gravel with<br>!.             | sand a lew                   | านของเป็นสายเป็นสาเป็สสาเป็สสสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตสตส | •        |             | •<br>•<br>•      | <br>  |             | ,     | 2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2 |  |
|                         | in the second | Δ                                       | SAND           | Light gray to g<br>medium sand gr | ray sand and gr<br>anule gravel,   | ave), fine to                | անակարութութական   |          |             | •                |   | :           |       |   |  |
|                         |   | 0 0<br>0 0                              | GRAVEL         | Light gray to g<br>granule gravel | ray gravel with<br>with a few sand | sand, subrou<br>y particles, | ndedimina  |          |             |                  |   |             |       |   |  |
|                         | nutunhatharheim   | 0 | GRAVEL         | Light grav<br>of granule grav     | el with sand, m<br>el.             | uch proportia                | u<br>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<br>HORIZONTAL   | PERPENDICULAR  | F                      | OREMA  | N     |            |       |       |               |  |  |
| LOCATION   | NEAR THE | AL-MUSANA'                                 | COMMENCED                  |  |                        | OGGED  |       |            |       |       |               |  |  |
| HOLE DIA.  |          | <u>Он</u> .                                | COMPLETED                  |  | C                      | HECKEL   |       |            |       |       |               |  |  |
| DEPTH<br>DEPTH<br>(m)<br>DEPTH<br>(m)<br>DATE  | LOG CLA  | SSIFICATION                                | DESCRIPTIO                 | ON AND STRUCT  | URES                   |  | DRILL | .1NG<br>30 |       |       | n/m)<br>60 70 |  |  |
| B) (B) (B) (B) (B) (B) (B) (B) (B) (B) (   |          | SAND                                       |                            | h gravel and carbon<br>lium to coase sand.<br>vith sand, much amo<br>and a few carbona | unt of<br>ate fragment |  | 20    | 30         | 40    | 50    |               |  |  |
| 42 million for the second seco |          | SAND                                       | Gray colored<br>material . | fine to medium sand  | with merly             |  | •     |            |       |       |               |  |  |
| 54 54  |          | SAND                                       |                            | medium sand.<br>medium sand with ti<br>of marly material.                              | he                     | ախուհունունունունունունունունունունու  |       | •          |       |       |               |  |  |
|  |          | ·<br>· · · · · · · · · · · · · · · · · · · |                            |  |                        | undruction de contraction de contrac |       |            |       | :<br> |               |  |  |

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<br>ANGLE FROM<br>HORIZONTAL PERPENDICULAR   | FOREMAN<br>LOGGED BY  |                                     |
|  | NEAR AL-MUSANA'AH   | COMMENCED  |   |                                     |
| HOLE DIA.  |   | COMPLETED  | CHECKED BY  |                                     |
| THICKNESS<br>(m)<br>DEPTH<br>(m)<br>ELEVATION<br>(m)<br>DATE | LOG CLASSIFICATION  | DESCRIPTION AND STRUCTURES   | DRIL<br>10 20   | LING TIME (min/m)<br>30 40 50 60 70 |
| 61 7   | SAND  | ,  | traefi ny   |                                     |
| C C C  | 0   | Carbonate coated old gravelly facies, dark<br>brown to gray granule / pebble with sand<br>and carbonate fragments. The sandy horize<br>intercalated between 63 and 66 meters; and<br>between 67 and 70 meters. | ng halandari  |                                     |
|  |   |  | aalissi kuntenduntun kuntun kuntun kuntun kuntun kun  |                                     |
|  |   |  | <u>սիսիսիստիստիսի</u>   |                                     |
|  |   |  | entre funte   |                                     |
|  | O<br>GRAVEL   | Grey to dark brown gravel and sand with<br>carbonate fragments, much content of gra<br>to pebble and moderate proportion of me<br>to coarse sand.  | umunu<br>anules<br>diumaaaaa  |                                     |
| 79 uu  |   |  |   |                                     |
|  | MARL  | Dark brown marl with sand, medium to co<br>sand drived from ophiolite and hard calcar<br>clayey layer. The alternate facies of s<br>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<br>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<br>HORIZONTAL            | HE BATINAH COAST<br>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<br>50  |         |          |
|   |                | 2       | 2  |   | SANDY SILT      | Light gray unco                     | nsolidated sandysilt  | <del>nalisaka da</del> n |        |      |        |             | ·.<br>· |          |
|   |                | 4       | nutundure.htm                                      | ۵<br>۵                                  | SAND            | Sand with granu contains carbona    | le and silt, occasionally ite fragments.  |                          |        |      |        |             |         |          |
|   |                |         | antoalmah  | 00                                      | GRAVEL          | clay varies each                    | I with clay, the proport<br>horizon, example for at<br>neters intercaltes clay la | ( <del>-</del>           | :      |      |        | •           |         |          |
|   |                |         | בי ישוניתנותנית מתומישישישים בי<br>ני ישוניתניתנית | 0                                       |                 |                                     |   | <u> باساساس</u>          |        | •    |        | 1           | · .     |          |
|   |                | 9<br>10 |  |   | CLAY            | Light gray sem                      | -consolidated to consolid   | lated                    |        | ·    |        |             |         | ÷.,      |
|   |                |         | or hard material to                                |   | CLAY            | Light gray clay<br>to consolidate c | with gravel, semi-conso<br>lay with granule to pebb                               | lidated<br>le.           |        | ·. · |        |             |         |          |
|   |                | 13      |  | • | GRAVEL.         | Light gray grave<br>clay with granu | el with clay, semi-consol<br>le to pebble.  | idated international and |        |      |        |             | :       |          |
|   |                |         |  |   | CLAY            |                                     | l, semi-consolidated claya<br>ttle proportion of gravel<br>1 in diameter.         |                          |        |      |        |             |         | :        |
|   |                |         |  |   |                 |                                     |   | <u> </u>                 |        |      |        | •<br>•<br>• |         |          |
|   |                | 24      | 2 191   e 131   e 111   1                          | F                                       |                 |                                     | ۰<br>۱۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰۰   | ութանություն             | :      |      | ·<br>· |             |         |          |
|   |                |         | adamtanlanten he                                   |   |                 |                                     | e e su constanta<br>Seconda   | <u> </u>                 |        | •    | • •    |             |         |          |
|   |                |         |  |   |                 |                                     |   | n-mil.                   |        |      |        |             |         |          |

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

| <br>1  | nnö      | ICOT   |         | HYDD      |                  | EOLOGICAL LOG OF WELL   | <br>1    |
|--------|----------|--|---------|-----------|------------------|---|----------|
|        |          | JECT<br>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<br>(m)                                 | THICKNE | LOG       | CLASSIFICATION   | DESCRIPTION AND STRUCTURES DRILLING TIME (min/m   |          |
| -      |          | 77)<br>m)                                    | SS      |           | SILT             | Silt, light gray to light brown silt with a little<br>of sand.  | 70       |
|        |          | entrutustadustentratustustati                | 5       |           | SAND             | Sand with granule and silt, light gray to light<br>brown semi-consolidated silt with gravelly<br>intercalation. |          |
|        |          | 10   | 5       | ,    <br> | SAND             | Light gray clean sand.  |          |
|        |          | 13 ամյանանական<br>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<br>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       | <br>      | 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<br>(m)  | THICKNES | LOG              | CLASSIFICATION | DESCRIPTION AND  | STRUCTURES                             |   | DRII<br>10 20 | LLING T<br>30 40                      |                                       |      | )<br>70 |
|          | 31  |          |                  | SAND           | Light gray medium sand.  |  |   |               |                                       |                                       | 1    |         |
|          | 32  |          | ······           | SILT           | Light gray silt with sand.   | ·                                      |   |               |                                       |                                       | ł    |         |
|          | 34  |          |                  | SAND           | Light gray to light brown  | :<br>:                                 | 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<br>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.<br>Light gray fine to mediu<br>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<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2<br>2 |          | ۵<br>۵           | SAND           | -carbonate fragments,<br>Gray sand with granule g<br>48 meters much amount | gravel, especially a                   |   |               |                                       |                                       |      |         |
|          | 48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>48<br>4             | 3        | 0<br>0<br>0<br>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 |               | ]                                     |                                       |      |         |
| <br>     | 52 <sup>-11</sup>   | 4        | 0                |                |  |  | ruduu si me                             |               | <br>· _                               | )<br>1. 21                            | i.   |         |
|          | նդրիստիստիզդիգրի։   | •        |                  | MARL           | Light brown to white ma<br>of granule gravel.                              | ristone with a little                  | ախուհավարերու<br>անություն              | [             |                                       |                                       | :    |         |
|          | ահականութ   | -        |                  |                |  |  | atrofootan<br>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  | .<br> | BARKA            | COMMENCED        |                             |  | GED BY        |          |                       |
| HOLE DIA.   |       | 10. <sup>#</sup> | COMPLETED        |                             |  | CKED BY       |          |                       |
| THICKNESS<br>(m)<br>DEPTH<br>(m)<br>ELEVATION<br>(m)<br>DATE  | LOG   | CLASSIFICATION   | DESCRIPTI        | ON AND STRUCTURES           |  | DRIL<br>10 20 | LING TIM | E (min/m)<br>50 60 70 |
| 93 <sup>1</sup> 93  |       | MARLSTONE        | Same as ab       | ove mentioned description - | i<br>nutuulenkeetee  |               |          |                       |
|   | HR    | MARLSTONE        | Lightgray to w   | white maristone with clay.  | a fia  |               |          |                       |
| 94 <u>EE 1</u>  |       | MARLSTONE        |                  | white maristone with grave  | -<br>Budunlandandandandan  |               |          |                       |
|   | E     |                  |                  |                             | inter<br>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<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1<br>1                     |       |                  |                  |                             | historiadan  |               | ,        |                       |

