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Office of Energy
Bureau for Science and Technology
United States Agency for International Development

PREFEASIBILITY STUDY

OIL SHALE UTILIZATION FOR POWER PRODUCTION IN THE HASHEMITE KINGDOM OF JORDAN

VOLUME III OF VI - APPENDICES 1 THRU 4
DESIGN BASIS, GEOLOGICAL DATA, PYROFLOW PROCESS, BLENDED SHALE SAMPLE REPORT

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JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY

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APPENDIX 1

DESIGN BASIS CRITERIA

APPENDIX 1

JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY
Project Design Basis Criteria

1. Resource Definition
   a. Site
      - Sultani Deposit
      - Located about 115 km south of Amman adjoining the Desert Highway

   b. Characteristics of the Resource
      - Available References
        - o NRA report dated July 1987 by Eng. M. Haddadin
        - o Technical Cooperation report for Project No. 78.2165.5 dated July 1985 by Heinz Hufnagel
        - o 1988 NRA Draft Report on Supplemental Core Drilling
      - Typical Properties
        - o Mean thickness oil shale - meters 32
        - o Fischer Assay Oil Content of Shale Variation in (% wt) - 3.2 to 17.2
      - Surface Elevation 822 meters above sea level (variation 700 - 1050m)

   c. Characteristics of the Oil Shale
      - NRA Average of 18 core holes

o Organic Carbon Content	9.2 wt %
o F. A. Oil Content	7.5 wt %
o Sulfur Content	2.6 wt %
o $CaCO_3$ Content	37.4 wt %

- Bechtel Mining Study	North Area	South Area
o F. A. Oil Content, (%w)	7.44	7.61
o Mineable Shale, (10^6 tonne)	320	658
o Stripping Ratio (m^3/m^3)	2.16	1.71

- Test Samples Furnished by NRA
  (from top beds only)
  - o F. A. Oil Content, (wt%) 8.4 to 8.6

- Fuel Specification Selected for Study Use

	Low Calorific Value Fuel	Performance Fuel	High Calorific Value Fuel
F.A. Oil Content, wt%	7.5	8.4	9.25
Range	6.7 - 8.3	7.5 - 9.0	8.4 - 9.9
Composition, wt%			
Organic Carbon	10.20	11.30	12.50
Inorganic Carbon (CO_2)	14.14	13.89	13.37
Hydrogen	1.02	1.13	1.25
Nitrogen	0.58	0.48	0.38
Sulfur	2.38	2.55	2.71
Moisture	3.20	3.20	3.20
Ash	67.30	66.80	66.25
Oxygen (by Difference)	1.18	0.65	0.34
	100.00	100.00	100.00
Gross Calorific Value			
BTU/Lb	2000	2250	2500

2. Climate Conditions
   a. Ambient Temeratures Profile (see Tables A & B attached).

   b. Annual Rainfall Profile (see Tables A & B).
   Snowfall occurs in December to March with mean number of days = 4 days/year. Maximum number of days with snow = 14 days/year. Maximum snow depth = 40 cm.

   c. Surface Wind Profile (see Tables A & B).

   d. Ground Water Availability
   Very limited - 2.0 million cu meter/year possible
   Marginal quality (see Table C).
   TDS 757 ppm
   Ph 7.36

4. Project Development Schedule
   20 MW Demo Unit on line by end 1992.
   First 100 MW Full Scale Unit on line by end 1997

5. Integrated Project Components
   - Mine - Based on Performance Fuel Quality
     Includes: Mining equipment, maintenance facilities and spare parts

     Excludes: Byproduct phosphate recovery

   - Raw Shale Processing - Prepares boiler plant feed
     Includes: Crushing, blending, conveying, and three days storage in silos.

   - Boiler Plant - Processes prepared feed consist, (minus 8mm/plus zero), in Pyroflow fluid bed combustors to generate steam:

Net Plant Output	20 MW	50 MW	100 MW
Steam Rate, lbs/hr	192,000	480,000	960,000
Steam Pressure, psig	1,550	1,550	1,550
Steam Temperature, ^{o}F	955	955	955

     Includes: Raw shale feed day bins, combustion chamber and boiler; ash cooling and baghouse.

   - Power Generation - Covers balance of plant facilities involved with boiler and generation of electric power.

     Includes: Steam turbines and generators, ash removal and treating, water supply and treatment systems, condensate cooling (air), project maintenance shop/warehouse, project office, control center and laboratory, site development including roads, sewers and lighting, fire control and security systems, communications systems, and employee support facilities.

     Excludes: Transmission line tie in to National grid.

- o Waste Disposal - Handles overburden, bottom ash and fly ash disposal. First 3 years will be via surface piling and thereafter returned to mine pit.

  Includes: Trucks and dozers - assumes ash is wetted to 20% and mulled in pug mills at power plant.

- o Infrastructure - Onsite: (covered under Power Generation)

  Offsite: Housing and community facilities for 1000± employees (and families in full scale development. (500± in demonstration plant case.)

6. Plant Sizes
   - 20 MW Demonstration Plant
   - 50 MW Prototype Plant
   - 4 X 100 MW Commercial Project

7. Environmental Standards
   Kindom of Jordan has not yet adopted regulations that would apply to a shale-to-power project. It is suggested that World Bank standards be considered as guidelines.

8. Economic Analysis Factors

o Project Life	25 years
o Debt/Equity Ratios	50/50 and 80/20
o Interest on Borrowed Capital	10% per year
o Resource Access Cost	100 fils/tonne (1000 fils = 1 dinar) (1 dinar = $3.00 U.S.)
o Land Rent	Zero Cost
o Import Duties on required equipment	None
o Taxes	
- Sales/Use	None
- Property, Equipment, Facilities	None
- Income Taxes for Project Operations	None
- Income Taxes for Expatriate Employees	None

- o Depreciation Rates — Straight Line
  - Trucks and Mechanical Equipment — 15% per year
  - Boiler and Power Generation Facilities — 10% per year
  - Offsite IIInfrastructure — 3% per year

- o JEA Working Conditions
  - 6 working days/8 days for shift
  - 3 shifts per day
  - 8 hours per shift

- o Labor Rates - (see Table D)
  - Includes all benefits burdens
  - Includes social security and health insurance costs

- o Contract Mining Costs
  - Overburden removal and transport up to 1-1/2 KM
    680 fils/cu. meter
  - Oil shale mining and transport to crusher
    870 fils/cu. meter
  - Oil shale transport over 1 KM
    29 fils/tonne/KM

- o Purchased Power Cost — 17 fils/kwh
- o Purchase Petrolum Fuels

	Local Production	Imported
Diesel	65 fils/liter	127 USD/ton
Motor Gasoline	180 fils/liter	188 USD/ton

9. Costs for Aqaba Oil Fired Power Plant (see Table E)

10. Capital Cost Estimates for Oil Shale Project
    - o 1988 Cost Indices for a USA Gulf Coast site
    - o USA Procurement
    - o USA Design Standards
    - o USA Construction Management
    - o Start-up and Initial Operations with USA Management

TABLE A

STATION: El-Rabbah 31° 16'N 35° 45'E ELEVATION: 920 m PERIOD: 1961-1985

MONTH / ELEMENT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	Y
TEMPERATURE C°													
Mean Monthly	7.8	8.7	11.3	15.0	18.9	21.8	23.3	23.3	21.7	19.2	14.3	9.4	1
Mean Daily Max.	11.9	13.3	17.1	21.0	25.7	28.6	29.8	29.8	28.0	25.4	19.5	13.6	2
Mean Daily Min.	3.7	4.2	6.2	8.8	12.0	15.0	16.8	16.9	15.4	13.2	9.1	5.2	1
Absolute Max.	26.4	28.0	32.0	33.8	39.0	38.7	39.0	40.4	38.5	36.0	30.0	25.5	
Absolute Min.	-5.1	-3.0	-3.5	-0.5	3.0	8.0	10.9	10.0	8.0	4.2	0.1	-4.8	-
NO. OF DAYS WITH MIN. AIR TEMP. EQUAL ZERO OR LESS "AIR FROST"													
Mean Monthly & Yearly	2.1	2.1	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	6
NO. OF DAYS WITH GRASS MIN. TEMP. "5 CM. ABOVE GROUND" EQUAL ZERO OR LESS "GROUND FROST"													
Mean Monthly & Yearly	14.4	9.4	5.8	1.8	0.2	0.0	0.0	0.0	0.0	0.0	2.5	9.4	4
RAINFALL AMOUNT MM													
Mean Monthly	77.5	67.1	62.6	21.7	2.9	Tr.	0.0	0.0	Tr.	4.2	30.0	64.0	33
Max. Amount in 1 Month	357.9	208.5	164.5	238.5	36.2	0.2	0.0	0.0	1.3	52.7	119.3	210.8	
Max. Amount in 1 Day	108.0	65.0	55.0	70.0	32.0	0.2	0.0	0.0	1.3	24.0	90.0	91.0	
RELATIVE HUMIDITY %													
Mean Monthly	70	66	59	50	42	41	43	46	50	50	57	67	53
WIND "KNOT"													
Mean Monthly	8.4	8.2	8.3	7.5	6.8	7.3	7.7	7.1	6.8	6.8	7.3	7.8	7

Prevailing wind in Winter is W-SWLY 12-18 kts occasional gales are experienced from a WLY direction IN Summer main[illegible] direction 8-15 kts.

TABLE B

STATION: OUTRAWEH

MONTH / ELEMENT	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.	YEARL'
TEMPERATURE C°													
Mean Monthly	9.1	9.3	12.8	16.5	19.8	22.3	23.7	24.1	22.6	18.2	13.6	8.7	16
Mean Daily Max.	15.1	15.8	19.4	23.3	27.3	30.2	31.5	31.8	30.9	26.0	20.3	15.4	23
Mean Daily Min.	3.1	2.8	6.2	9.6	12.2	14.5	15.9	16.2	14.3	10.5	6.9	2.0	9
Absolute Max.	24.4	23.8	29.3	32.8	37.4	37.5	37.0	41.2	38.4	33.4	31.0	23.3	
Absolute Min.	-2.5	-2.0	-2.8	2.8	5.8	10.0	11.8	12.2	9.0	4.0	0.4	-4.8	-4
RAINFALL AMOUNT MM													
Mean Monthly	27.3	26.4	18.0	5.4	3.2	0.0	0.0	0.0	0.0	2.3	8.0	20.8	111
RELATIVE HUMIDITY %													
Mean Monthly	61	58	51	51	38	39	39	46	48	50	62	64	51

WIND

Winter: Mainly S-W'LY and the average speed 10-15 Kts. Occasional gale wind is from SW-W'LY direction. Calm wind is often experienced at night and early morning 20-30% of the occasions.

Summer: Mainly W-N'LY 8-15 Kts. It increases in the afternoon reaching a speed 15-20 Kts. During the night and early morning the wind is generally light and variable.

DUST

The number days with dust reducing the visibility one Km or less are about 4 days in a year. While the number days with dust reducing the visibility 5 Km or less are 15 days in a year.

StaffGrp 1

TABLE C

JORDAN SULTANI GROUND WATER ANALYSES

	PPM
Electrical Conductivity	1230
T.D.S.	757
Elemental Analysis	
Ca	83
Mg	45
Na	47
K	4.3
Cl	170
SO_3	101
HCO_3	320
NO_3	2.3
TH	392

StaffGrp 1

TABLE D

LABOR RATES (Total)*

MANNING	RATE (JD/MONTH)
Plant Manager	800
Admin Manager	258
Accountant	266
Clerk	125
Secretary	125
Nurse	125
Driver (Truck Drivers and Loader Operators)	150
Mechanical Technician	239
Electrical Technician	239
Instrument Technician	239
Laboures	125
Safety Man	151
Security Guard	125
Shift Engineer	434
Foreman	283
Boiler Operator	239
Turbine Operator	239
Auxiliary Operator	239
Chemical Technician	239

*Source: Jordan Electricity Authority

TABLE E

FUEL OIL FIRED THERMAL POWER STATION 2X130 MW AT AQABA

Average annual production cost (fils/KWh) 1987

Alternative Costs	(Fils/Kwh)
Diesel Oil	0.02
Fuel Oil	8.86
Maintenance	0.27
Operational Costs	0.08
Fixed Costs	
Salaries	0.66
Insurance	0.07
Administrative Costs	0.02
Depreciation (Life Time 30 Years)	2.28
Total Production Costs Generated	12.25
Total Production Costs Sent-Out*	13.60

Please note that the actual capital costs of the station is 318 JD/KW installed

*Additional 2 fils/kwh for loan interests and 2 fils/kwh for overheads and transmission losses shall be included.

Source: Jordan Electricity Authority

APPENDIX 2

SULTANI DEPOSIT GEOLOGICAL DATA

- 1987 NRA Report
- 1988 Draft NRA Report on Supplemental Core Drilling

APPENDIX 2

JORDAN ELECTRICITY AUTHORITY

سلطة الكهرباء الاردنية

Ref. : 5/2/9/2/1.7

Date : 7/8/1987

الرقم : _____

التاريخ : _____

Mr.Willian Linton,PE.
Manager,Operating Plant Services
Western Power Division
San Francisco Area Office
Engineers-Construct
Fifty Beal Street
P.O.Box 3965
San Francisco,CA 94119

Subject:- Jordanian Oil Shale to Power
Pre-feasibility study

Dear Mr.Linton ,

We enclosed herewith the Geological/Core Assay Report for Sultani deposit as per LRA promise during your last visit to Jordan.

We are in process to ship the sample to Finland shortly.

Looking forward to meet with you at your earliest.

Sincerely Yours

W. J. OUNI
Assistant Director General

P.o. Box 2310. Amman - Jordan - Tel 815615-20 817615-19 ص.ب ٢٣١٠ ـ عمان ـ الأردن ـ تلفون ٢٠ ـ ٨١٥٦١٥/١٩ ـ ٨١٧٦١٥
Cable : SAKA - Telex 21259 JEASAK - 23270 JEA. برقيا ساكا تلكس ٢١٢٥٩ جيا ساك ٢٣٢٧٠ جيا

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١٦

THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY AND MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

Geology Directorate

Economic Geology Division

SULTANI OIL SHALE DEPOSIT

Prepared By: The Project Staff

Edited By : Eng. M. Haddadin

July 1987

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Fig. 17 - OS 19, OS 18, OS 17

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Appendix 1 - Lithology description of boreholes oil shale deposits

Appendix 2 - Chemical analysis of Sultani Oil Shale Deposit

I. INTRODUCTION

This report is the first publication of the Economic Geology Division which was established at the beginning of 1987.

Jordan has a large oil shale potential, spread over the eastern plateau extending from the Yarmouk River to Ras En Naqb. Oil shale has been encountered in many exploratory wells drilled for other purposes, for example, groundwater exploration. It occurs mainly in the Muwaqqar Chalk Marl Formation (MCM) either actually exposed, as in the northern part of Jordan, or found at shallow depths, as in Central Jordan. It also occurs in the underlying Al Hasa Phosphorite Formation in Central Jordan.

The Government of Jordan wants to assess the potential of exploiting the oil shale for use in the generation of electric power by the direct combustion.

The Sultani deposit has been selected as a trial site for the direct combustion tests for the following reasons:

1. The El Lajjun oil shale deposit will be exploited for producing oil by retorting.
2. The Sultani oil shale deposit has an average oil content of about 7.5% which is less than that of El Lajjun oil shale by 2.5%.
3. The area is traversed by both the Hijaz railway and the Amman-Aqaba Highway.
4. The reserves are more or less proven and of a quantity that justifies the installation of a commercial processing plant.
5. Groundwater is available.

6. The mining conditions for opencast mining are favourable.

7. The area is flat and no structural complications are known to exist.

II. LOCATION AND ACCESS

The area of investigation is situated 115km south of Amman approximately midway between Qatrana and El Hasa. It is easily accessible from Qatrana by the many dirt tracks branching off the main highway some 20km south of Qatrana. The Hijaz railway also passes across the investigated area which covers about 25km^2 (Fig. 1).

III. TOPOGRAPHY AND REGIONAL GEOLOGY

The Sultani area forms the southern part of the 1:50,000 Jabal Al Mutarammil Map Sheet. It is essentially a flat area bordered on the east by a ridge of moderately high mountains which trend NNW/SSE and forms the limit of the oil shale deposit.

The highest point of these mountains reach 920m a.s.l., but generally the elevation ranges from 800 to 870m a.s.l.

Wadi Sultani crosses the area from NR to SW changing its direction at the Sultani dam to approximately E-W. There are many tributaries to Wadi Sultani which drain from the eastern heights and several wadis drain from the NE and also change their courses towards the west.

The area of Jabal Al Mutarammil comprises rock formations ranging in age from Holocene (Mudflat) to the Campanian (Amman Silicified Limestone).