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| ſ               |                 |  |                  | GE                                    | OLOGICAL  | LOG OF WE   | <br>[_ [_   |                   |
|-----------------|-----------------|--|------------------|---------------------------------------|---|---|---|-------------------|
|                 | HOL             | JECT<br>E NO.                            | HYD              | ROLOGIC OBSERVAT<br>BM 2              | TION PROJECT IN<br>ANGLE FROM<br>HORIZONTAL           | THE BATINAH COAST<br>PERPENDICULAR                          | SITE<br>FOREMAN   | WADLAL-MA'AWIL    |
| -               | HOLI            | ATION<br>E DIA.                          | NOR              | TH OF AL WASIT                        | COMMENCED<br>COMPLETED                                |   | LOGGED BY<br>CHECKED BY   |                   |
|                 |                 |  |                  |                                       |   | L   |   | LING TIME (min/m) |
| 1               | VATION<br>(III) | DEPIN<br>(m)                             | LOG              | CLASSIFICATION                        | DESCRIPTIO  | ON AND STRUCTURES   | 10 20   | 30 40 50 60 70    |
|                 |                 | 2  | 0                | GRAVEL                                | Gravel with sil<br>facies, and cla<br>the lower hori: | t, white to light gray colore<br>y dominant layer is much a | ed T  |                   |
|                 |                 | and hushers                              | 0<br>0<br>0<br>0 | GRAVEL                                |   | ith a few fine sand   | imfaatonkaetur  |                   |
|                 |                 | nuluuluuluuluu<br>7                      |                  |                                       |   |   | uniteritania.   |                   |
|                 |                 | antur de de de due ka                    | 00000            | GRAVEL                                | Gravel with fin<br>material, the l<br>in matrix.      | ne sand and a little of clay<br>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<br>taatuu<br>taatuu  |                   |
|                 |                 | 20                                       | 00               | · · · · · · · · · · · · · · · · · · · |   |   |   |                   |
|                 |                 | 1  | 00               | GRAVEL                                | Gravel with sa  | and.  |   |                   |
|                 |                 | trolous house of                         | 0000             | GRAVEL                                | Light gray to<br>little of sand.                      | gray gravel with silt and a                                 | limburli altantaria   |                   |
| ·  <br>·  <br>· |                 | և սիսությությունը                        | 0                |                                       |   |   |   | :<br>             |
|                 |                 | 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<br>         |             |
| 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<br>11  | 000000                                | GRAVEL | Gray gravel with sand, clay and carbonate fragments.                 | »<br>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)<br>1991<br>1991<br>1991<br>1991<br>1991<br>1991<br>1991<br>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<br>CLAY Brown sand and clay with a little of granule.   | -  | 54 2   |                                       | GRAVEL | Gray to light gray gravel with sandyclay<br>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

|           |             |           | ·<br>·                       |                | OLOGICAL LOG OF  | ······································ |  |                      |                                       |                                       |
|-----------|-------------|-----------|------------------------------|----------------|--|--|--|----------------------|---------------------------------------|---------------------------------------|
| PROJ      |             |           | HYD                          | BM 2           | TION PROJECT IN THE BATINAH COA<br>ANGLE FROM<br>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<br>(m) | THICKNESS | L06                          | CLASSIFICATION | DESCRIPTION AND STRUCT   | URES                                   | DRILL<br>10 20   | אוד זאנ דוא<br>30 40 |                                       | n/m)<br>60 70                         |
|           |             |           | 0 0 0 0 0                    | GRAVEL         | Gray gravel with sandysilt and carbo<br>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                |                |  | -<br>-<br>-                            |  |                      |                                       |                                       |
|           |             |           |                              | GRAVEL         | Light gray gravel with sand and car<br>material, facies is concreated by ca<br>matrix. | bonate<br>arbonate                     | landmilianhanhanhan  |                      |                                       |                                       |
|           |             |           | °                            | GRAVEL         | Light gray gravel with silt and a f  | lew sand.                              |  |                      |                                       |                                       |
|           |             |           | ° 0<br>0<br>0<br>0<br>0<br>0 |                |  |  |  |                      |                                       |                                       |
|           |             |           |                              | GRAVEL         | Dark gray gravel, facies is compose<br>amount of large sized gravel.                   | sed of muc                             |  |                      | :                                     |                                       |
|           |             |           |                              |                |  |  | doordood oo doordood and an  |                      |                                       |                                       |
|           |             |           |                              |                |  |  | set as least a |                      |                                       |                                       |
|           |             |           | 0<br>0<br>0<br>0             |                |  |  | uderlandaulandau   |                      | <b>.</b>                              |                                       |

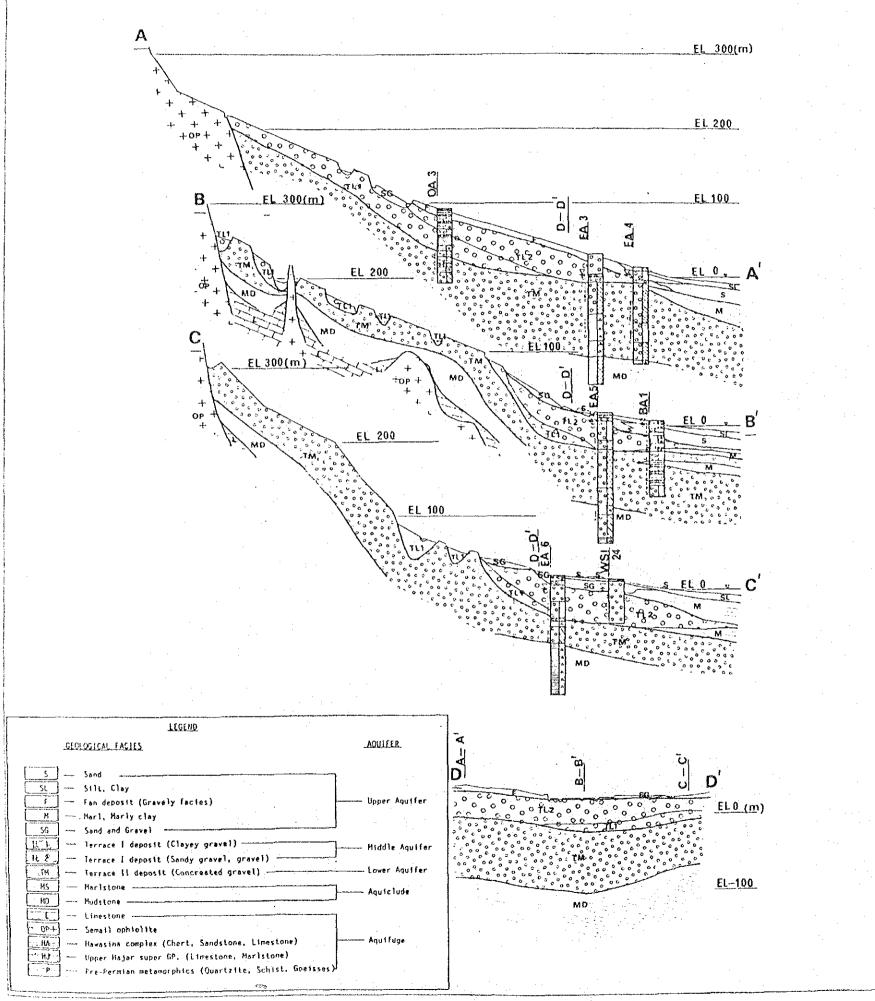
|  |                               | GE             | OLOGICAL LOG OF WEI   | LL                      |         | <br>-<br>- |     |                  |                 |       |  |
|--|-------------------------------|----------------|---|-------------------------|---------|------------|-----|------------------|-----------------|-------|--|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

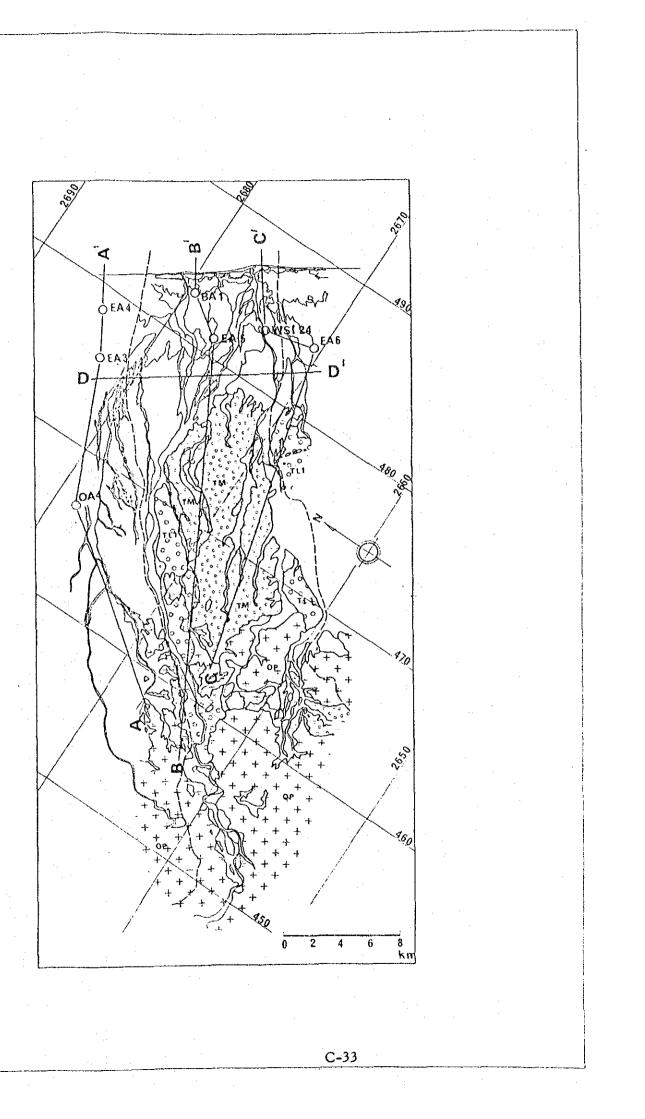
## Fig. C-2-1(9) Geological Log of Observation Well, BM3

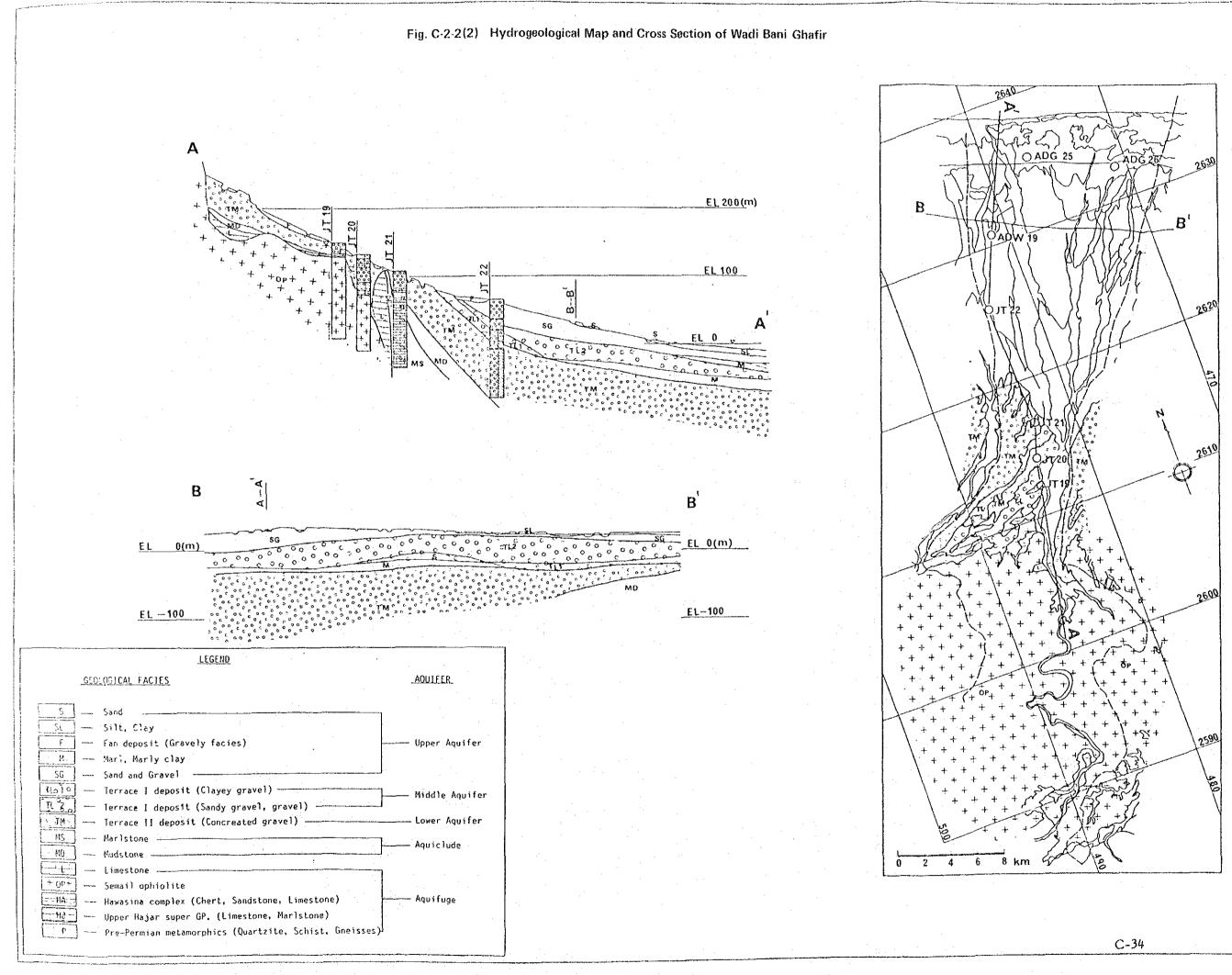
Fig. C-2-1(9) Continued

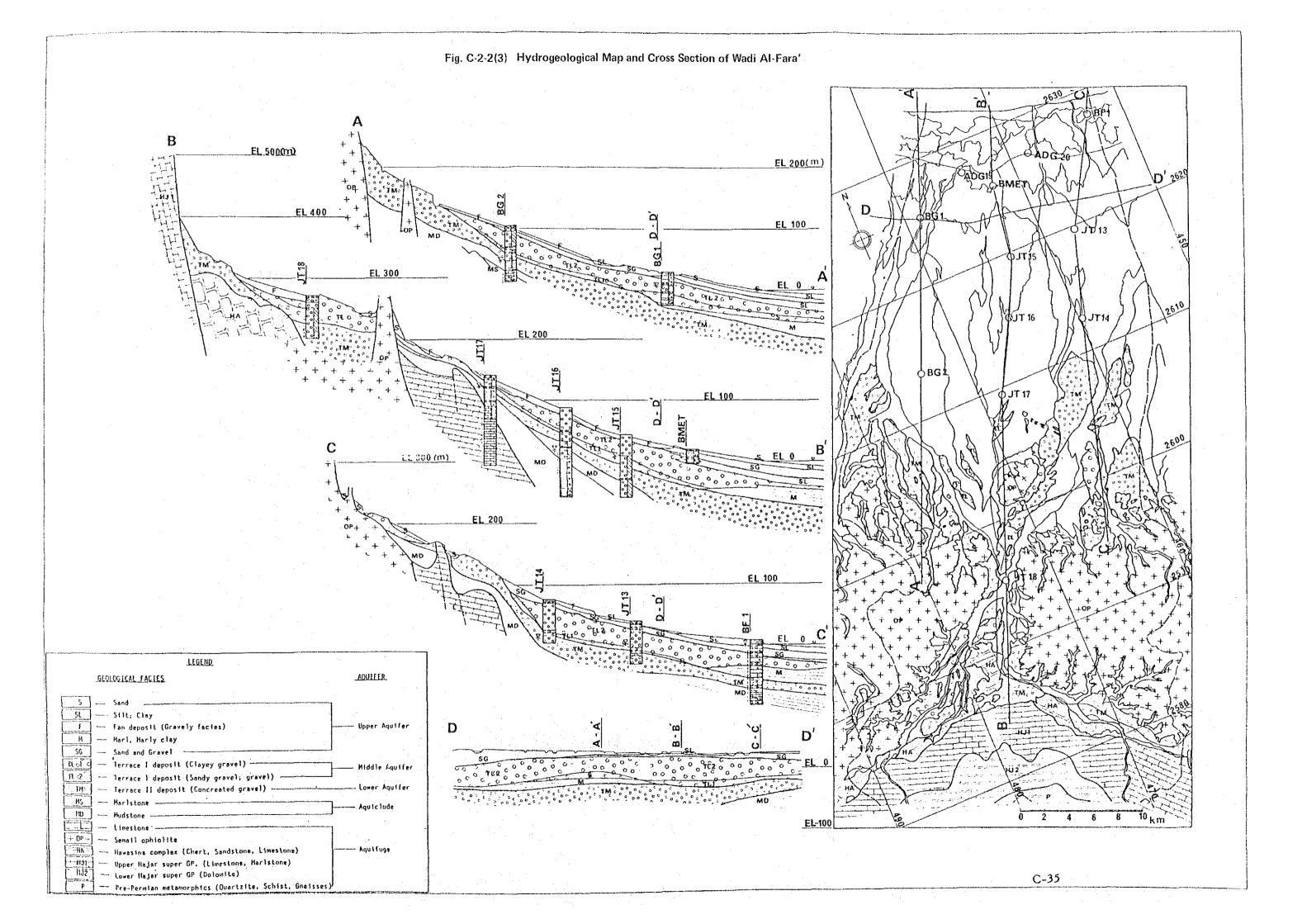
| PR0       | JECT   | TYD                                   | ROLOGIC OBSERVA |  | THE BATINAH COAST   | SITE  |               | WADI  | AL MA'AWIL            |
|-----------|--|---------------------------------------|-----------------|--|---|---|---------------|---|-----------------------|
| HOL       | E NO.  |                                       | BM 3            | ANGLE FROM<br>HORIZONTAL   | PERPENDICULAR   | FORE  | EMAN          |   |                       |
|           | ATION  | UPSTREAM OF HIFRI                     |                 | COMMENCED  |   | }   | GED BY        |   |                       |
| HOL       | E DIA.                                       | <u></u>                               | 10 "            | COMPLETED C  |   | CHEC  | CKED BY       |   |                       |
| ELEVATION | THICXNESS<br>(m)<br>DEPTH<br>(m)             | LOG                                   | CLASSIFICATION  | DESCRIPTIO   | N AND STRUCTURES  |   | DRIL<br>10 20 | LING TIM<br>30 40   | E (min/m)<br>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<br>gravel dominant<br>beded, carbonate<br>the whole horize | , gray sand rich facies and<br>layer are alternately inter<br>e fragments are rare throu<br>on. | ⊶. '<br>waadaa hadaa hadaa ahaa hadaa had |               | a de conservante de la conservante de l |                       |
|           | landandanlan<br>bankan<br>42                 |                                       |                 |  |   | بسامينكسا سباسيا  |               | and and the second s |                       |
|           | anturshadenshaden-husterilandas              | 0 0 0 0 0                             | GRAVEL          | Brownish gray g<br>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<br>calcarious sedi   | lay with sand and granule,<br>ments are contained.  | التقاصلينا بتنابينا   |               | *<br>•<br>•<br>•  |                       |
|           | uniondantion feederate                       |                                       |                 |  | N   | يمنكبه أيبدل يتدايد التداير   |               |   |                       |
|           | n landar hardera badar.                      |                                       |                 |  |   | անտեսունունու   |               |   |                       |
|           | dimater for                                  |                                       |                 |  |   |   |               | · .   |                       |