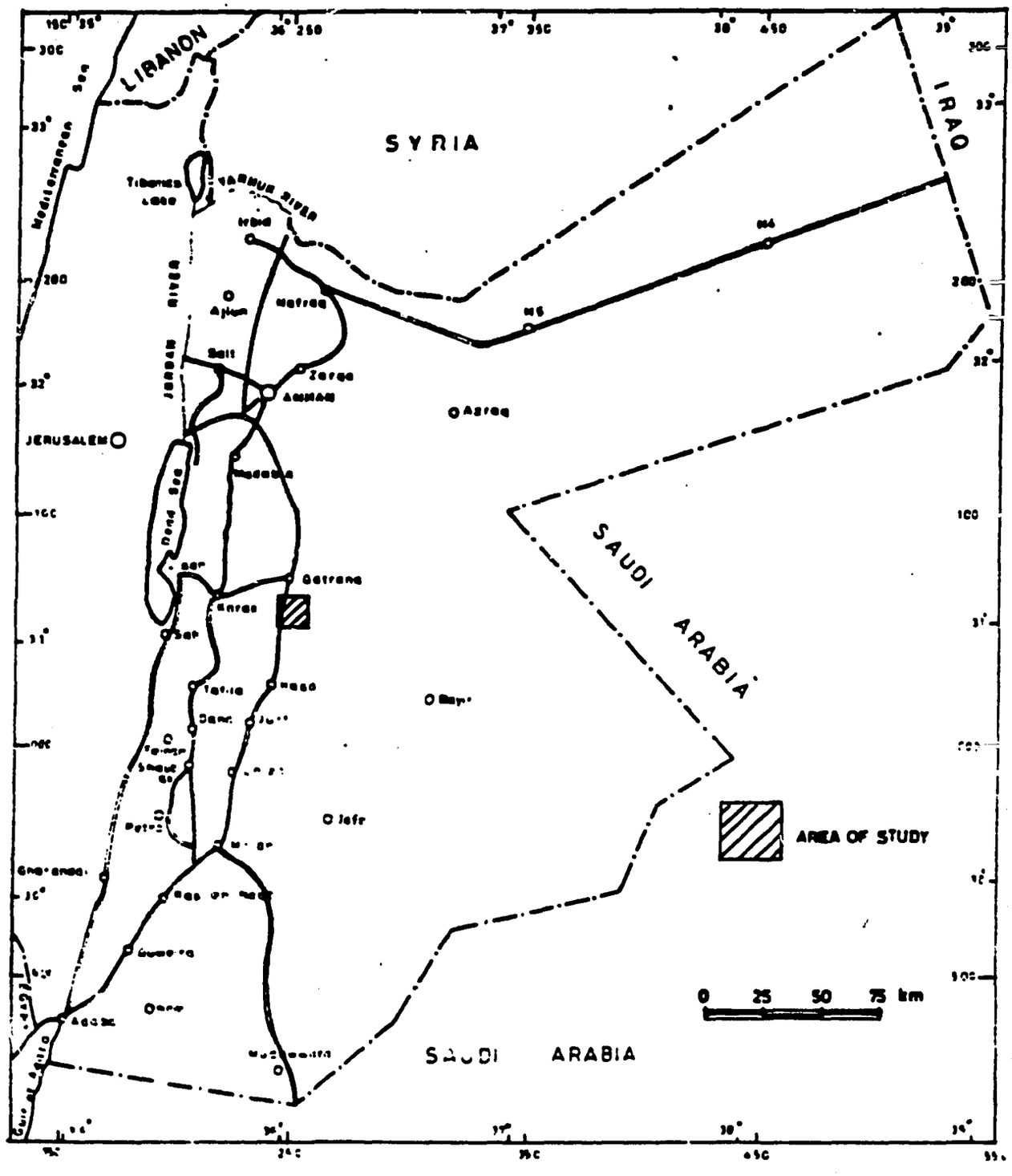
LIBANON
SYRIA
IRAQ
Mediterranean Sea
YARMUK RIVER
JORDAN RIVER
Dead Sea
JERUSALEM
Irbid
Mafraq
Ajlun
Salt
Zarqa
AMMAN
Azraq
Madaba
Karak
Tafila
Ma'an
Jafr
Aqaba
SAUDI ARABIA
AREA OF STUDY
0 25 50 75 km

Fig. 1

Two sets of faults exist in the area; the first set trends NW-SE and the other set, of minor faults, trends N-S.

IV. PREVIOUS INVESTIGATIONS

The Sultani area was geologically investigated by Quennell and is included on his 1:250,000 geological map published to accompany Burdon (1959) report on the Geology of Jordan.

It was mapped by Heimbach (1962-64) at a scale of 1:25,000 and was also included within the Phosphorite Project carried out by NRA in collaboration with the UN (1972-1974) during which a geological map scale 1:25,000 was completed and five boreholes drilled.

During further drilling for underground water, started more than twenty years ago by NRA/UNDP Sandstone Project, six water wells were drilled in the Sultani area down to the Amman Silicified and Wadi Sir Formation. Oil shale has been encountered in these wells.

Haddadin (1975) made a compilation of the known occurrences of bituminous rocks in the Phosphorite Formation from the data obtained from the boreholes drilled.

During 1970s and early 1980 the Jordan Phosphate Mining Company carried out detailed drilling program in the area of Wadi Abiad just 4kms south of the oil shale deposit.

In 1982 a drilling program for oil shale investigation was initiated by NRA and seven boreholes were drilled in the Muwaqqar Chalk Marl Formation. The Natural Resources Authority and BGR of Federal Republic of Germany carried out a drilling program during the first half of 1983 and 19 boreholes were drilled.

Finally the Sultani area was included in the 1:50,000 geological map and accompanying report of Jabal Al-Mutarammil (El-Hiyari, 1985) which forms part of the National Geological Mapping Project carried out by NRA in cooperation with the British Geological Survey.

V. FIELD ACTIVITIES

(a) Geological Mapping

Many geological maps at different scales are available for the area in question; Blake (1939), Quennell (1959), German Geological Mission (1961-1966), Phosphate Exploration Team/NRA (1972-1974), Sadaqh (1983) and Hiyari (1985).

During the present project detailed geological map of scale 1:10,000 was compiled based on El Hiyari geological map of Jabal Al-Mutarammil; aerial photographs, scale 1:25,000 were used during field investigation and map compilation (Fig. 2).

(b) Drilling

A drilling program was carried out to evaluate the potential of the oil shale sequence of the Sultani area ; a total of 53 boreholes were drilled 26 of which were by NRA in conjunction with BGR (1982-83) and the remainder independently by NRA during 1986 through a local contractor. Initially 2050 meters were drilled by down-hole hammer drilling and 255.6 meters by core drilling (1982-1983).

The second phase of drilling carried out in 1986 was considered to be complementary to the previous phase since the new boreholes were sited within the old network of close intervals. A total of 2087 meters were drilled of which 387 meters are core material (Table 1).

An open pit mine was driven in the northwestern part of the graben and work is still in progress.

(c) Logging and Sampling

On site, logging of boreholes was carried out when the drilling was over. The cutting samples from the oil shale were usually preserved in polythene bags and were lithologically described in the field then loaded to the laboratories in Amman for analysis.

VI. GEOLOGY

(a) Stratigraphy

The following formations are exposed in the studied area:

1. Amman Silicified Limestone Formation (ASL) Campanian

This formation is equivalent to the Silicified Limestone Unit of the German Geological Mission (1961-1966). Small outcrops of this formation occur in the eastern parts of the investigated area where the exposed portion attains a thickness of about 45m.

It is composed of thin chert layers of different colours ranging from grey to brown, alternating with limestone and marl. The contact with the overlying Sultani Phosphate Member is characterised by the clear gradual increase of the phosphatic limestone and chert.

TABLE 1

B.H.No	Coordinates		Elevations of B.Hs	Thickness of over burden(m)	Thickness of Oilshale (m)	Total depth of B. H'S (m)	Stripping ratio OV/OS
	E	N					
OS1	247,325	55,820	824,70	43,8	25,8	72,80	1,70
OS8	249,020	57,000	843,14	56,1	25,1	81,25	2.24
OS9	248,725	56,790	838,52	54.0	23,5	84.0	2.30
OS10	249,725	57,375	852,14	Ne.	Ne.	82,0	-
OS11	247.960	56.350	828,51	69.5	29.4	98.95	2.36
OS13	249.850	55.000	833.31	Ne.	-	71.0	-
OS14b	249.000	54.530	827.18	60.0	39.7	101.5	1.51
OS16	250.820	55.355	842.27	68.0	10.7	79.3	6.36
OS17	251.925	53.600	859.19	90.0	65.0	155.0	1.38
OS18	251.080	53.200	844.83	54.0	56.0	111.5	0.96
OS19	249.950	52.900	837.84	84.0	45.6	131.0	1.84
OS20	249.100	52.590	833.46	-	-	113.0	-
OS21	252.525	51.820	870.22	-	-	120.0	-
OS22	521.590	51.500	855.43	-	-	110.0	-
OS23	250.550	51.550	845.03	-	-	100.0	-
OS24	251.925	52.350	859.70	86.0	35.7	121.7	2.41
OS25	250.575	52.250	843.45	88.0	52.0	141.5	1.69
OS26	249.600	52.200	835.62	-	-	63.0	-
OS27A	246.860	56.915	821.91	37.5	11	48.5	3.4
OS27B	246.550	58.150	821.55	34.0	19	53.0	1.79
OS28	277.330	58.320	826.20	57.5	28.5	85.0	2.02
OS29	246.805	57.670	820.10	39	13.5	-	-

TABLE 1

B.H.No	Coordinates		Elevations of B.H's	Thickness of over burden(m)	Thickness of Oilshale (m)	Total depth of B. H'S (m)	Stripping ratio OV/OS
	E	N					
OS32	246.820	58.500	824.03	36.0	34.0	70.0	1.06
OS33	246.020	53.435	829.38	102	-	108.0	-
OS34	249.870	53.780	833.09	62	46	113.8	1.35
OS35	250.830	54.140	839.67	53	34	92.7	1.56
OS36	251.710	54.720	853.03	84	44	139.0	1.91
OS37	248.960	53.675	826.60	91	-	91.0	-
OS38	249.840	54.390	831.20	55	42	108.2	1.31
OS39	250.840	54.725	839.86	52.5	42.75	106.25	1.23
OS40	248.500	54.890	824.66	55	55.65	110.65	0.98
OS41	249.250	55.270	829.83	51	39	93.0	1.31
OS42	250.050	55.720	839.52	96	-	96.0	-
OS43	247.910	55.820	836.26	100	-	100.0	-
OS44	248.860	56.380	836.23	46	44	90.0	1.05
OS45	247.600	57.050	828.74	60.5	21	81.5	2.88
OS46	248.230	57.400	836.19	42	18	60.0	2.33
OS47	248.950	57.735	844.02	57.5	18	75.5	3.19
OS48	247.200	56.380	826.56	72	-	72.0	-
OS49	251.520	54.080	850.10	86.0	46.5	134.5	1.85
OS50	248.600	55.610	827.65	102	-	102.0	-
OS51	249.350	56.000	835.02	56	26.7	100.7	2.10
OS52	249.690	56.570	843.14	110	-	100.7	-
OS53	250.180	54.850	835.10	105	-	110.0	-

2. Al Hasa Phosphorite Formation (AHP) Maestrichtian

This formation is equivalent to the Phosphorite Unit of Bender (1974). It is exposed mainly at the eastern borders of the Sultani graben. Minor exposures exist at the western limits of this graben. The lower part of the formation (Sultani Phosphorite Member) outcrops in the eastern part and the Qatrana Phosphorite and Bahiya Coquina Members are found in western part of the investigated area, otherwise, the phosphorite was only encountered in the boreholes.

The formation consists of phosphorite, phosphatic chert, phosphatic limestone, chert, limestone and marl. The chert varies in colour from pale grey to brown. The Bahiya Coquina Member consists of oyster rich shaly limestone (grainstone) and is characterised by large scale, cross-stratification. The marl has a yellowish to tan colour.

The contact with the overlying Muwaqqar Chalk Marl Formation is marked by the disappearance of all the phosphate and chert layers and the appearance of a soft marl sequence of various colours, mainly yellowish, reddish and dirty white.

3. Muwaqqar Chalk Marl Formation (MC) Danian

Most of this formation is covered by superficial deposits. A few outcrops can be observed within fault-bounded NW striking blocks. The formation consists of yellowish to reddish marl, chalky marl and chalk; grey to dark brown chert beds

are also present and thin layers of granular phosphate and phosphatic chert are occasionally found near the base (EL Hiyari 1985).

A bituminous facies is present locally in a syndepositional tectonic depression. The exact thickness of this formation is unknown but the measured thickness in the boreholes ranges from 50 to 100m.

The presence of the bituminous facies within small syndepositional, tectonic, sub-basins, suggests a restricted depositional environment with the bituminous facies developing where anerobic conditions existed at sediment water interface (El Hiyari 1985).

4. Fluviatile and Lacustrine Gravel of Pleistocene Age (PL)

These sediments form relatively elevated portions above the graben erosional surface. They are composed of sub-rounded pebbles, cobbles and boulders of limestone, chert, phosphatic chert, and phosphatic limestone and are poorly sorted. The gravels are considered to have been deposited by flash-flood during the Pleistocene.

5. Alluvium and Wadi Sediments Holocene to Recent

These sediments consist of unsorted, coarse, limy and siliceous gravel with a coarse grained sandy matrix.

(b) Structure

The most outstanding structural feature dominating the studied area is the Sultani graben in which the Muwaqqar Chalk Marl is preserved. The eastern boundary fault has a NNW-SSE trend. The western boundary fault has the same over-all trend but it exhibits a gradual change in strike to WNW/ESE; this curvature is concave to the NE. The two faults meet in the southeastern corner of the studied area. Other faults cross the area with a NW-SE trend.

A small horst structure is present in the north western part of the area in which the Al Hasa Phosphorite Formation is found. There is a general dipping of strata towards the NE.

The structural contour map drawn on the contact surface between the Amman Silicified Limestone Formation and the overlying Sultani Phosphorite Member shows a small NNW-SSE trending syncline existing beneath the alluviated Sultani area (El Hiyari, 1985).

VII. EVALUATION OF THE OIL SHALE

(a) Overburden
(b) Lithology
(c) Thickness and Distribution
(d) Oil Content
(e) Organic Carbon
(f) Sulphur

(a) Overburden

The complete rock succession overlying the oil shale member is considered to be the overburden. It is composed of the superficial deposits which in turn cover chalk and marls with few chert intercalations.

The overburden thickness ranges from 34 to 86m and the stripping ratio (overburden thickness to oil shale thickness)ranges from 1 to 3.4, although most of the values fall between 1.3 and 2.3.

The overburden thickness was found to be minimum in the NW part of the area. It increases towards the southeastern parts of the graben where it attains a thickness of 86m (Fig. 7)

(b) Lithology of the Oil Shale

The lower part of the Muwaqqar Chalk Marl consists mainly of bituminous calcareous marl. It is mainly grey-brown and dark grey in colour.

The bituminous marl is characterised by thin bedded and laminated features.

Intercalations of bituminous limestone, grey to light grey in colour exist within the bituminous marl sequence. Phosphatic marl, which is slightly bituminous was encountered in the lower portion of some boreholes. Thin beds of black chert slightly bituminous are embedded in the middle and lower parts of the bituminous marl sequence. These beds start to appear in the middle part of the graben and increases towards the south.

No marker beds could be recognised in Sultani Oil Shale Deposit.

(c) Thickness and Distribution

The thickness of the oil shale and its distribution within the graben is based on the results of fifty-three boreholes drilled in 1982/1983 and 1986. The oil shale deposit is confined to a NW-SE trending graben structure some 8km long and 4km wide.

The drilled thickness of the oil shale varies from 1.5 meters to 65 meters. The greatest thickness can be observed in the south-east part of the graben where the sequence attains a thickness of 60 meters. The oil shale, here, forms an anticlinal lens cut by the eastern boundary fault of the graben that seems to have divided it into two parts. The axis of this lens appears to be normal to the trend of the graben faults.

The oil shale in the middle of the graben has the form of a synclinal lens whose axis trends NNE-SSW.

The oil shale close to the eastern fault seems to have an extension towards the upthrow side of the graben but due to the later uplift which took place, the oil shale and the chalk marl have been removed by erosion (Fig. 6)

(d) Oil Content

The oil content was determined by Fischer analysis in which the oil shale was pyrolized up to 520°C and the amount of oil was determined.

The distribution of the oil content within the oil shale deposit can be abbrecciated from the iso-chemical map (Fig. 8).

It can be seen that there is a positive relationship between the thickness of the oil shale and its oil content; the higher values of oil shale thickness correspond to higher values of oil content.

(e) Organic Carbon

The organic carbon content was determined by LECO carbon analysis after removing the carbon with HCL. The organic carbon is chemically bound to pyrolizable organic substances and depends on the type and maturity of the organic matter present in the rock (Hufnagel 1980).

Organic carbon was found in amounts confined between 8-11%.

The content of the organic carbon can be correlated with the oil yield and the gross calorific value (Fig. 10).

(f) Sulphur

The total sulphur content of the oil shale was determined by combustion in oxygen with LECO analysis. The value of sulphur varies between 1.6 and 4.3% but most of the sulphur values fall between 2%-3%. The effect of sulphur in the direct combustion process is related to the environment pollution it generates.

The high sulphur content of the retorted oil indicates that a considerable part of the sulphur is chemically bound to the organic mineral (Hufnagel 1980). Mean chemical composition of the oil shale of El Lajjun, Sultani and Jurf Ed Darawish is shown in (Table 3).

VIII. CALCULATION OF RESERVES

The "area of influence" method has been adopted for computing the oil shale reserves of Sultani (Fig. 3). The interval between the drilled boreholes is not less than one km, therefore the reserves are assigned to the category "Indicated Reserves". Many boreholes are to be drilled to verify the nature of oil shale occurrence.

The polygons around the boreholes can be seen in Figure 3, and the reserves figures are listed in Table (3). A total of about 1.130 billion tons has been indicated.

IX. CONCLUSIONS AND RECOMMENDATIONS

Sultani area is located in Central Jordan, about 115km south of Amman. It can be reached by Amman-Aqaba Highway. It is also accessible from Munzil railway station by many dirty roads branching off the highway and traversing the area in question towards east.

The oil shale is enclosed within NW-SE striking graben structure about 8km long and 4km wide. On average the thickness of the oil shale varies between 1.6m and 65m.

As well as the dominant lithology, which is a bituminous shale, occurrences of bituminous limestone are also found.