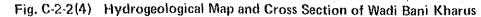


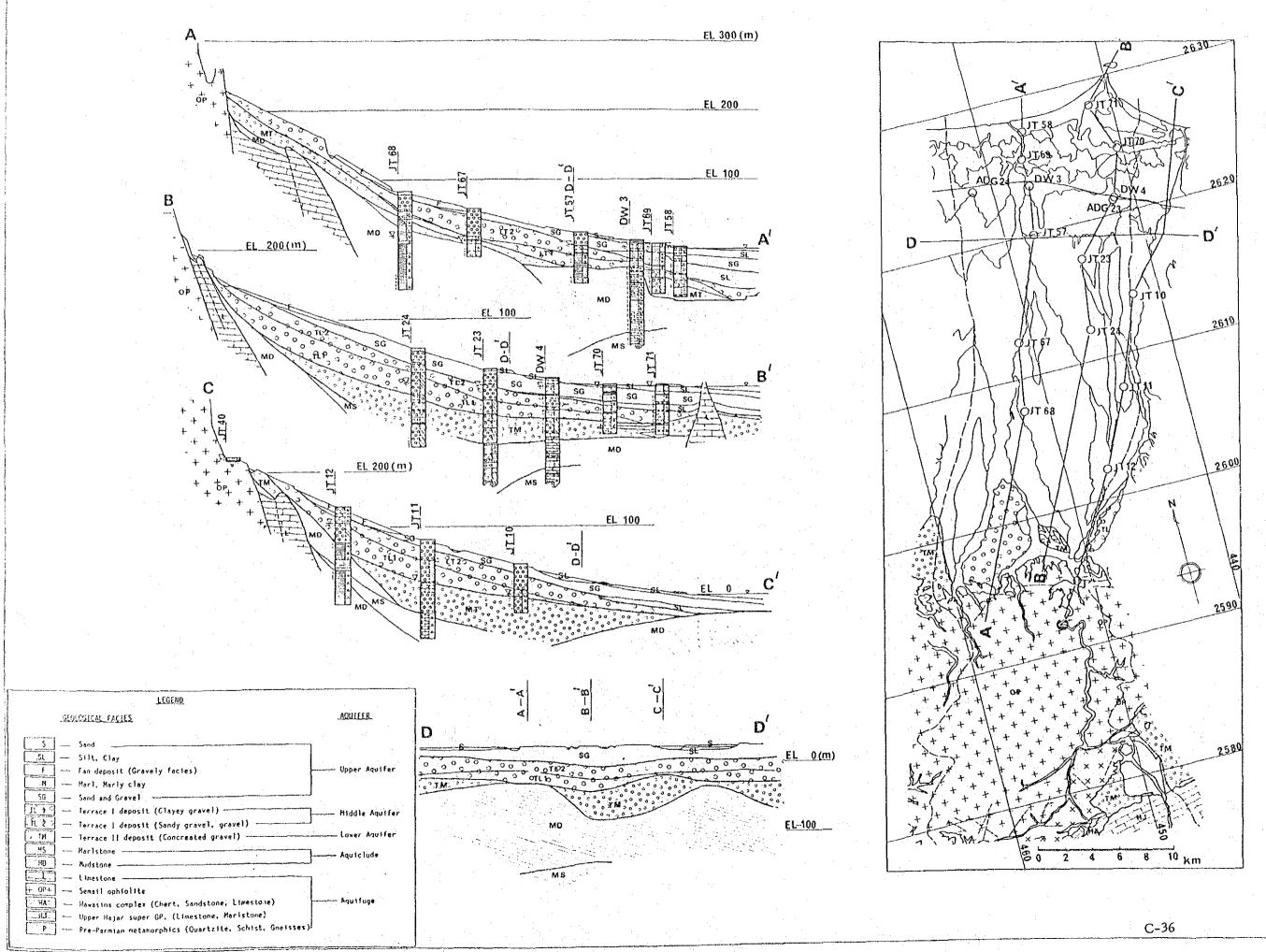


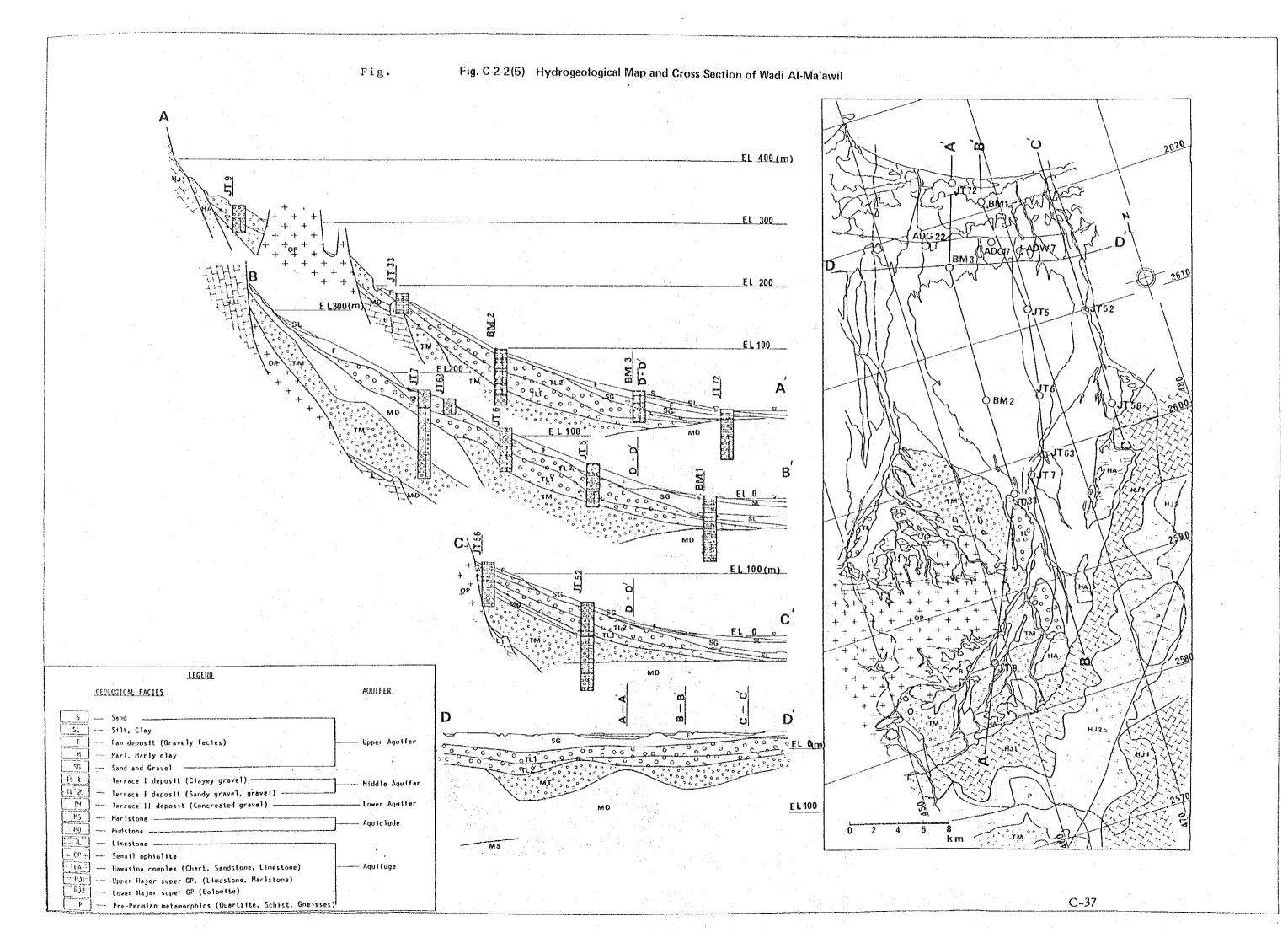












#### 2.2 Geo-resistivity Sounding

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

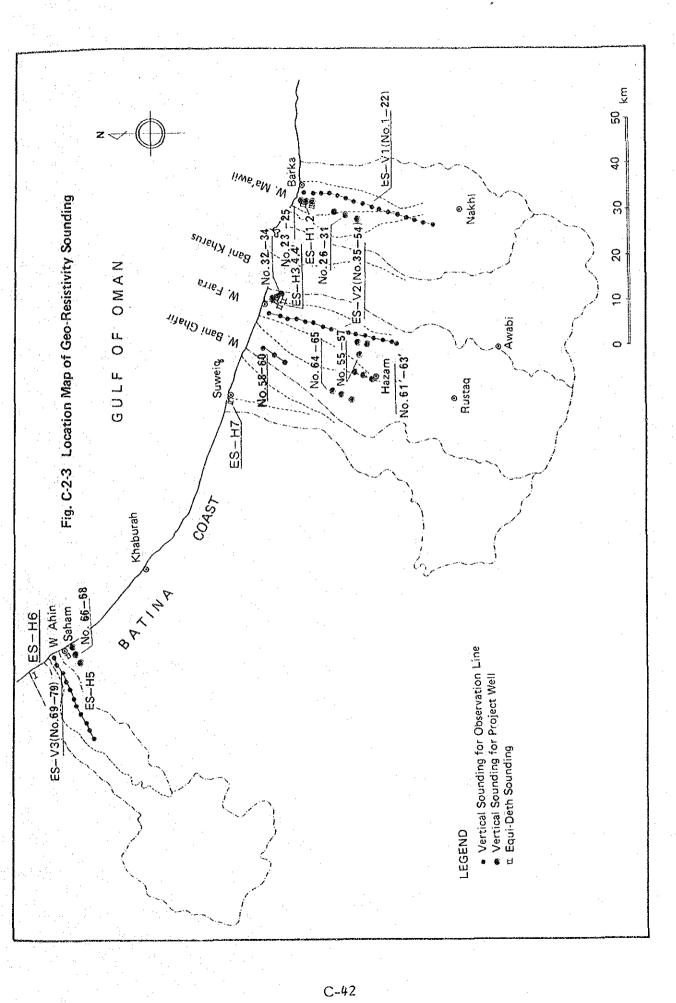
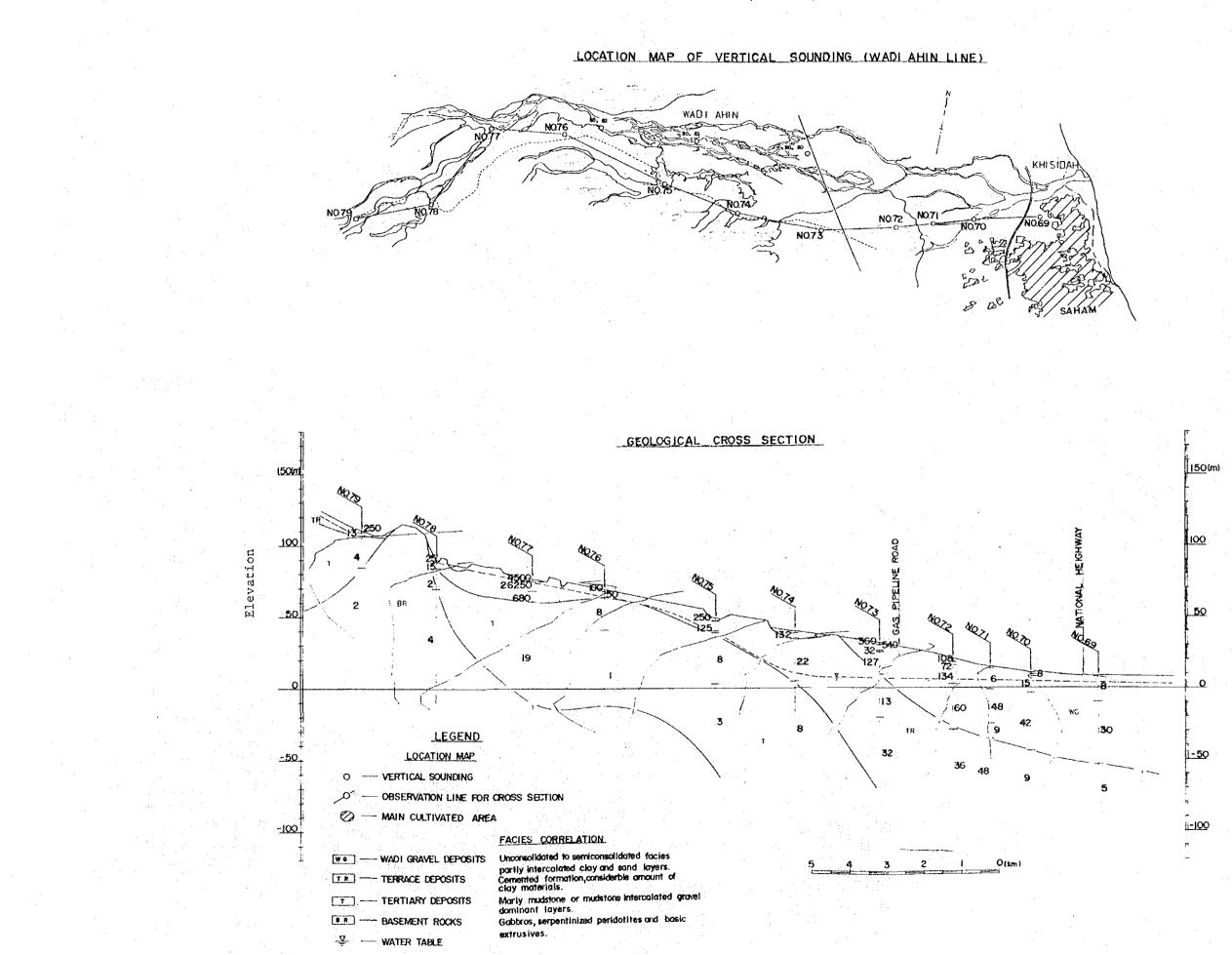
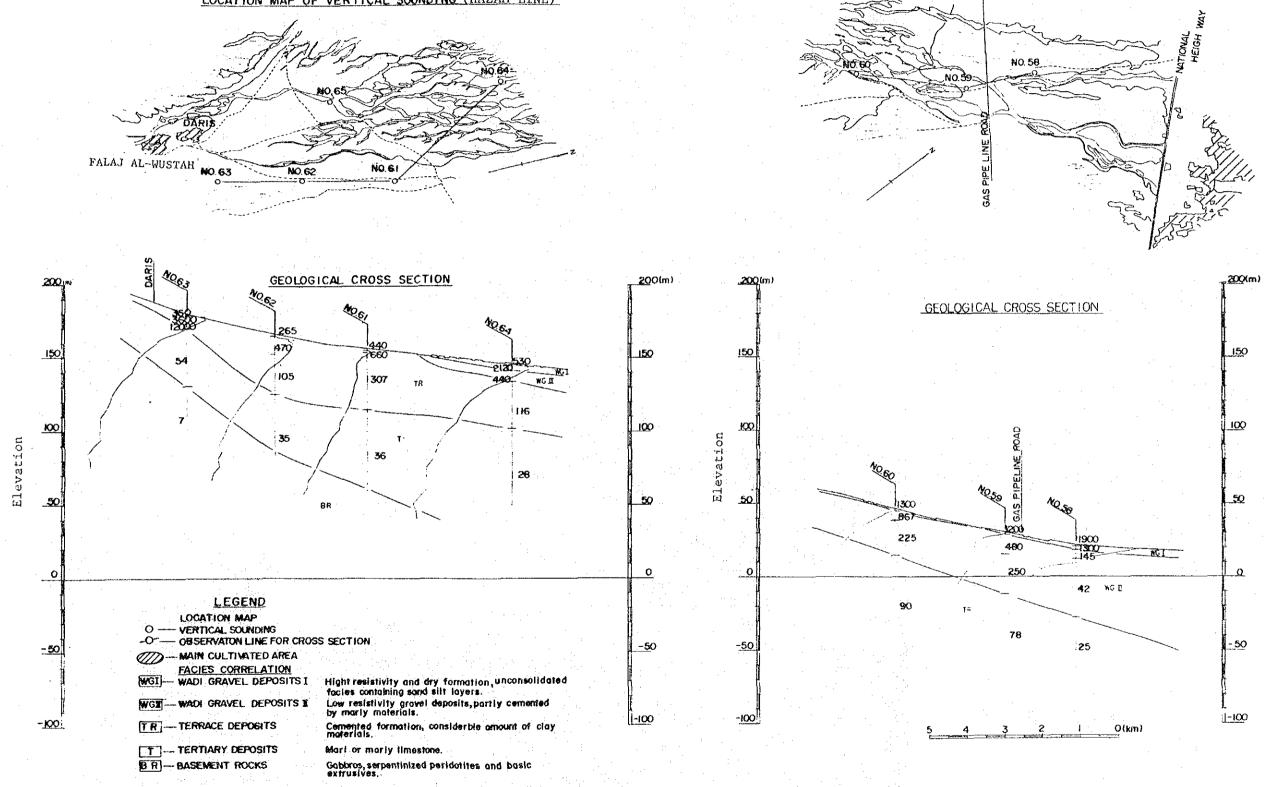