The overburden thickness ranges between 34m in the northeastern part of the graben and 86m in the southern part of the graben. The stripping ratio (Overburden thickness/Oil shale thickness) varies between 0.96 and 3.4, most of the values range between 1.3 and 2.3.

The oil content ranges from 6.6 to 10.0%. Most of the values fall between 7.5 and 9.5%. The mean oil content is more or less proportional to thickness of the oil shale.

The organic carbon values range from 8-11%. The inorganic carbon ranges from 2.4 up to 6.7% but most of the values fall between 3.5 and 5%.

Total sulphur content ranges from 1.6 up to 4.3%, but most of the values fall between 2 and 3%.

The indicated oil shale reserves are about 1.13 billion tons.

On the basis of the present study the following points have to be emphasized.

(a) The borehole interval is insufficient for an accurate proven reserves calculation, although several more boreholes would be needed for this sort of calculation.

(b) The interval structure of the graben merits a geophysical investigation to explain some of the questions raised by the drilling results.

(c) Some deep boreholes are required to penetrate the phosphorite formation in order to evaluate the phosphate potential of the area since the El Abiad phosphate mines are only a few kilometors away.

(d) The potential water resources of the area should be evaluated in a special hydro-geological feasibility study.

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TABLE 2

B.H.No	Moist-ure %	Oil %	CaCo3%	Total S%	In Organic C%	Organic C%	Total C%
OS8		9.8					
OS9		7.3					
OS10		Ne.					
OS11		9.8					
OS13		Ne.					
OS14b		9.3					
OS16		8.7					
OS17		10.0					
OS18		9.8					
OS19		8.7					
OS20		Ne.					
OS21		Ne.					
OS22		Ne.					
OS23		Ne.					
OS24		9.6					
OS25		9.6					
OS26		Ne.					
OS27A		7.9	20.0	3.53	2.40	9.46	11.86
OS27B		7.5	31.0	3.54	3.73	9.10	12.75
OS28		6.9	55.84	1.73	6.70	8.52	15.22
OS31		-	-	-	-	-	-
OS32		7.8	33.00	3.84	3.96	9.48	13.44
OS33		Ne.					
OS34		7.4	43.15	1.85	5.14	8.99	14.13
OS35		7.9	32.54	1.63	3.90	9.62	13.53
OS36		7.0	37.18	1.88	4.47	8.47	12.92
OS37		Ne.					
OS38		9.4					
OS39		7.4	31.65	2.24	3.85	9.00	12.88
OS40		7.8	38.64	2.26	4.76	9.59	14.10
OS41		7.1	35.3	2.41	4.23	8.68	13.24
OS42		Ne.	-	-	-	-	-
OS43		Ne.	-	-	-	-	-
OS44		7.4	32.83	2.56	3.94	8.90	12.92
OS45		9.4	46.92	4.29	5.63	11.36	16.98
OS46		6.6	30.41	2.94	3.65	7.90	11.55

TABLE 2

B.H.No	Moist-ure %	Oil %	CaCo3%	Total S%	In Organic C%	Organic C%	Total C%
OS47		9.3	49.90	3.71	5.98	11.17	16.76
OS48		Ne.					
OS49		7.50					
OS50		Ne.					
OS51		8.9	51.1	2.4	6.12	11.3	17.43
OS52		Ne.	-	-	-	-	-
OS53		Ne.	-	-	-	-	-

Table : Calculation of Reserves .

No.OB.H.	area(m^2)	Thickness	Volume	Weight Ton
OS1	445500	25.8	11,493900	20,689020
OS8	330500	25.1	8,295550	14,931990
OS9	247000	23.5	5,804500	10,448100
OS11	343000	29.4	10,084200	18,151560
OS12	281400	1.5	424100	763380
OS14	584900	39.7	23,220530	41,796954
OS15	731400	3.0	2,194200	3,949560
OS16	756000	10.7	8,089200	14,560560
OS17	859000	65.0	55,835000	100,503000
OS18	974800	56.0	54,588800	98,259840
OS19	765000	45.6	34,884000	62,791200
OS24	1142100	35.7	40,772970	73,391346
OS25	929600	52.0	48,339200	87,010560
OS27A	276500	11	3,041500	5,474700
OS27B	203500	19	3,866500	6,959700
OS28	701000	28.5	19,978500	35,961300
OS29	276900	13.5	3,738150	6,728670
OS30	373700	20.0	7,474000	13,453200
OS31	214300	39.0	8,357700	15,043860
OS32	203000	34.0	6,902000	12,423600
OS34	690300	46.0	31,753800	57,156840
OS35	648200	34.0	22,038800	39,669840
OS36	570000	44.0	25,080000	45,144000
OS38	513400	42.0	21,562800	38,813040
OS39	450500	42.75	19,258875	34,665975
OS40	692900	55.65	38,559885	69,407793
OS41.	553000	39.0	21,567000	38,820600
OS44	397800	44.0	17,503200	31,505760
OS45	424700	21.0	8,918700	16,053660
OS46	841800	18	15,152400	27,274320
OS47	601500	18	10,827000	19,488600
OS49	506000	46.5	23,529000	42,352200
OS51	542700	26.7	14,490090	26,082162
				1,130,000,000

Table 4

Mean Chemical Composition of the Oil Shale of El Lajjun, Sultani and Jurf Ed Darawish

	El Lajjun	Sultani	Jurf Ed Darawish
SiO_2 (bywt)	16.13	26.26	9.30
Al_2O_3 -	3.77	2.87	3.76
Fe_2O_3 -	1.51	1.12	1.55
MgO -	0.85	0.95	0.22
CaO -	30.43	26.30	38.73
P_2O_5 -	3.31	3.48	1.53
SO_3 -	4.83	4.38	4.32
Loss on Ignition	38.0	33.0	39.50
As (ppm)	n.b.	17	10
Cu -	92	115	68
Mo -	73	94	20
Ni -	167	139	102
Sr -	1015	707	1187
U -	22	25	17
Zn -	451	649	190
Ba -	113	46	35
Cr -	431	267	226
V -	162	268	101
Moisture(bywt)	2.43	5.47	5.50
Calorific Value KJ/Kg	5480	5680	3610

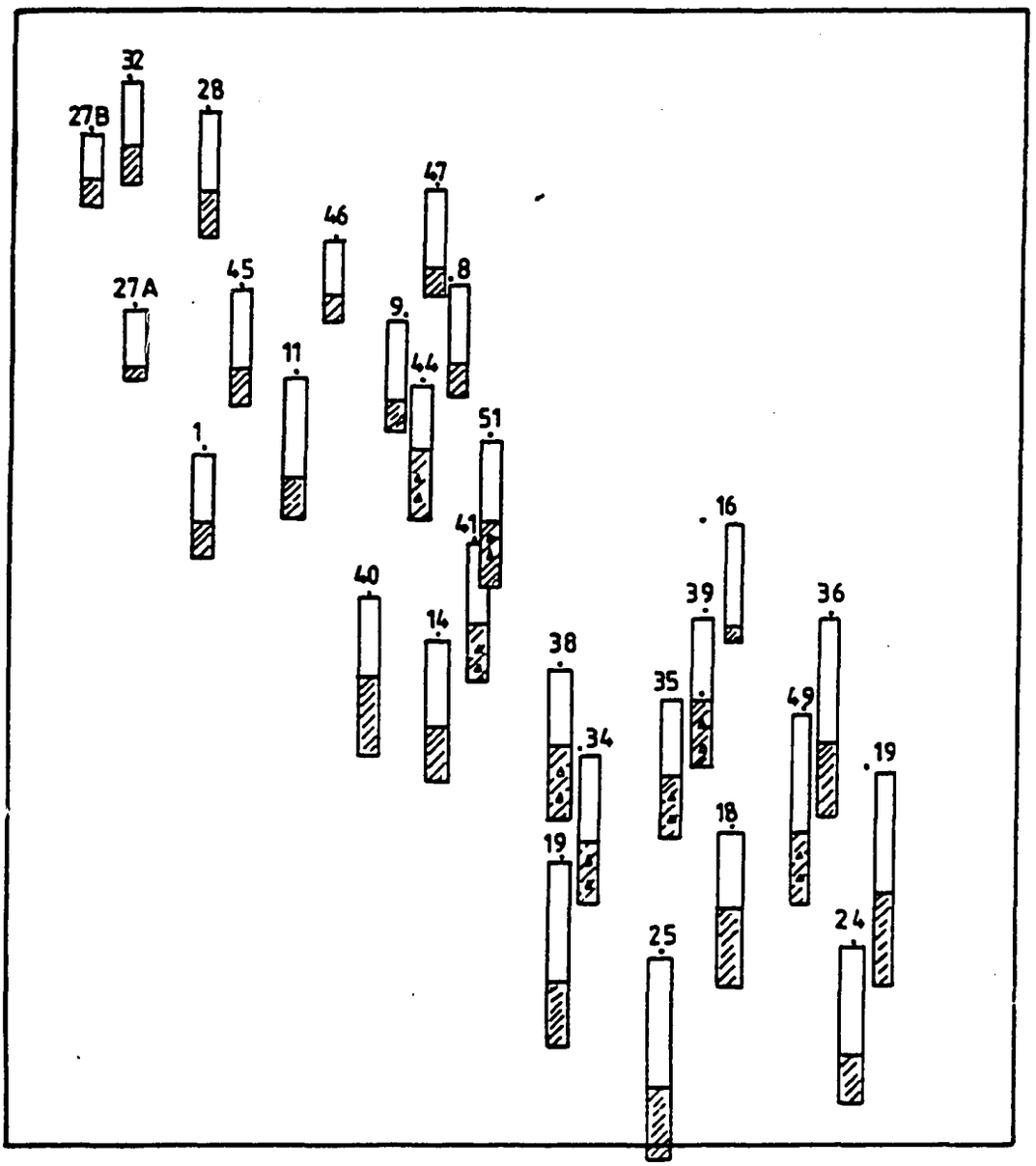
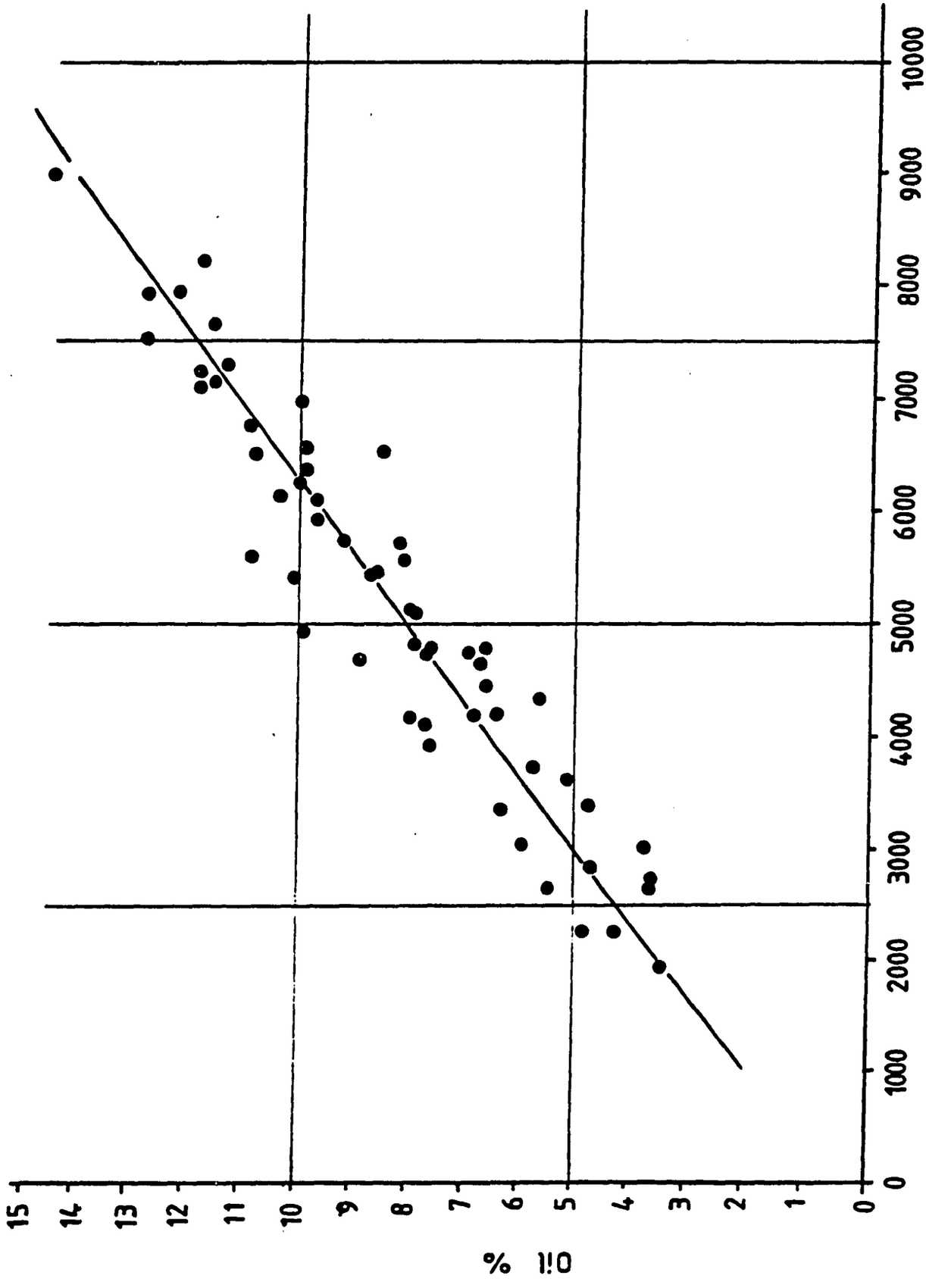


Fig 9: Mining chart of the drilled boreholes.

Fig 10 : Relationship between oil content and gross calorific value of the Sultani Oil Shale.



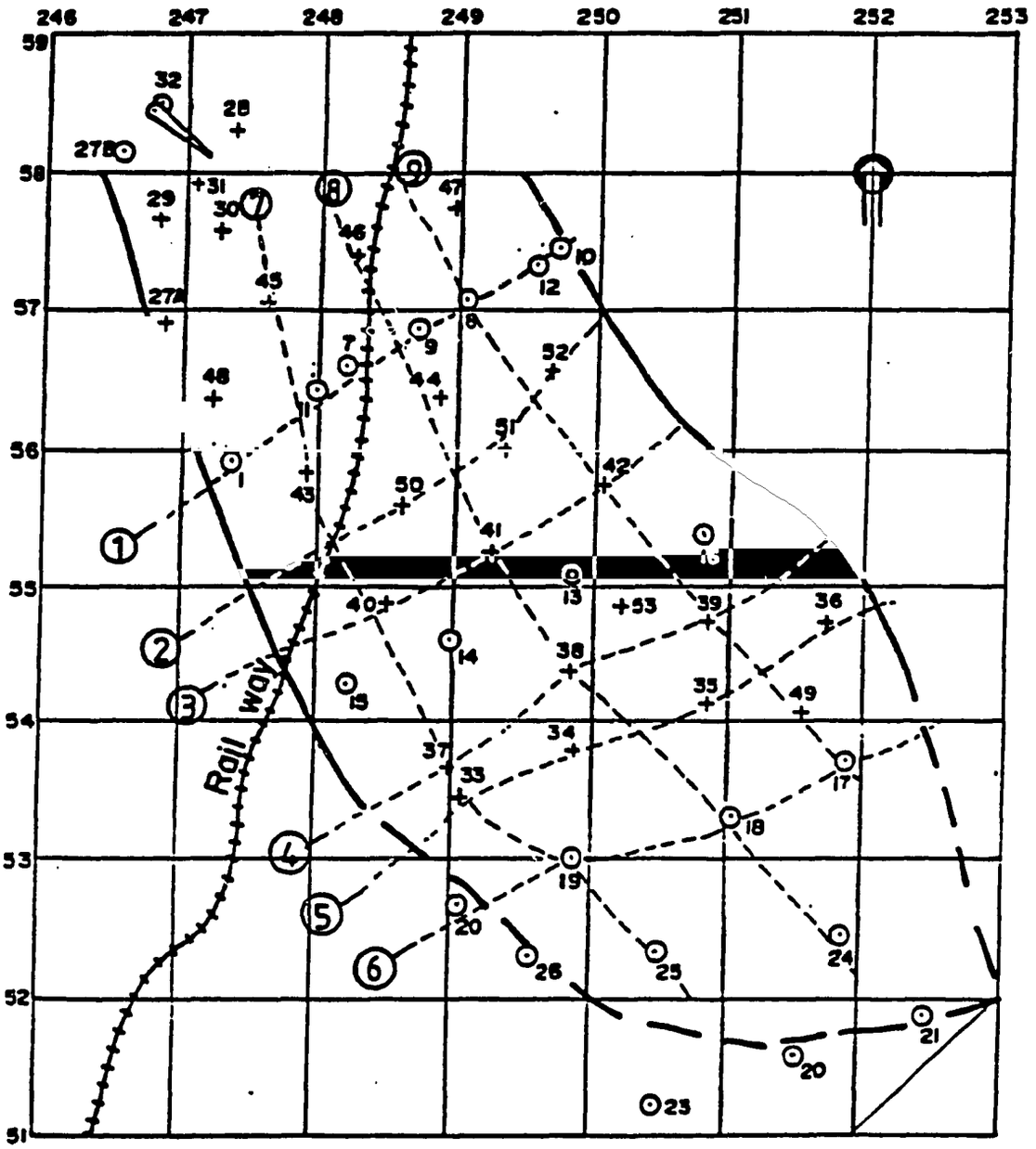
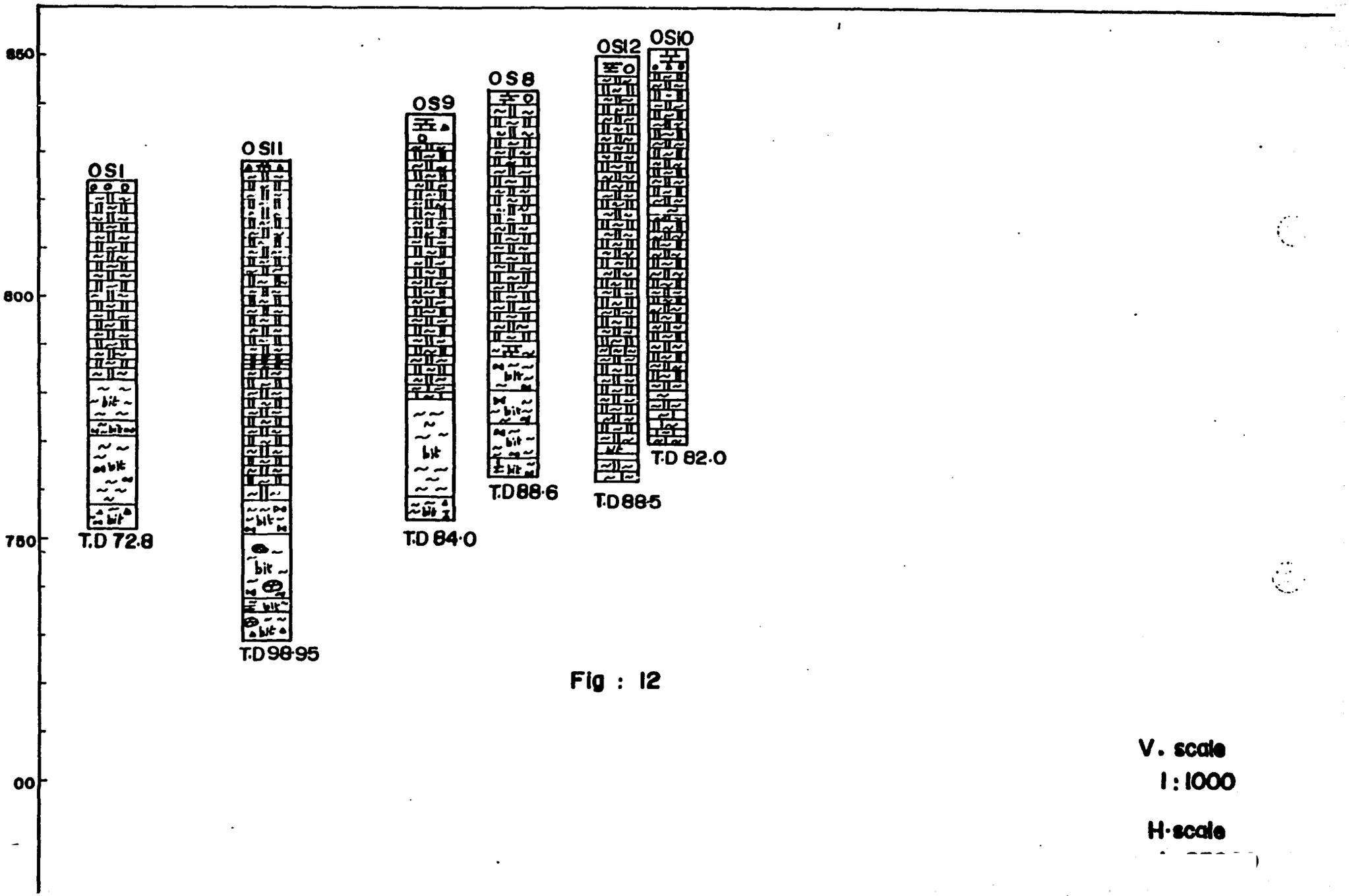


Fig : 11 Index map of the correlation chart of boreholes of Sultani Oilshale Deposit .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800
750
00
OS1
T.D 72.8
OS11
T.D 98.95
OS9
T.D 84.0
OS8
T.D 88.6
OS12
T.D 88.5
OS10
T.D 82.0
V. scale
1 : 1000
H. scale

Fig : 12

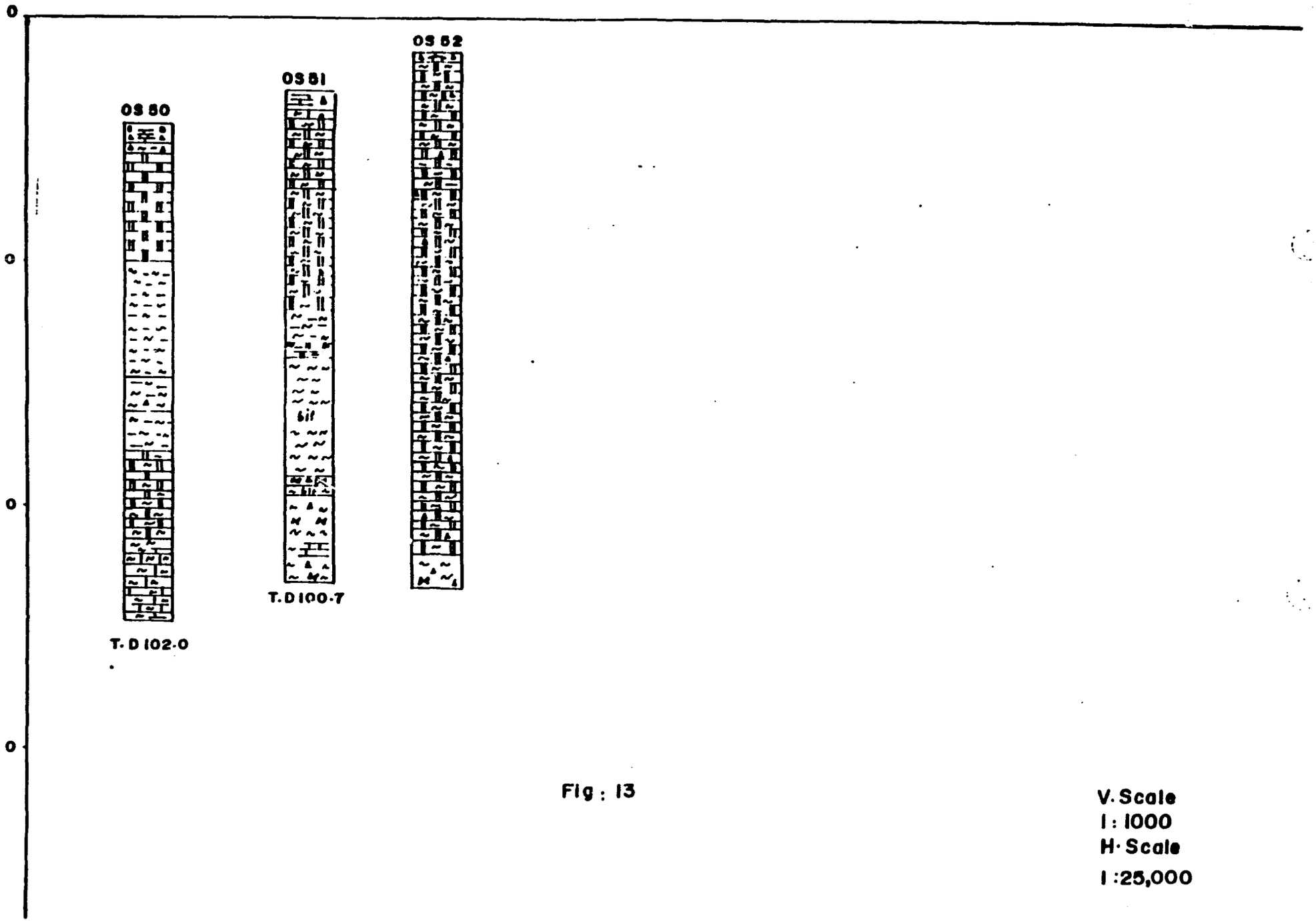

Fig : 13

V. Scale
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H. Scale
1 :25,000

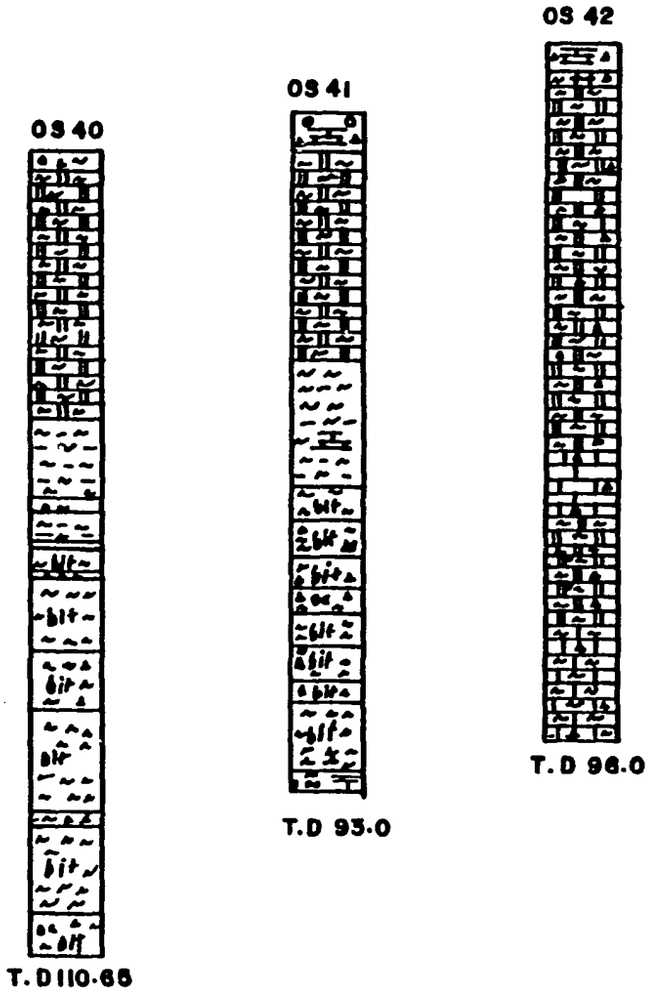

Fig : 14

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H.Scale
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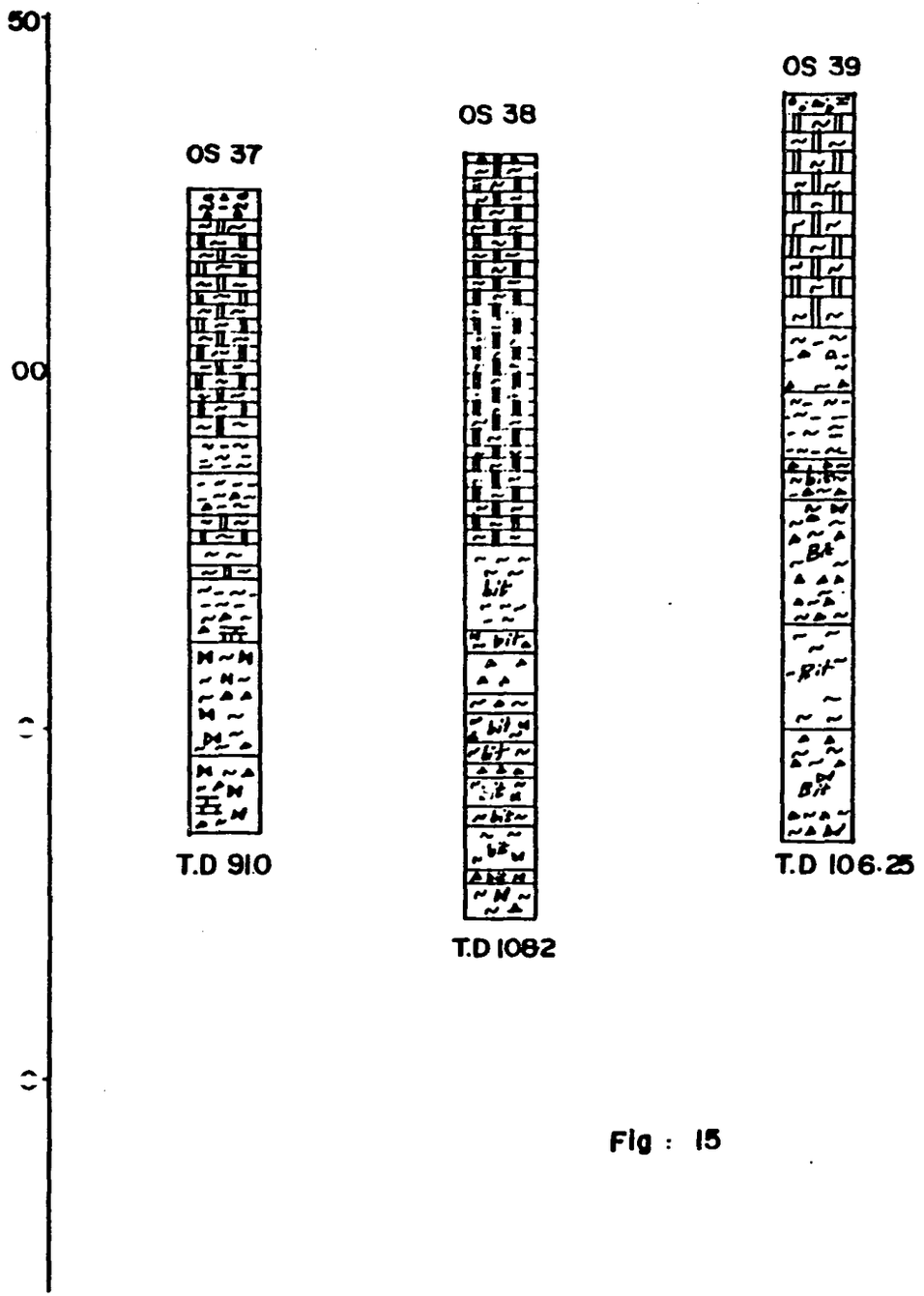
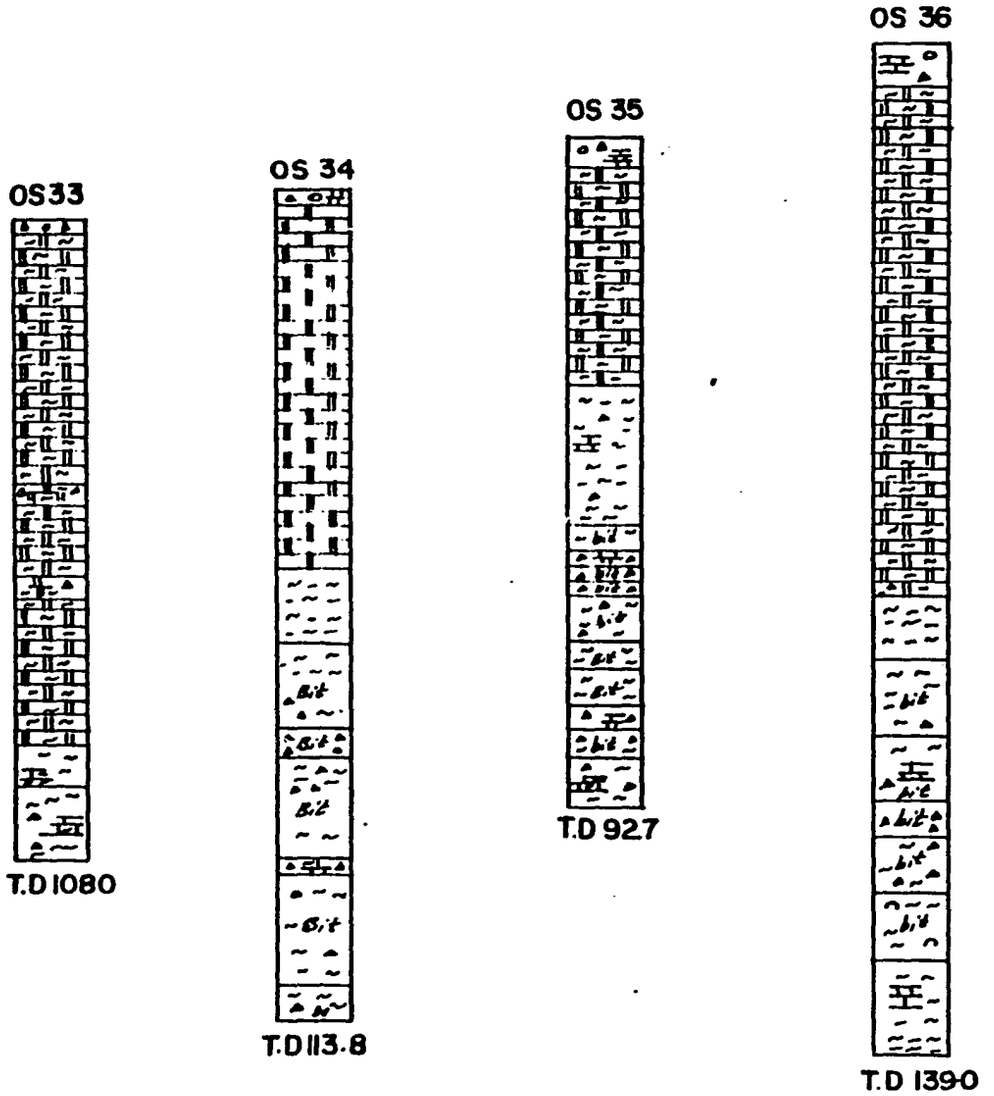