Fig. C-2-4(1) Vertical Geo-Resistivity Soundings, Wadi Ahin Line

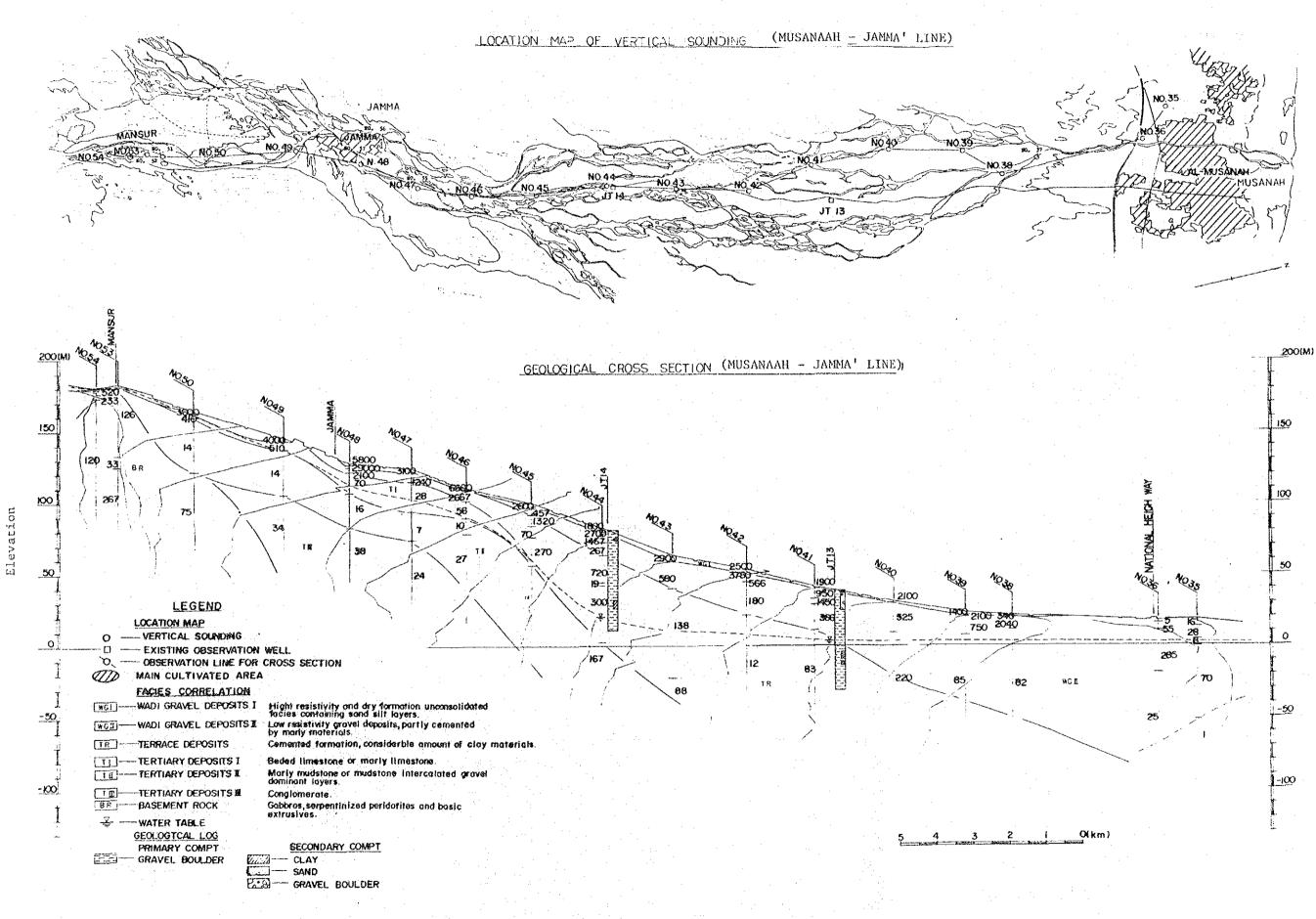


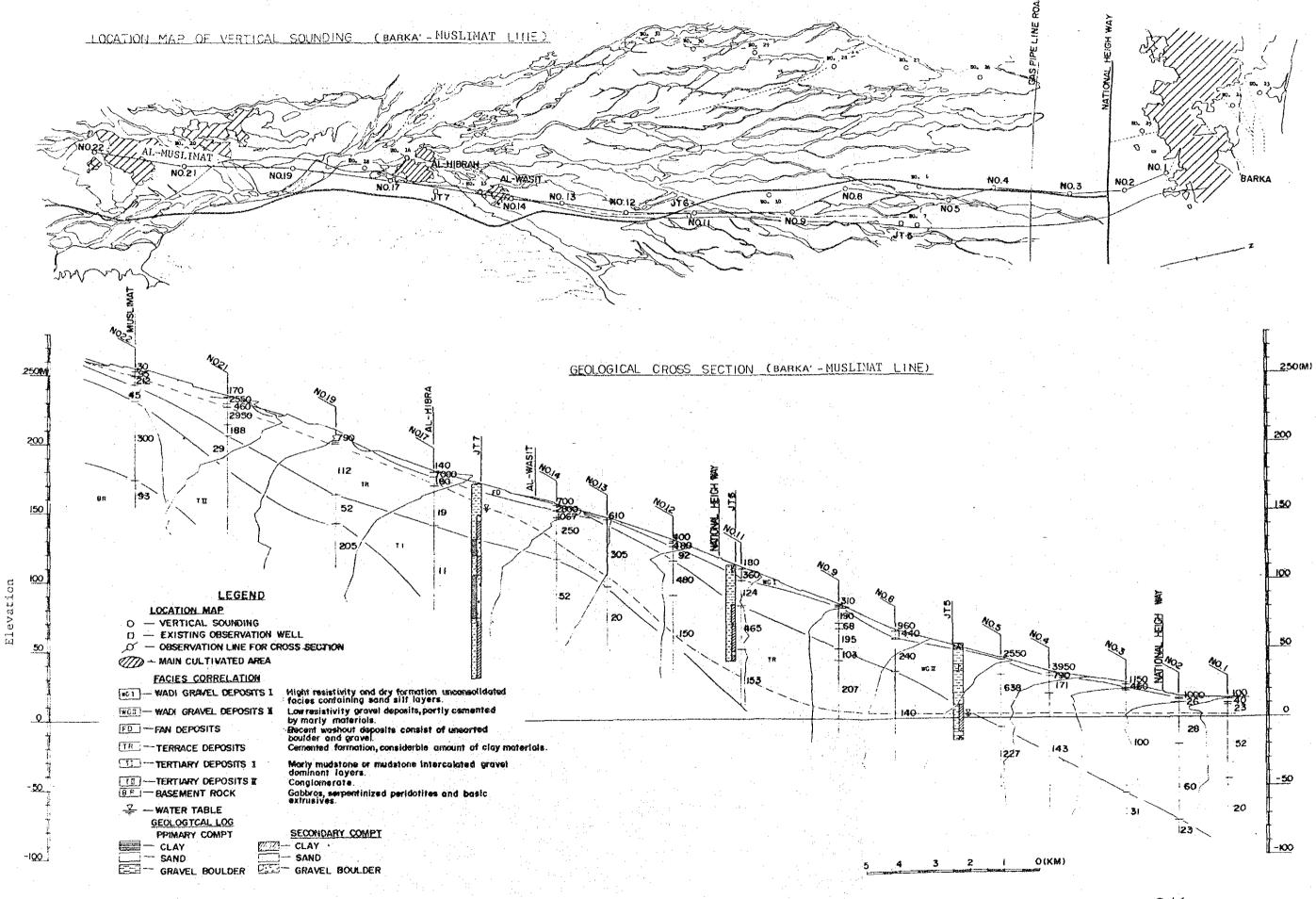


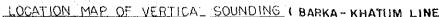
LOCATION MAP OF VERTICAL SOUNDING (HAZAM LINE)