Fig : 15

V. Scale
1:1000

H. Scale
1:25000



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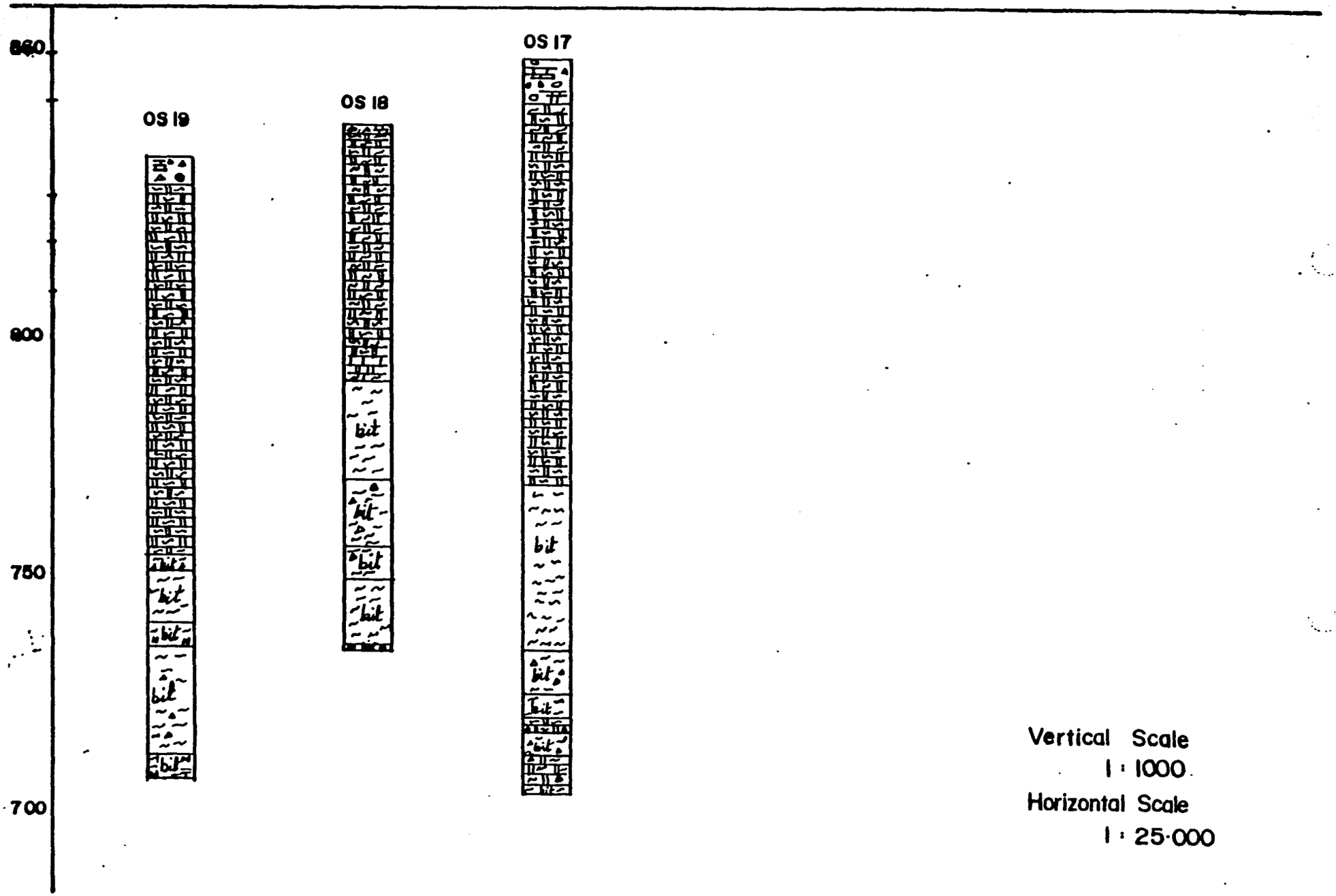
H. Scale
1:25000

Fig : 16

Fig : 17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800
750
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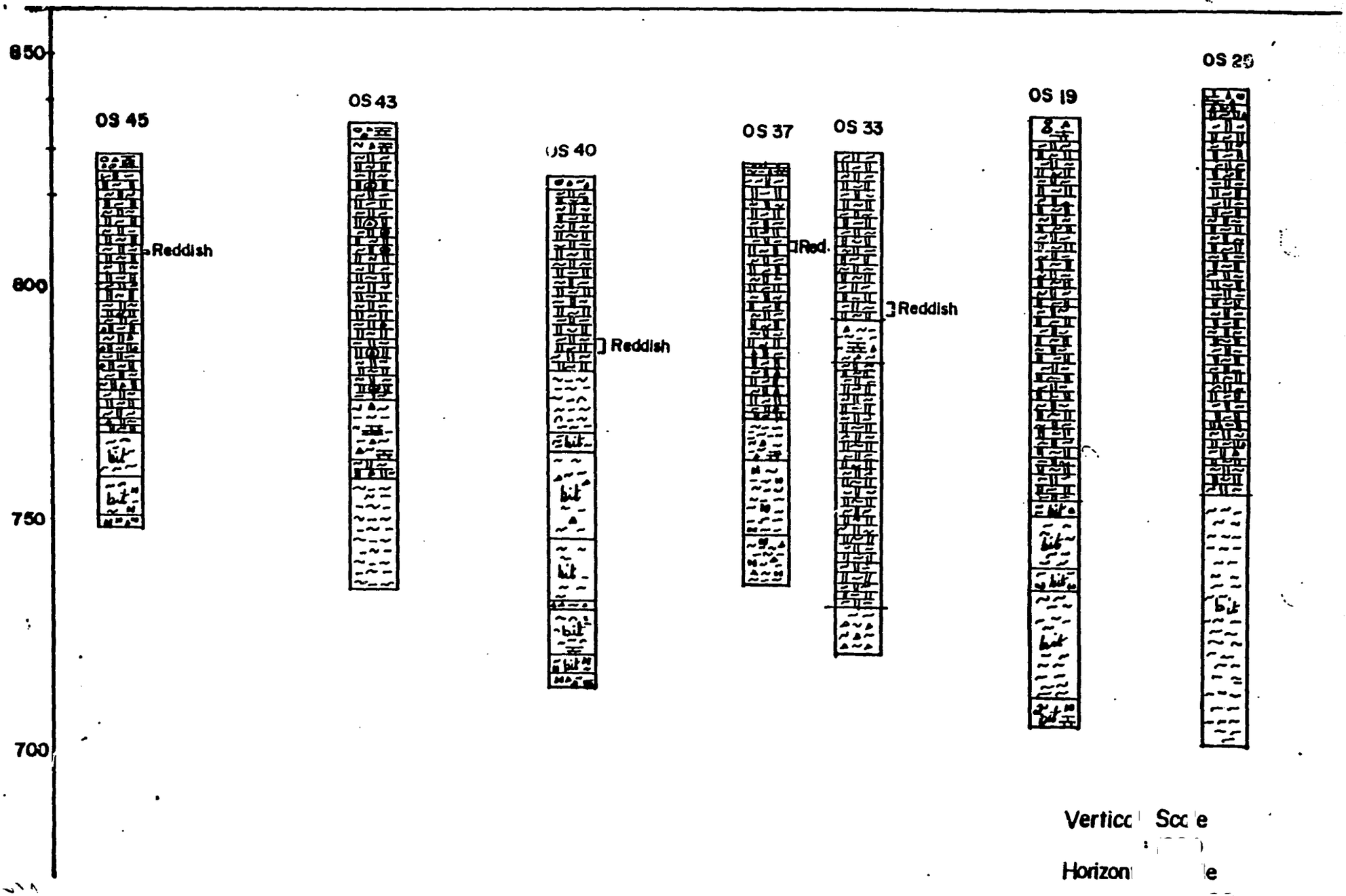
OS 19
OS 18
OS 17
bit
Vertical Scale
1 : 1000
Horizontal Scale
1 : 25·000

Fig 18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800
750
700
OS 45
Reddish
OS 43
OS 40
Reddish
OS 37
Red.
OS 33
Reddish
OS 19
OS 29
Vertic Sc e
Horizon e

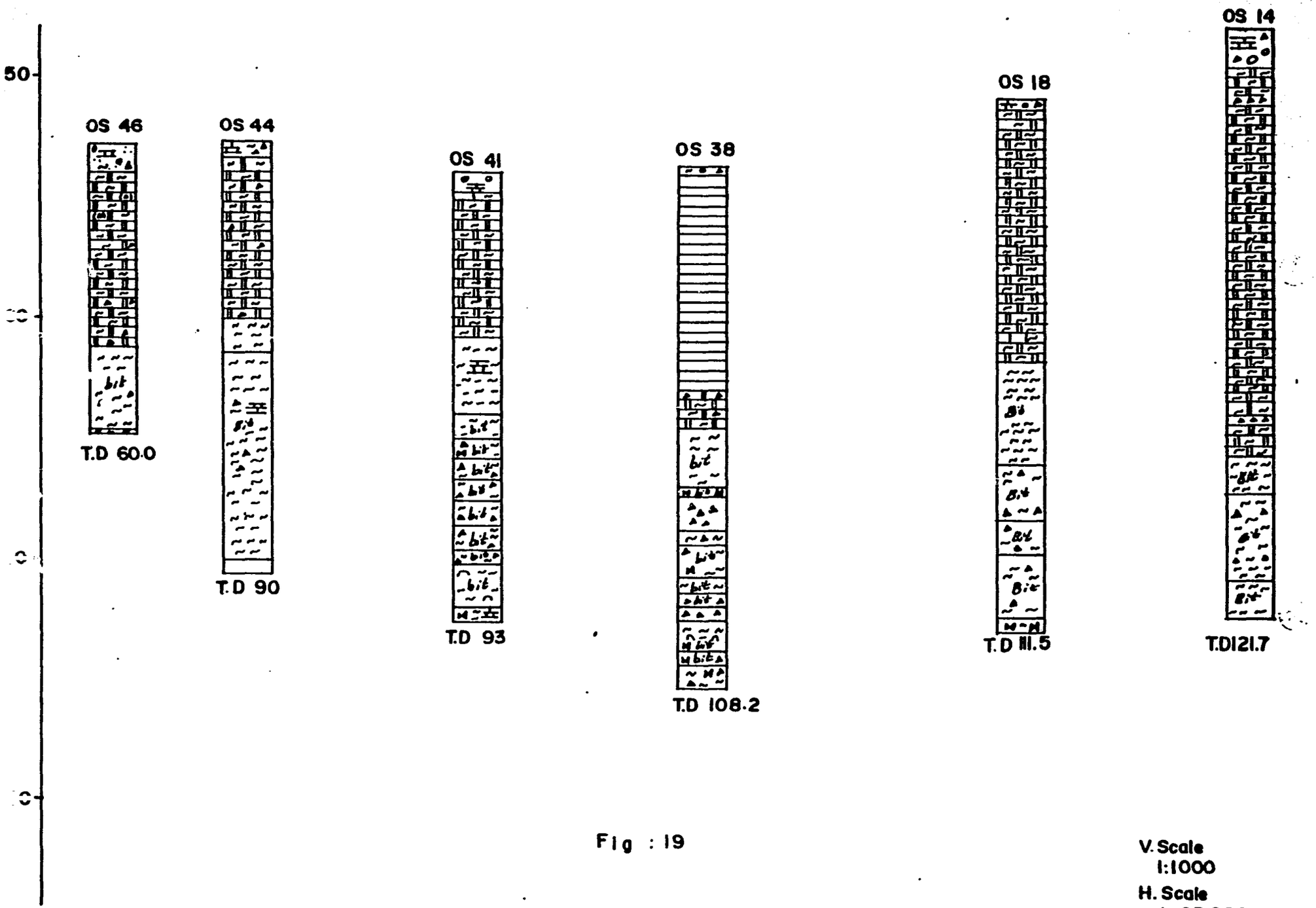

Fig : 19

V. Scale
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H. Scale
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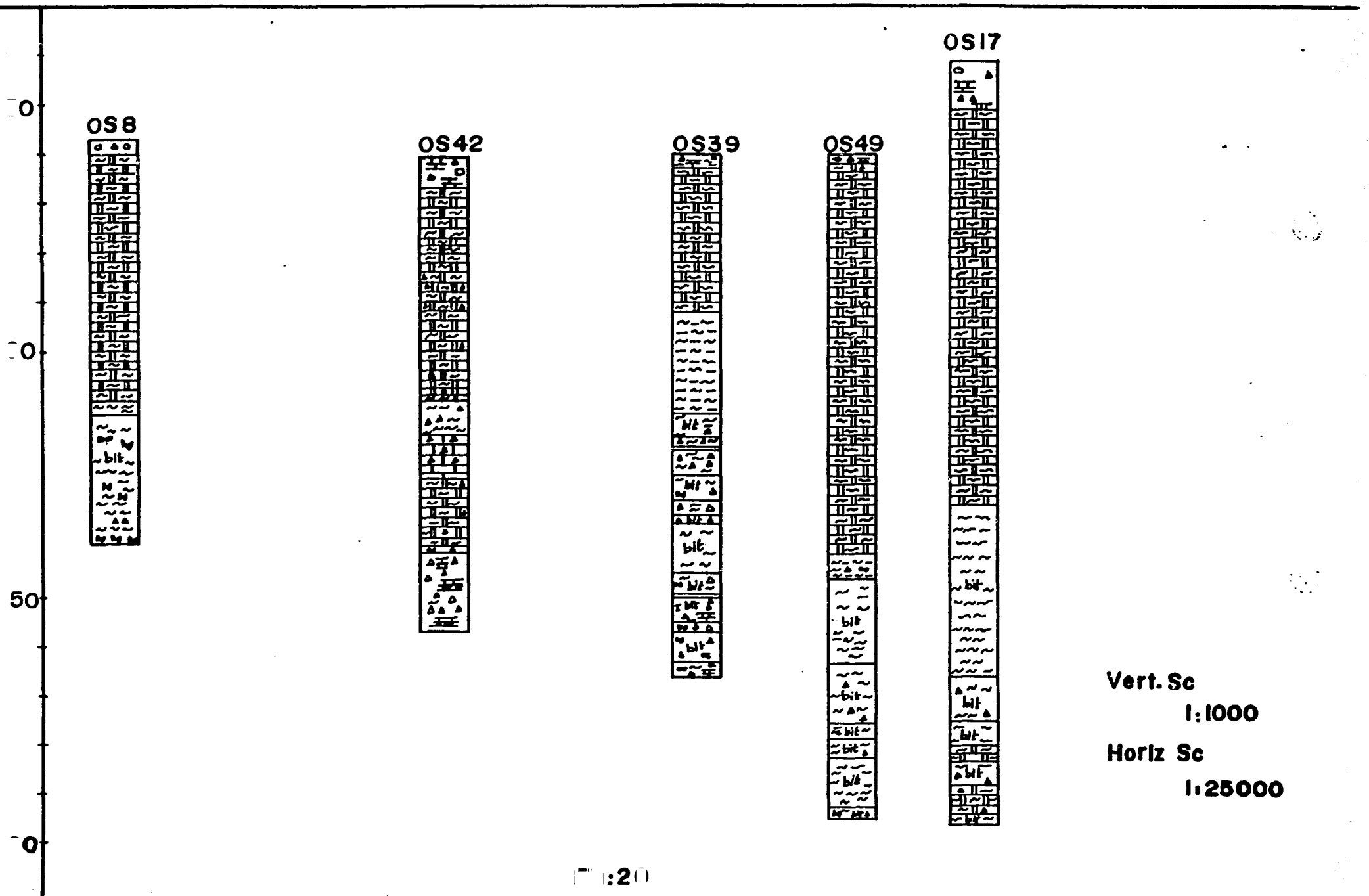
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bit
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Horiz Sc
1:25000

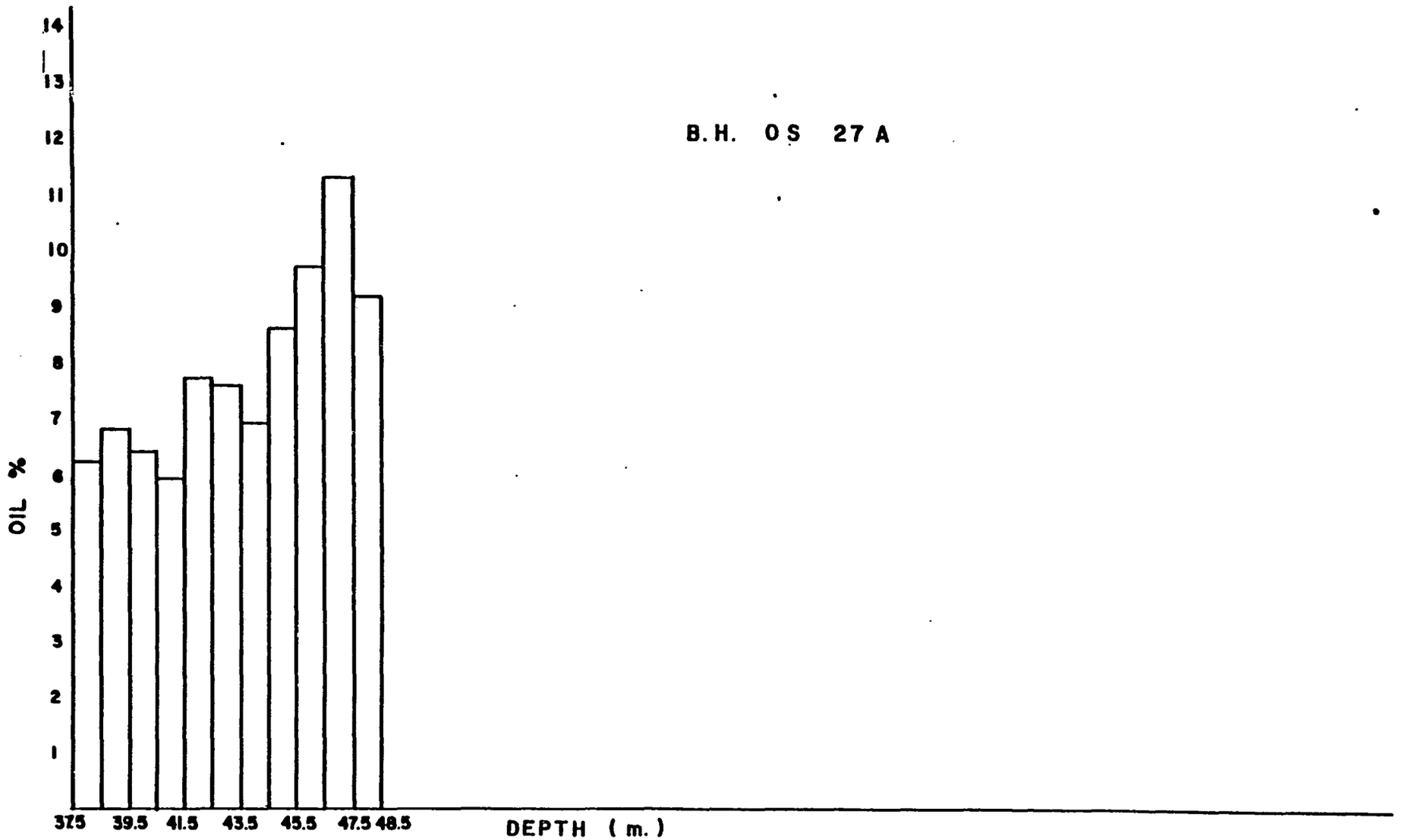
B.H. OS 27 A
OIL %
14
13
12
11
10
9
8
7
6
5
4
3
2
1
37.5
39.5
41.5
43.5
45.5
47.5
48.5
DEPTH (m.)

Fig : 1

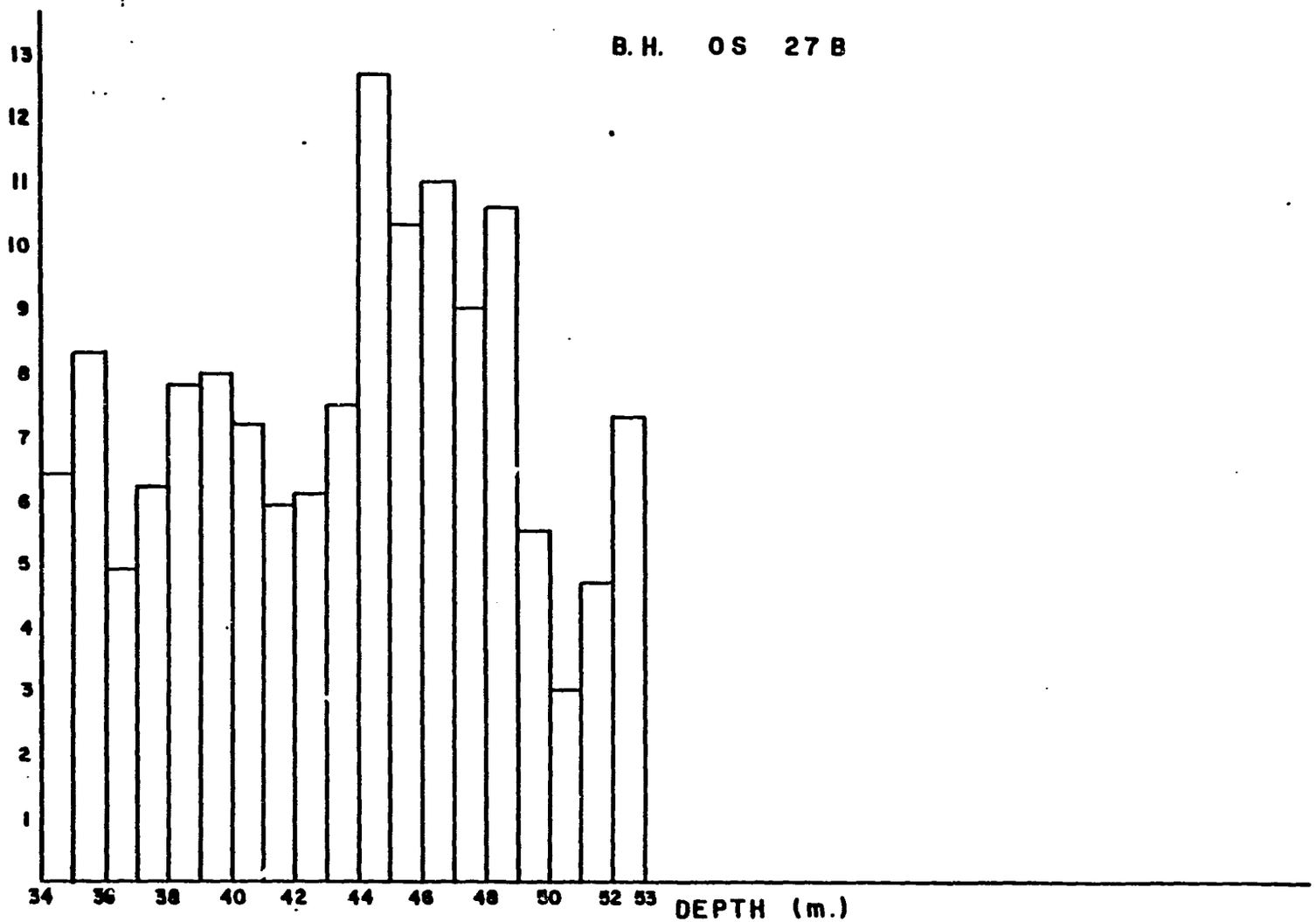
B. H. OS 27 B
13
12
11
10
9
8
7
6
5
4
3
2
1
34
36
38
40
42
44
46
48
50
52
53
DEPTH (m.)

Fig: 22

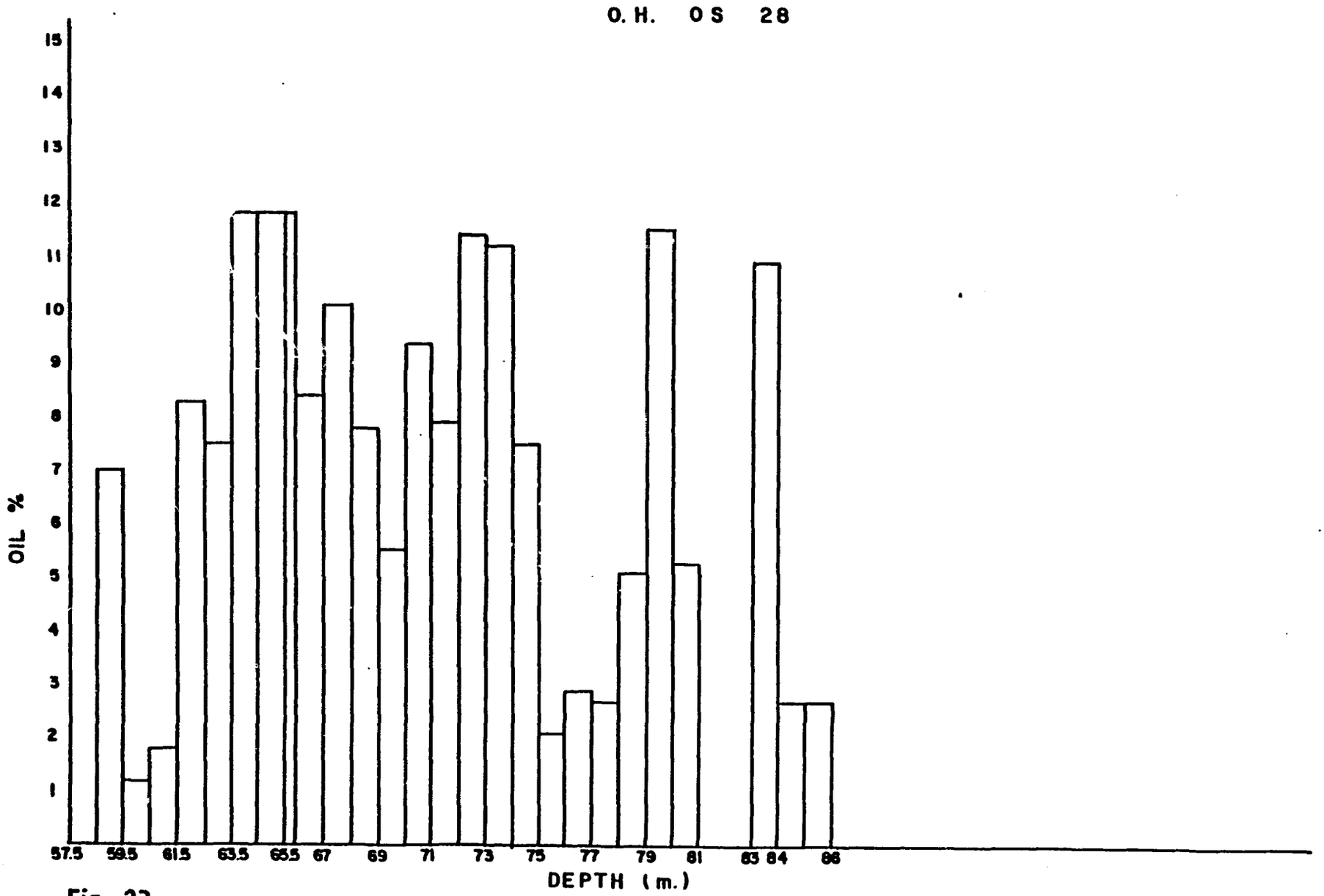
O. H. OS 28
OIL %
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
57.5
59.5
61.5
63.5
65.5
67
69
71
73
75
77
79
81
83
84
86
DEPTH (m.)

Fig : 23

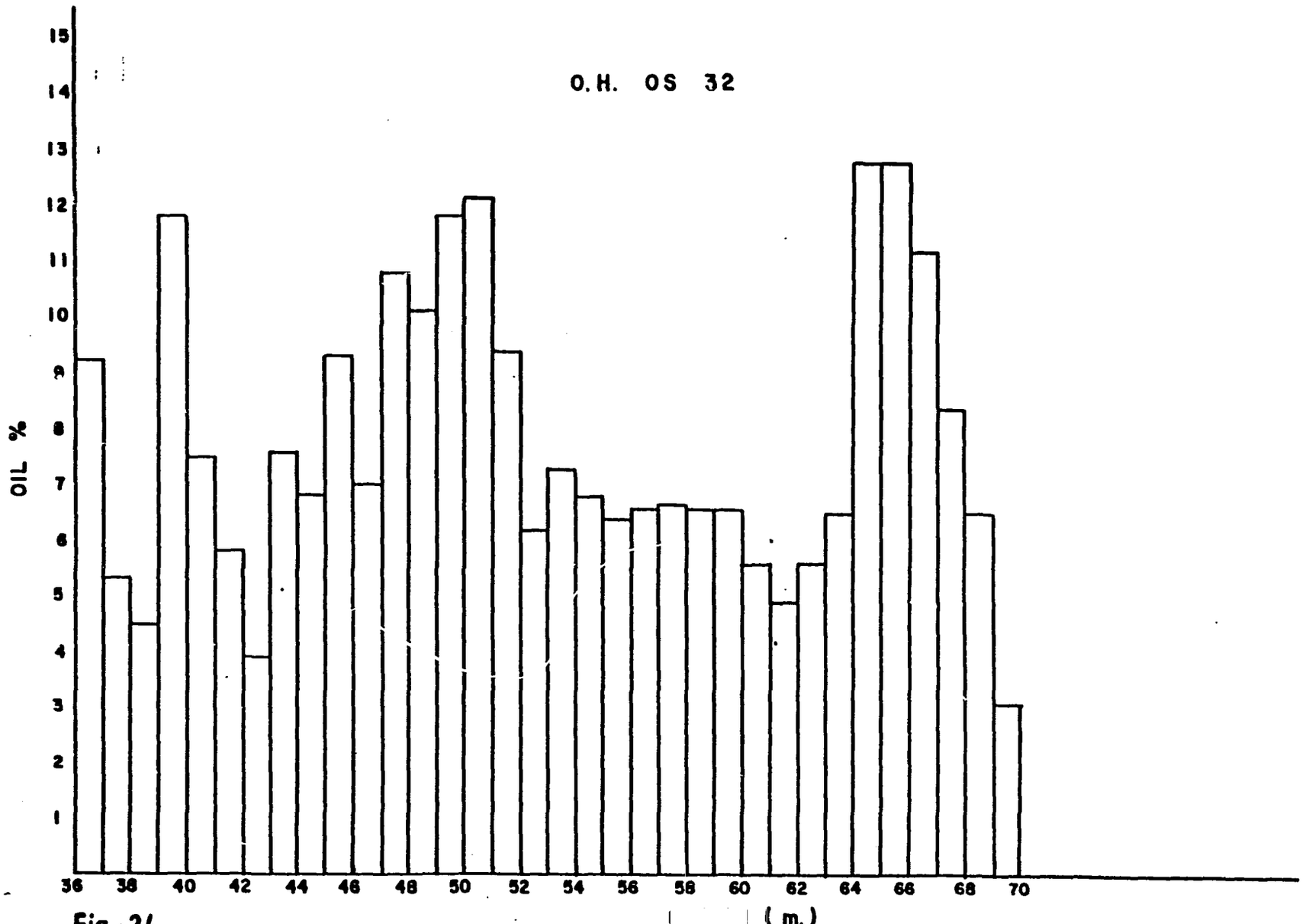
O.H. OS 32
OIL %
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70
(m.)

Fig : 24

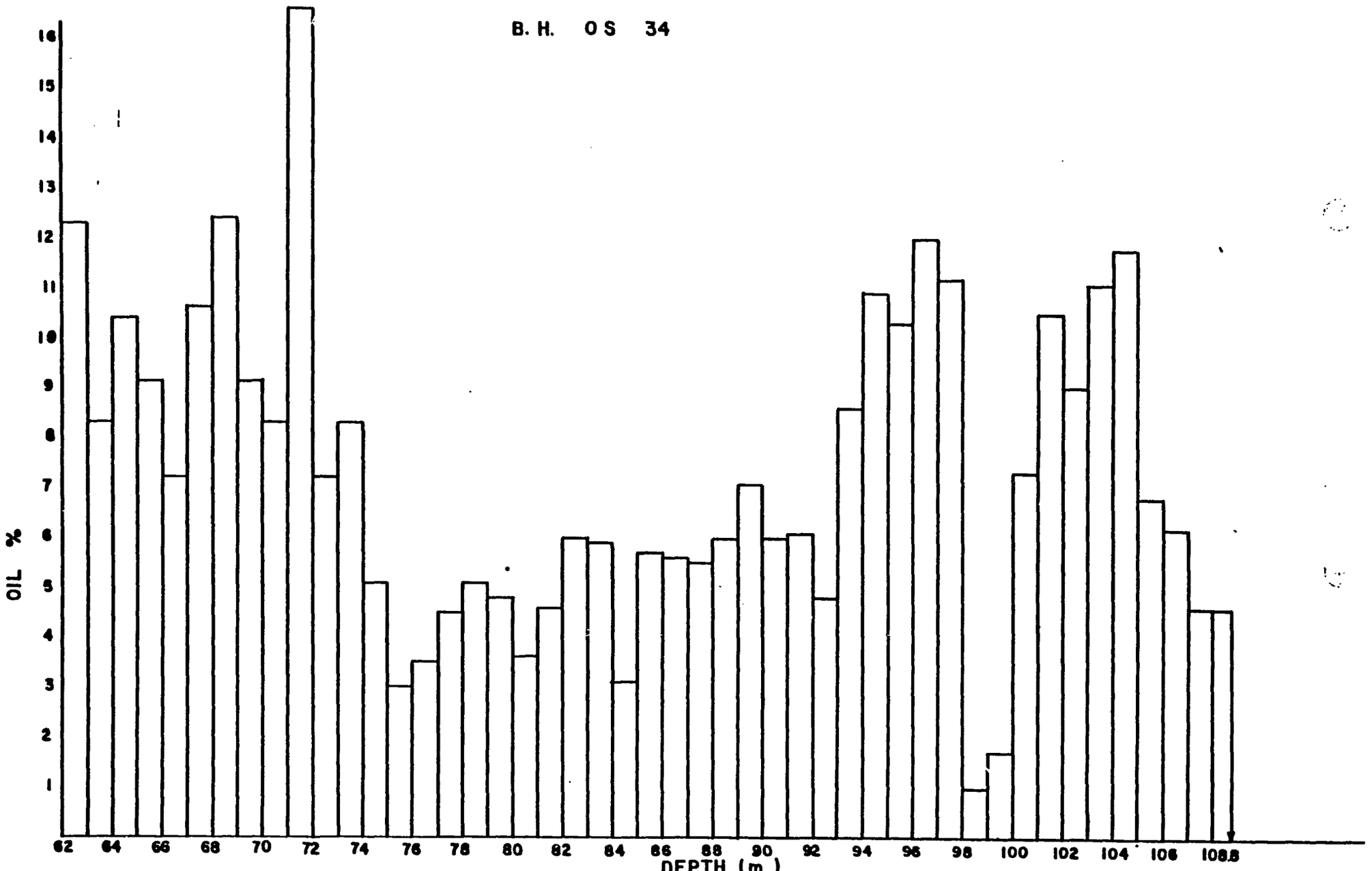
B. H. OS 34
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
92
94
96
98
100
102
104
106
108.8
DEPTH (m.)