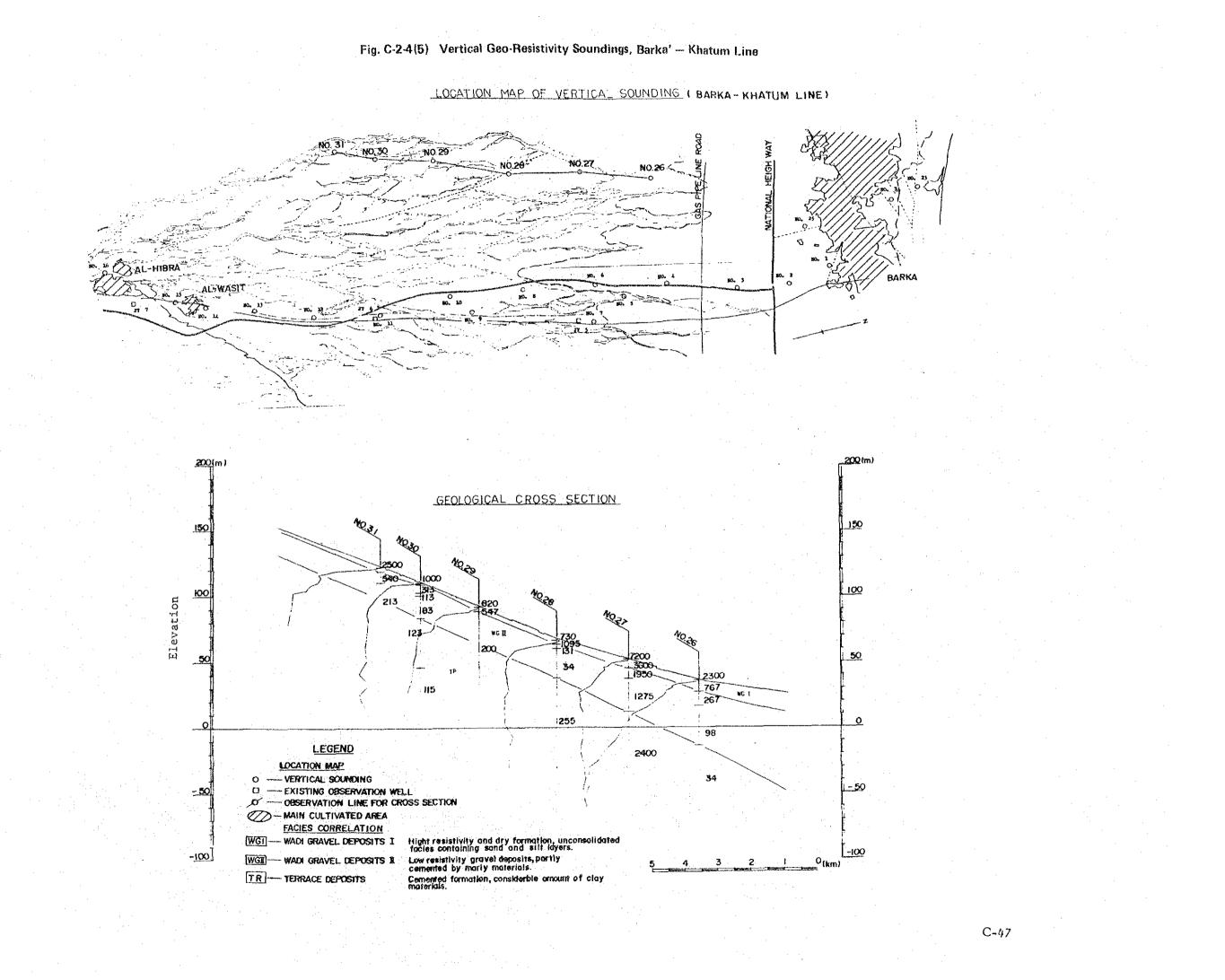
ZZ

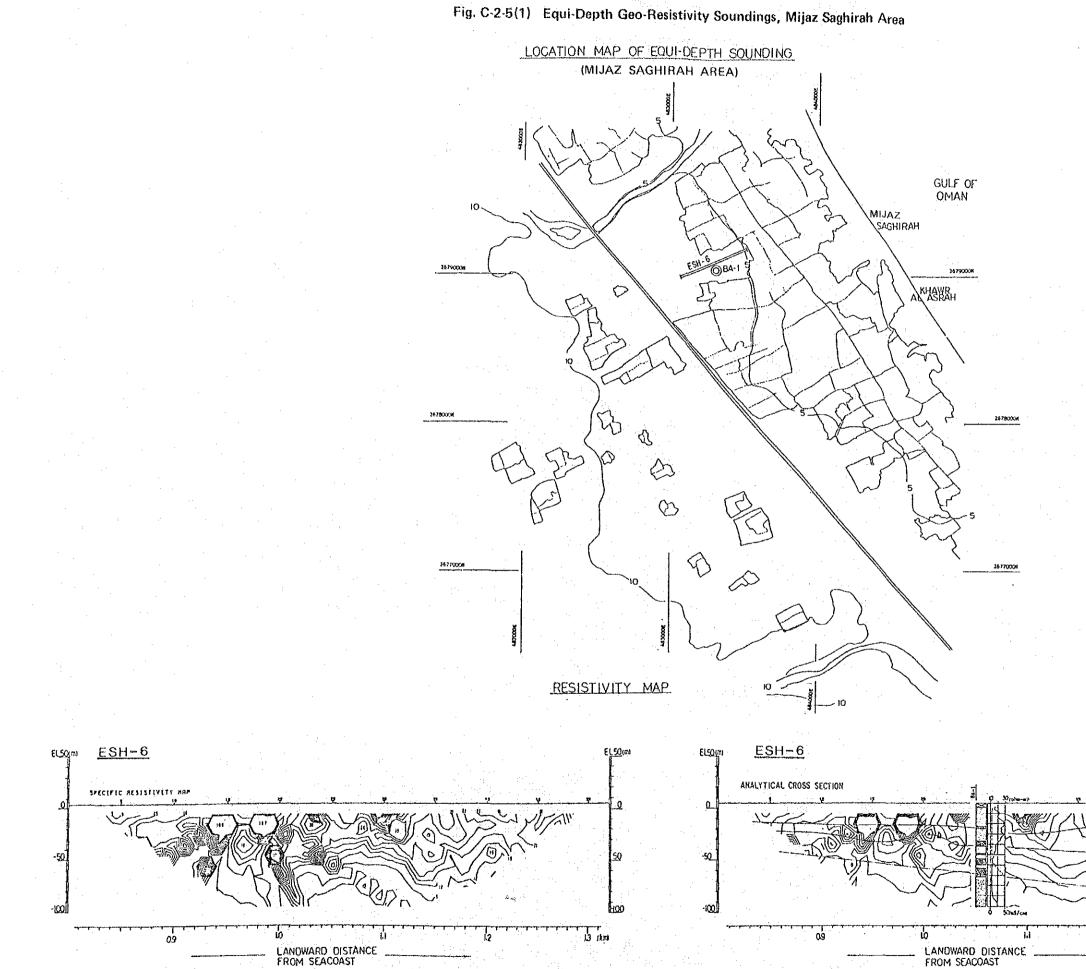
#### LOCATION MAP OF VERTICAL SOUNDING (MULADDAH LINE)