Fig : 25

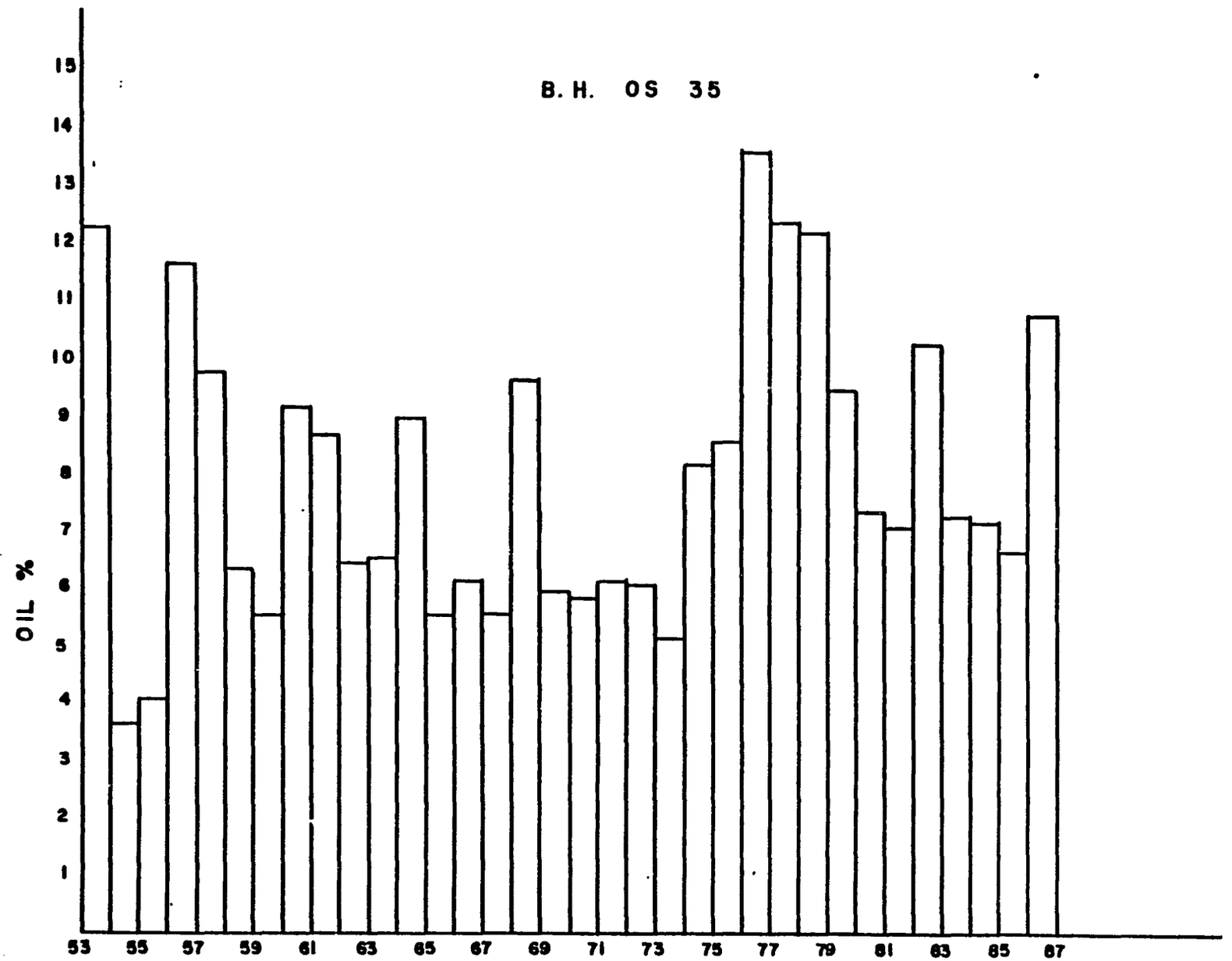
B. H. OS 35
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
53
55
57
59
61
63
65
67
69
71
73
75
77
79
81
83
85
87
(m.)

Fig: 26

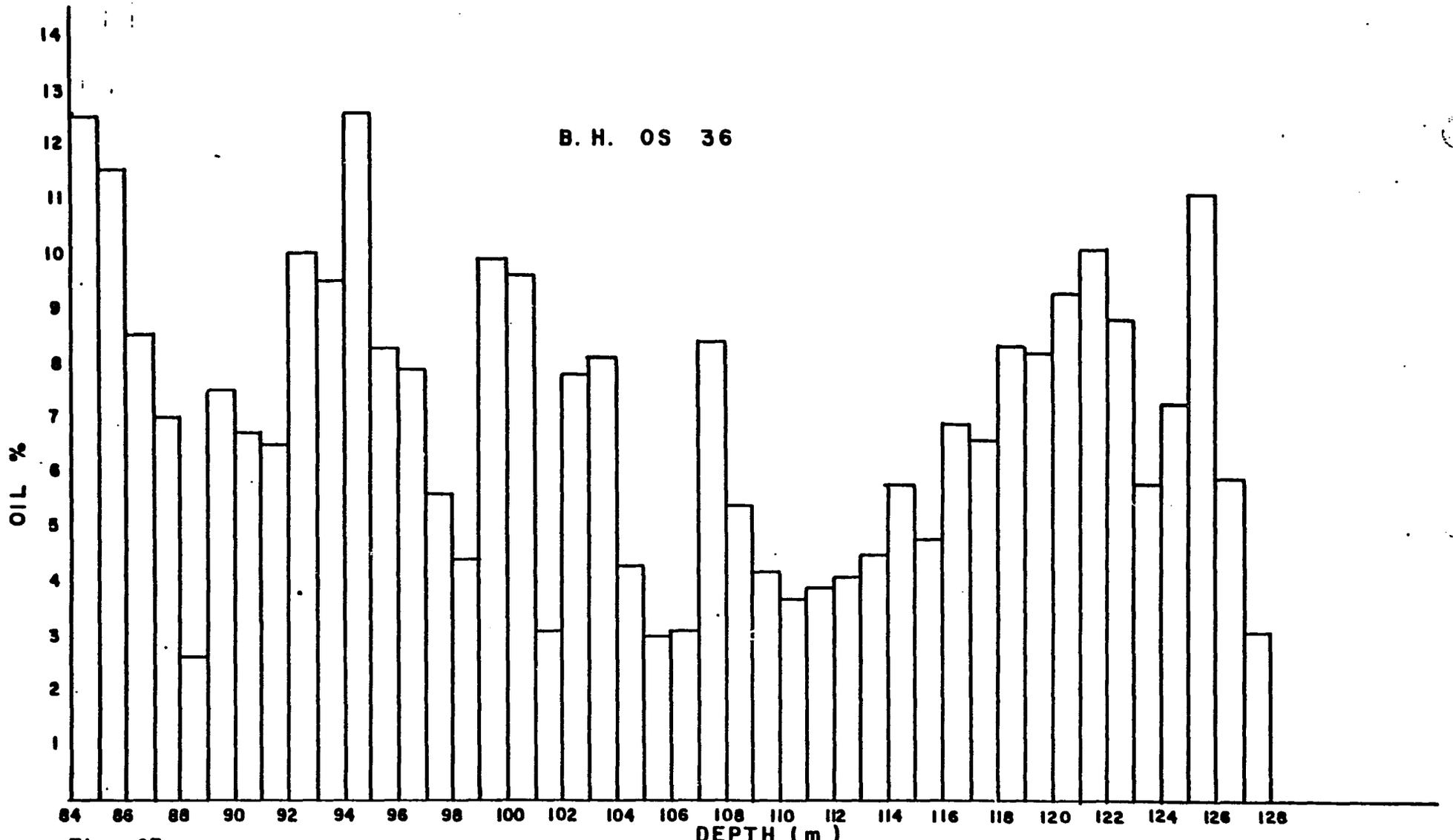
B. H. OS 36
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
84
86
88
90
92
94
96
98
100
102
104
106
108
110
112
114
116
118
120
122
124
126
128
DEPTH (m.)

Fig: 27

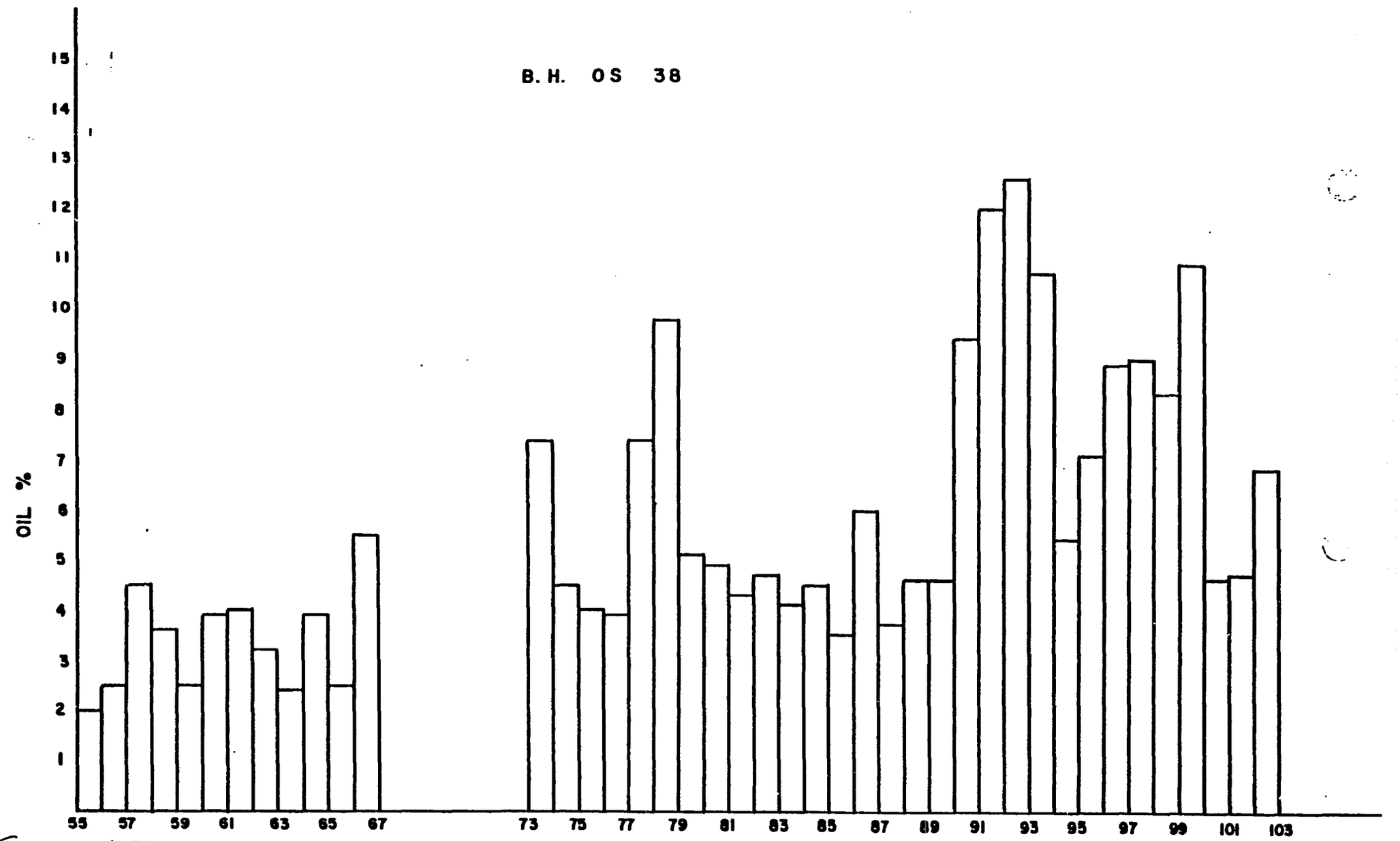
B. H. OS 38
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
55
57
59
61
63
65
67
73
75
77
79
81
83
85
87
89
91
93
95
97
99
101
103
n.)

Fig: 28

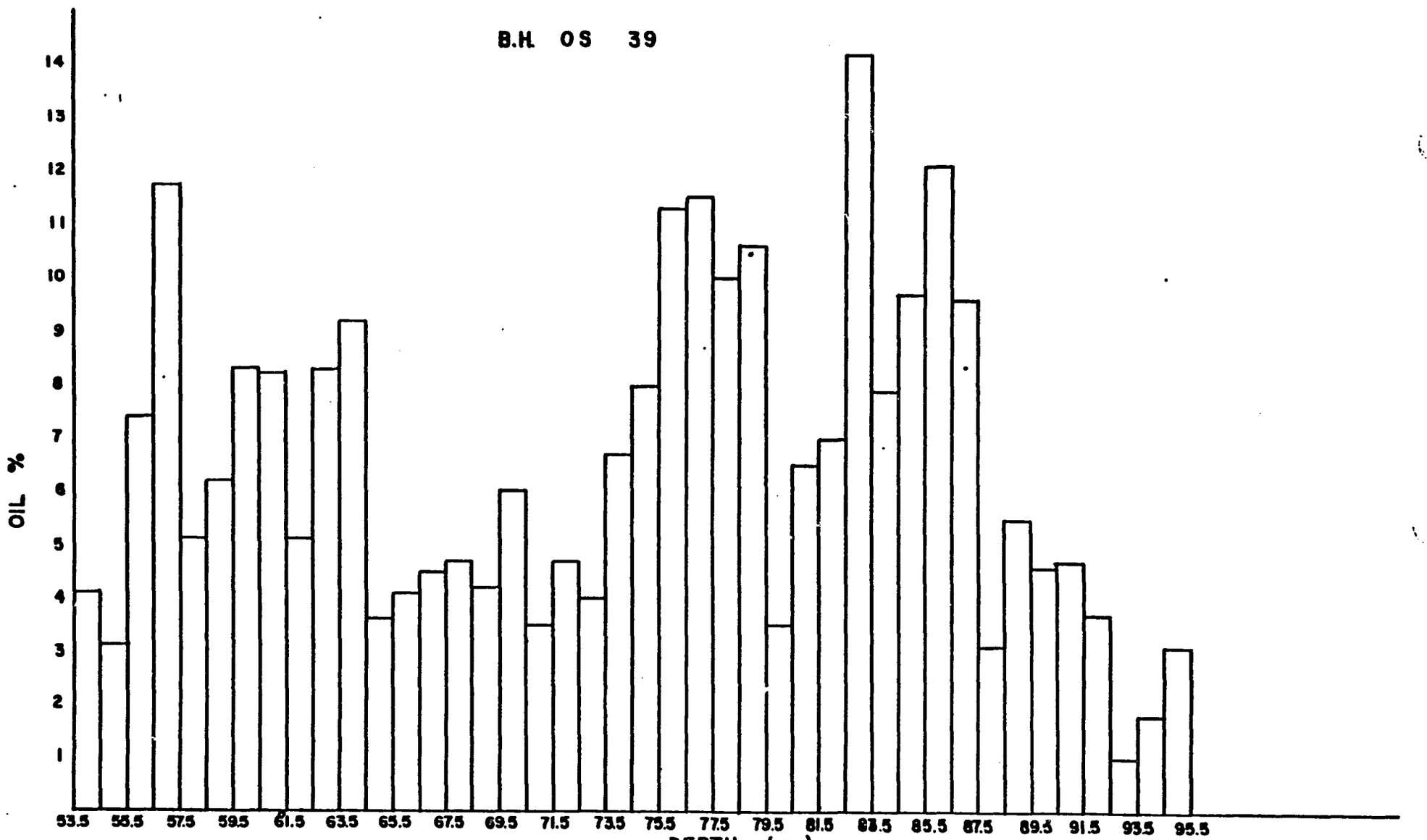
B.H. OS 39
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
53.5
55.5
57.5
59.5
61.5
63.5
65.5
67.5
69.5
71.5
73.5
75.5
77.5
79.5
81.5
83.5
85.5
87.5
89.5
91.5
93.5
95.5
DEPTH (m.)

Fig : 29

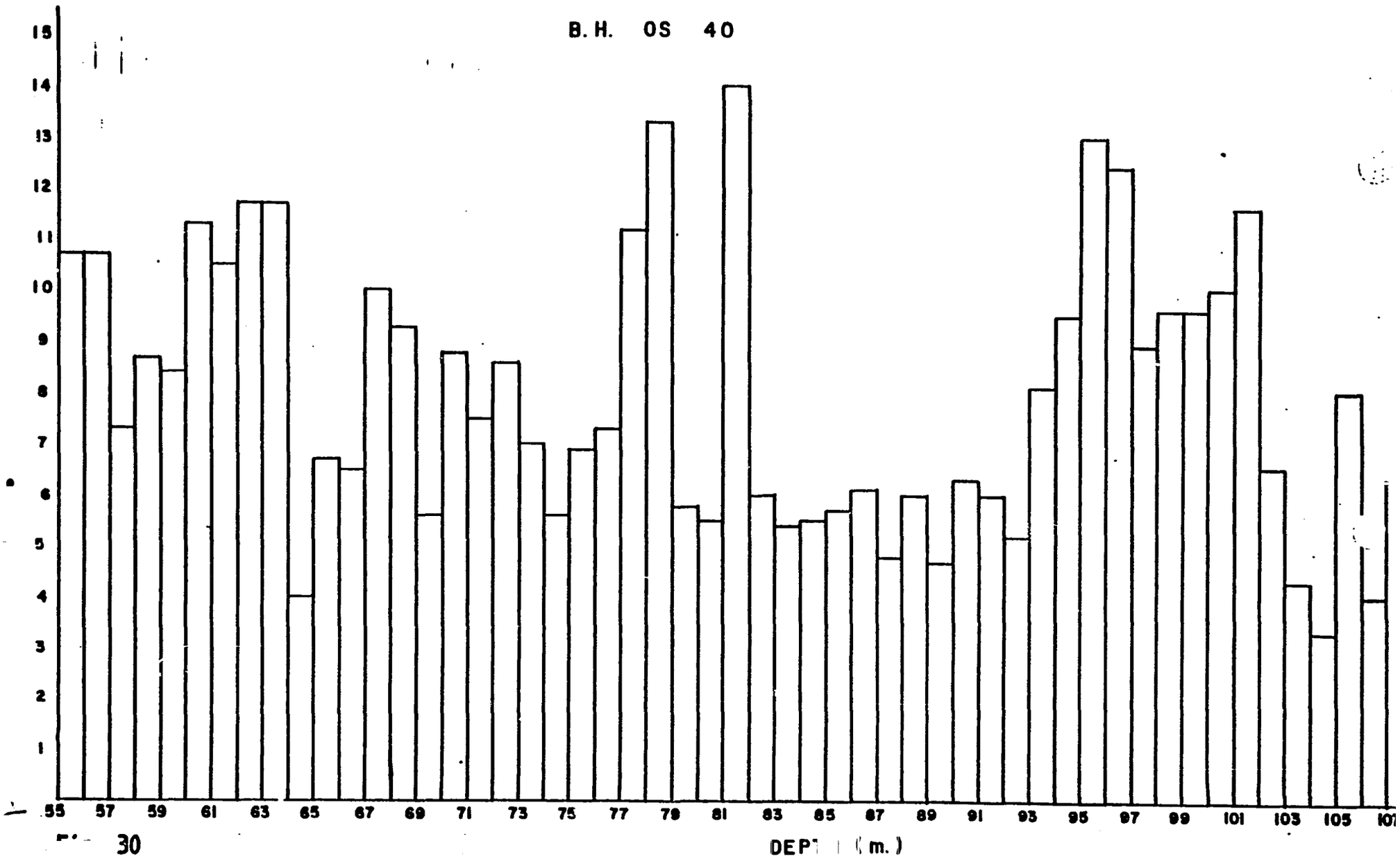
B. H. OS 40
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
55 57 59 61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97 99 101 103 105 107
DEPTH (m.)