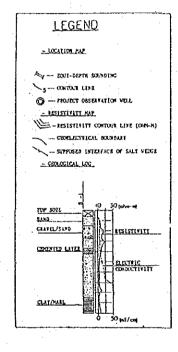


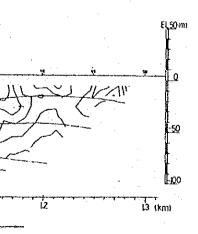












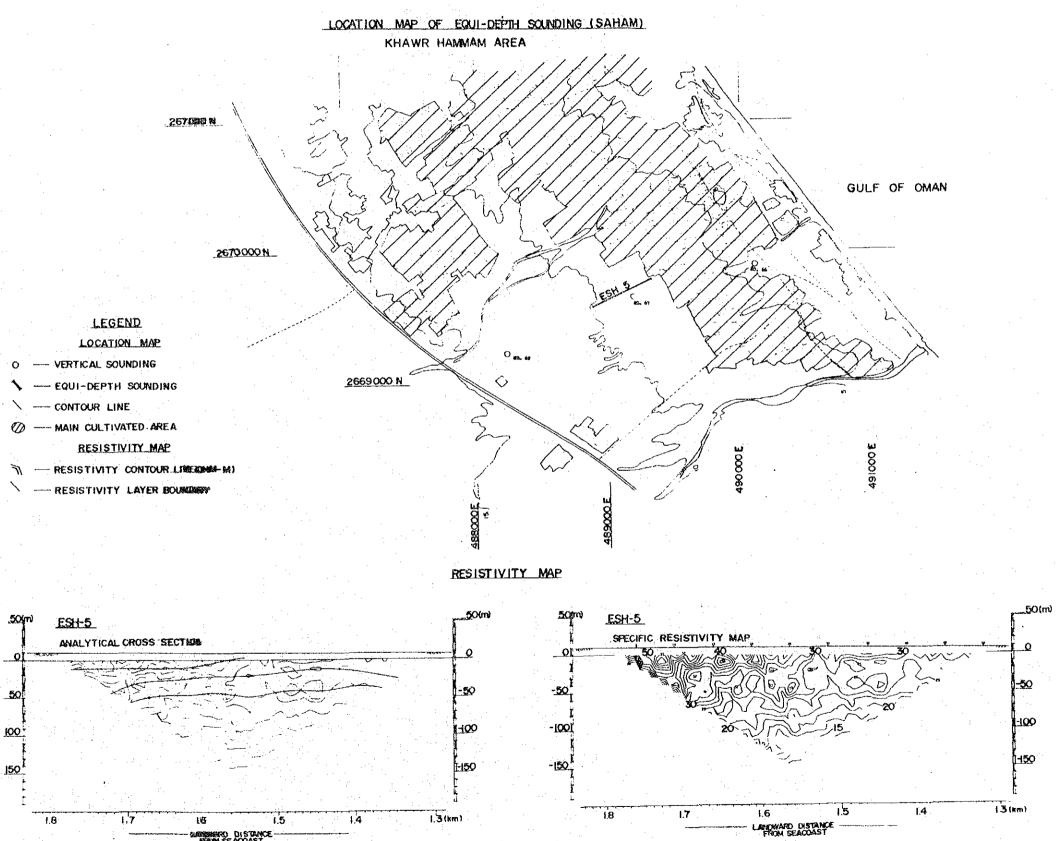
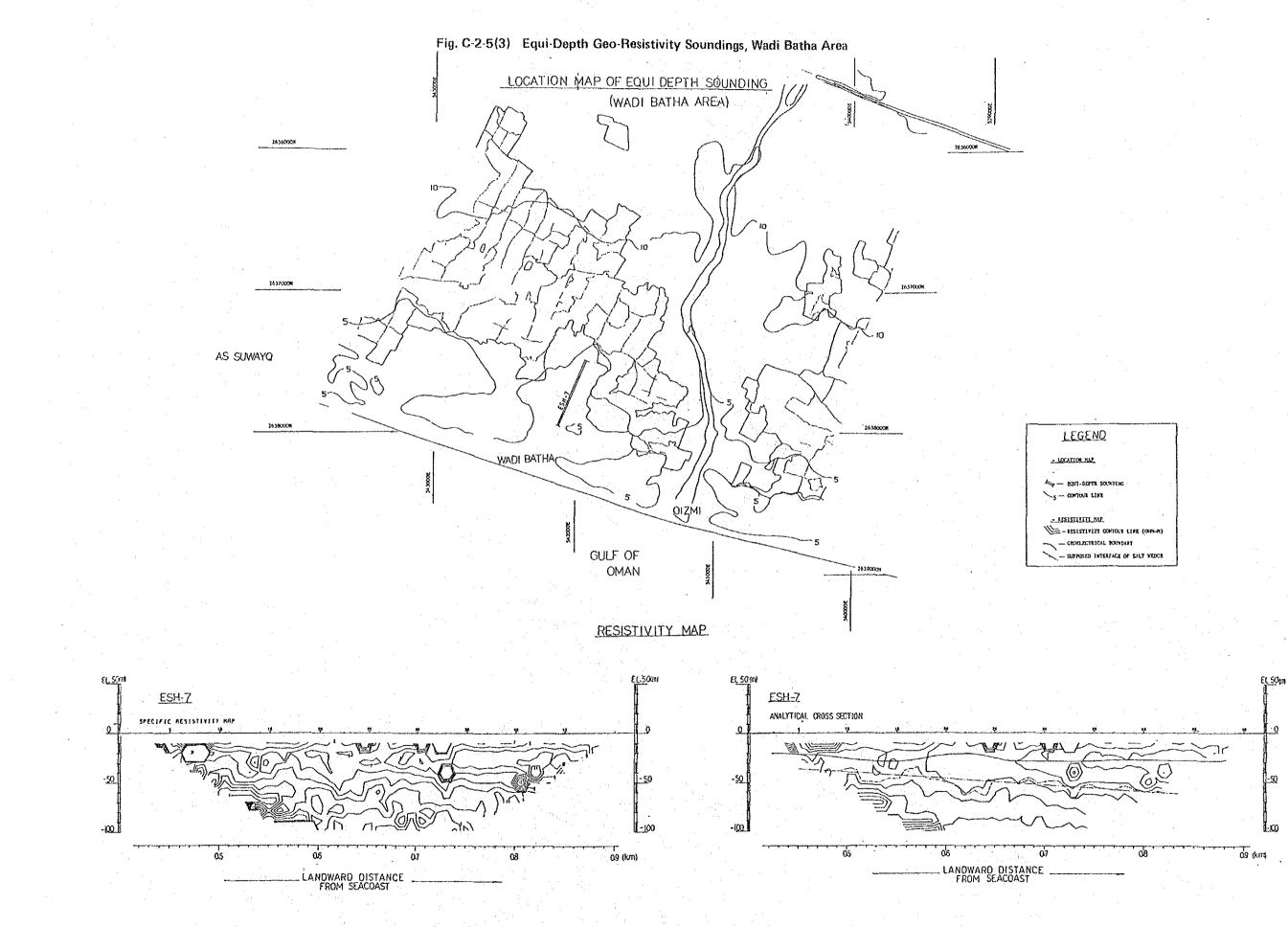


Fig. C-2-5(2) Equi-Depth Geo-Resistivity Soundings, Khawr Hammam Area

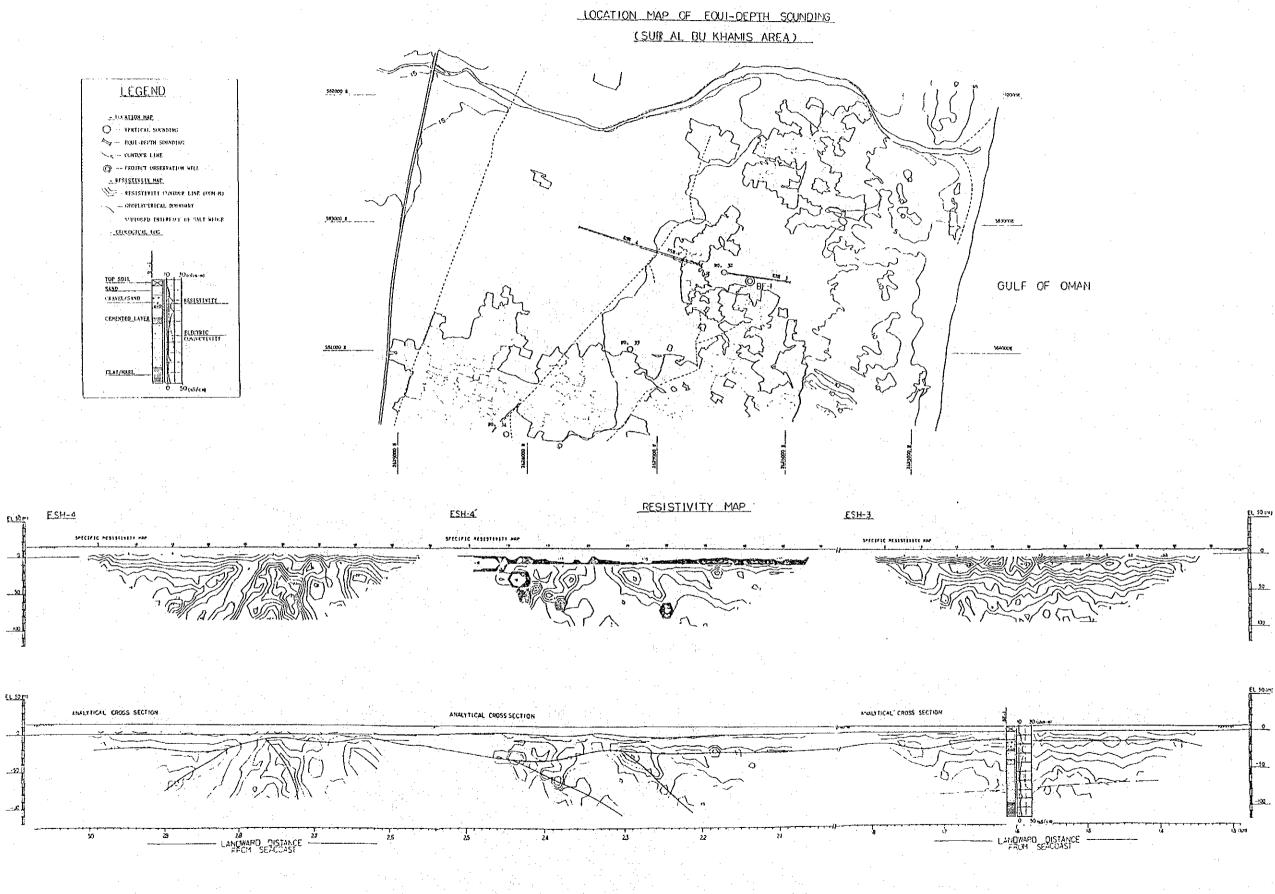
PROMISE ACCAST

50

150



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



EL 50 (raj

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