FIG. 30

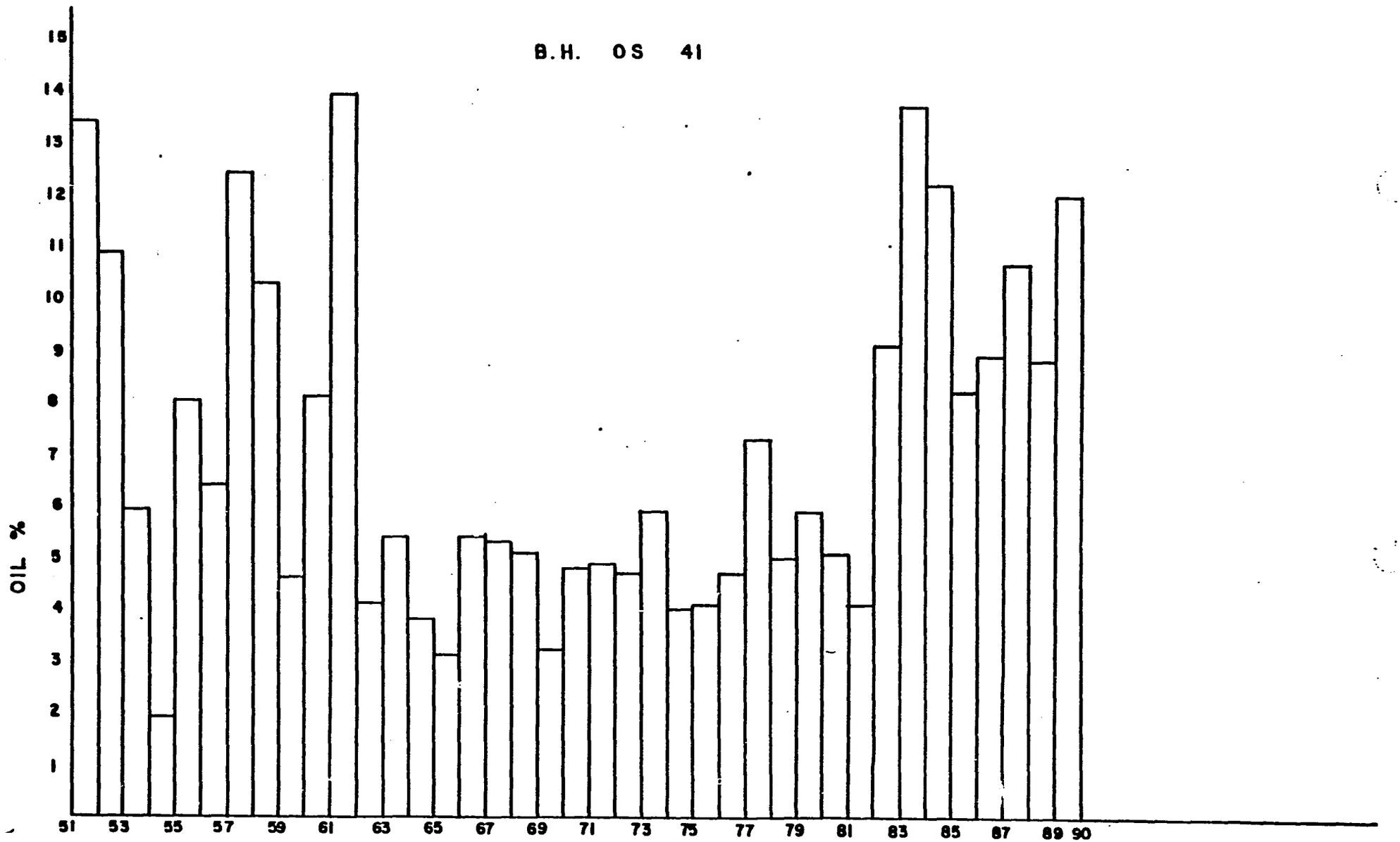
B.H. OS 41
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
51
53
55
57
59
61
63
65
67
69
71
73
75
77
79
81
83
85
87
89
90
DEPTH (m.)

Fig: 31

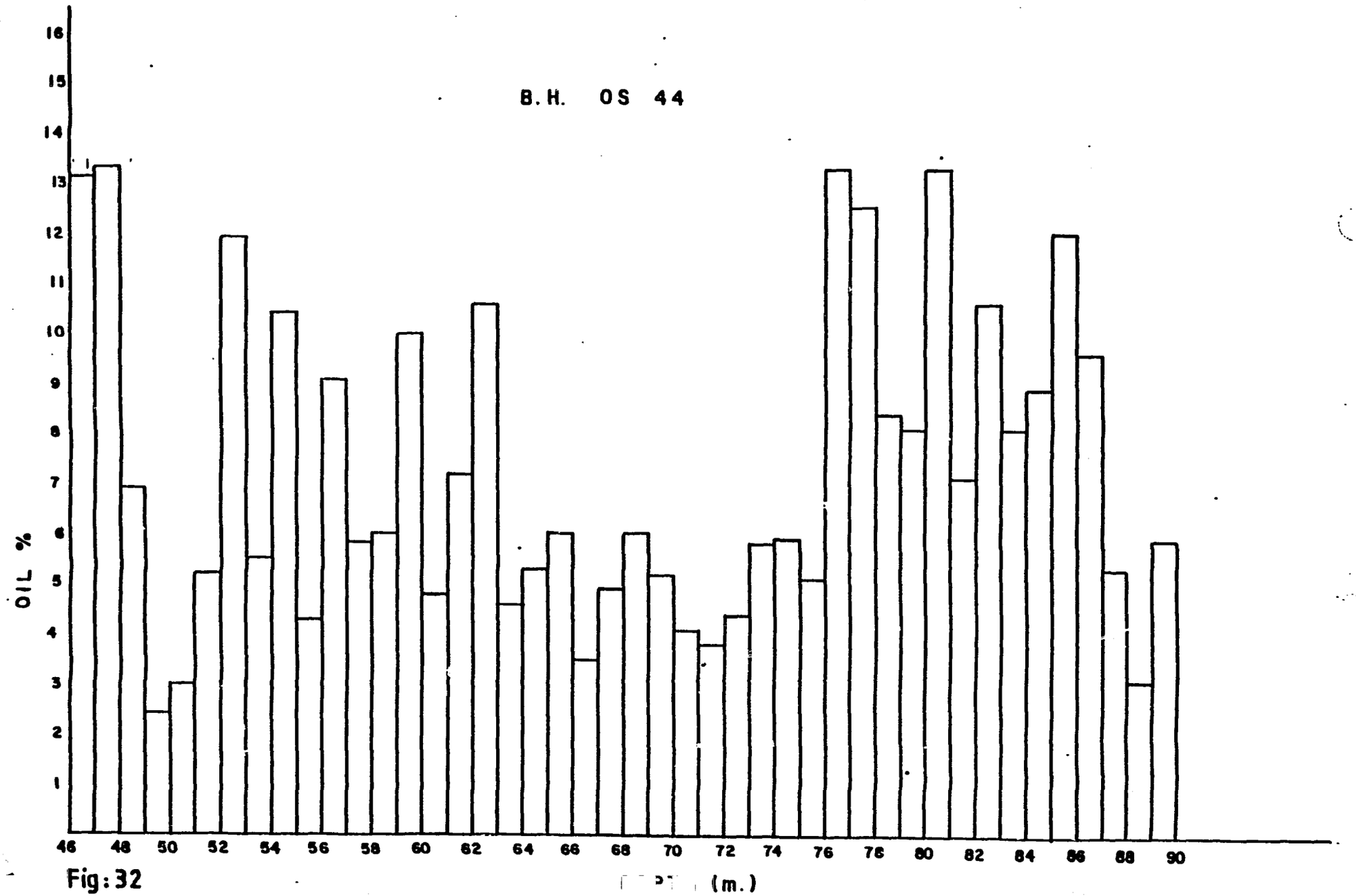
B.H. OS 44
OIL %
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
88
90
(m.)

Fig: 32

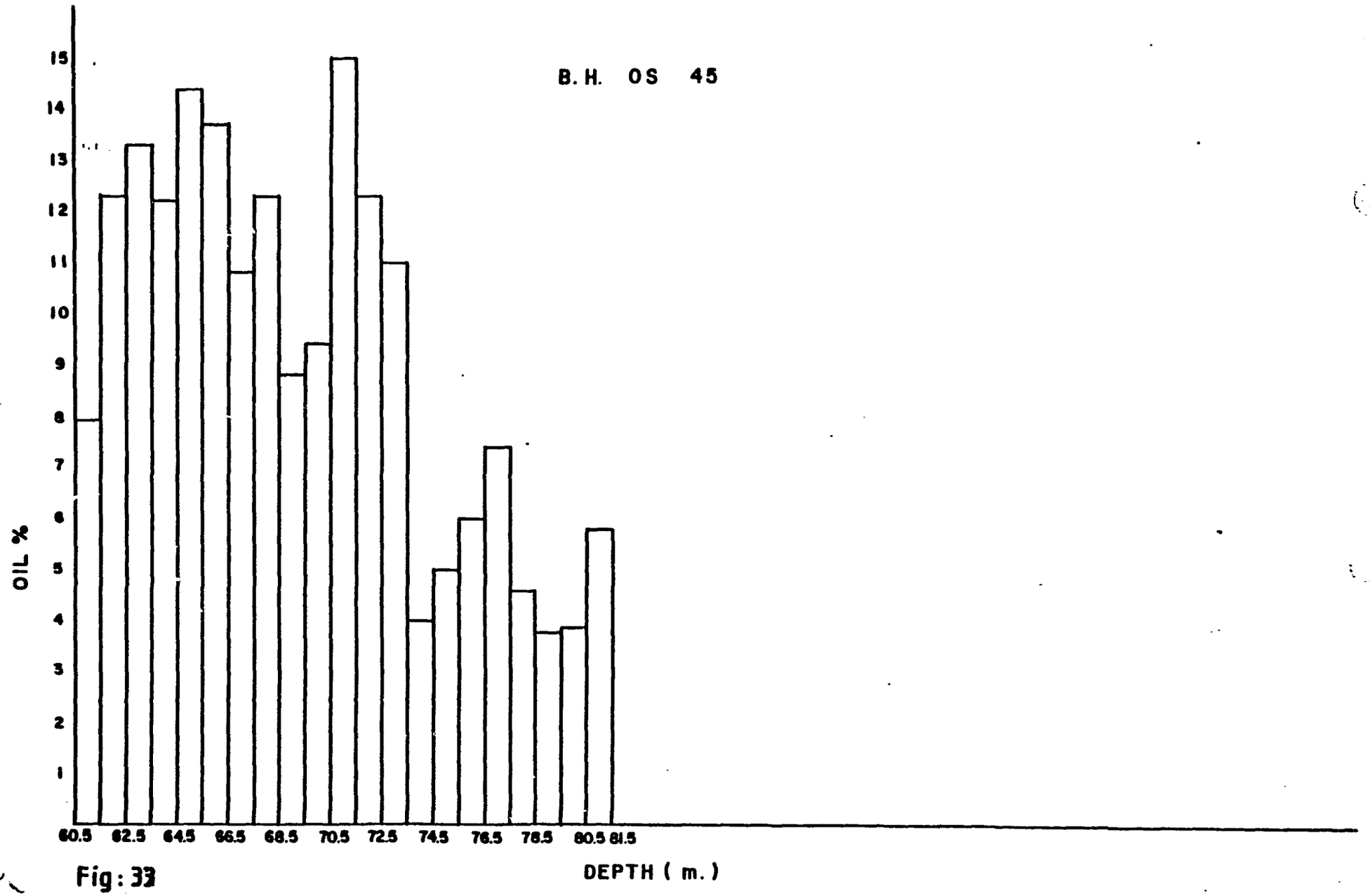
B. H. OS 45
OIL %
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
60.5
62.5
64.5
66.5
68.5
70.5
72.5
74.5
76.5
78.5
80.5
81.5
DEPTH (m.)

Fig: 33

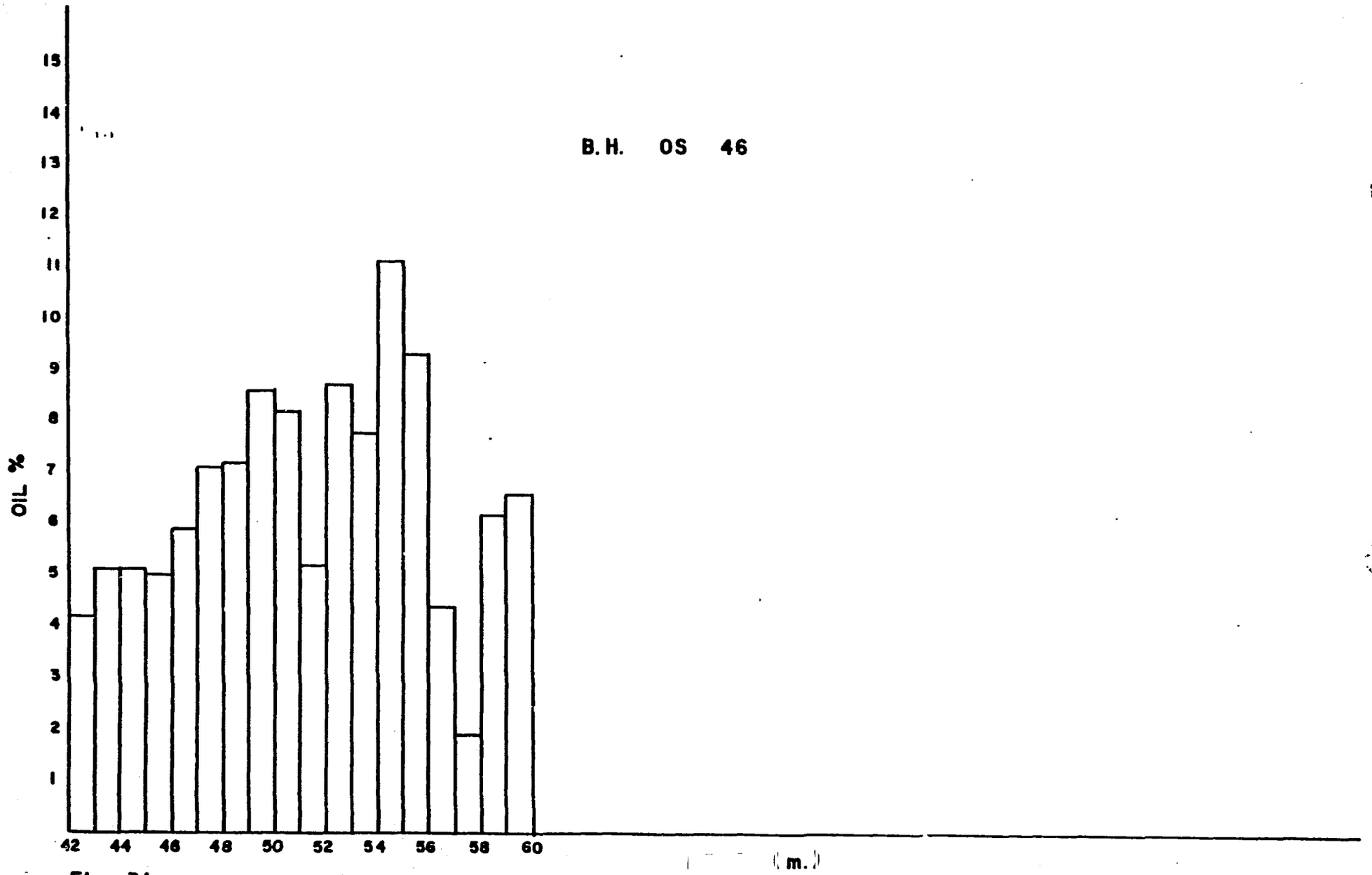
B.H. OS 46
OIL %
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
42
44
46
48
50
52
54
56
58
60
(m.)

Fig. 34

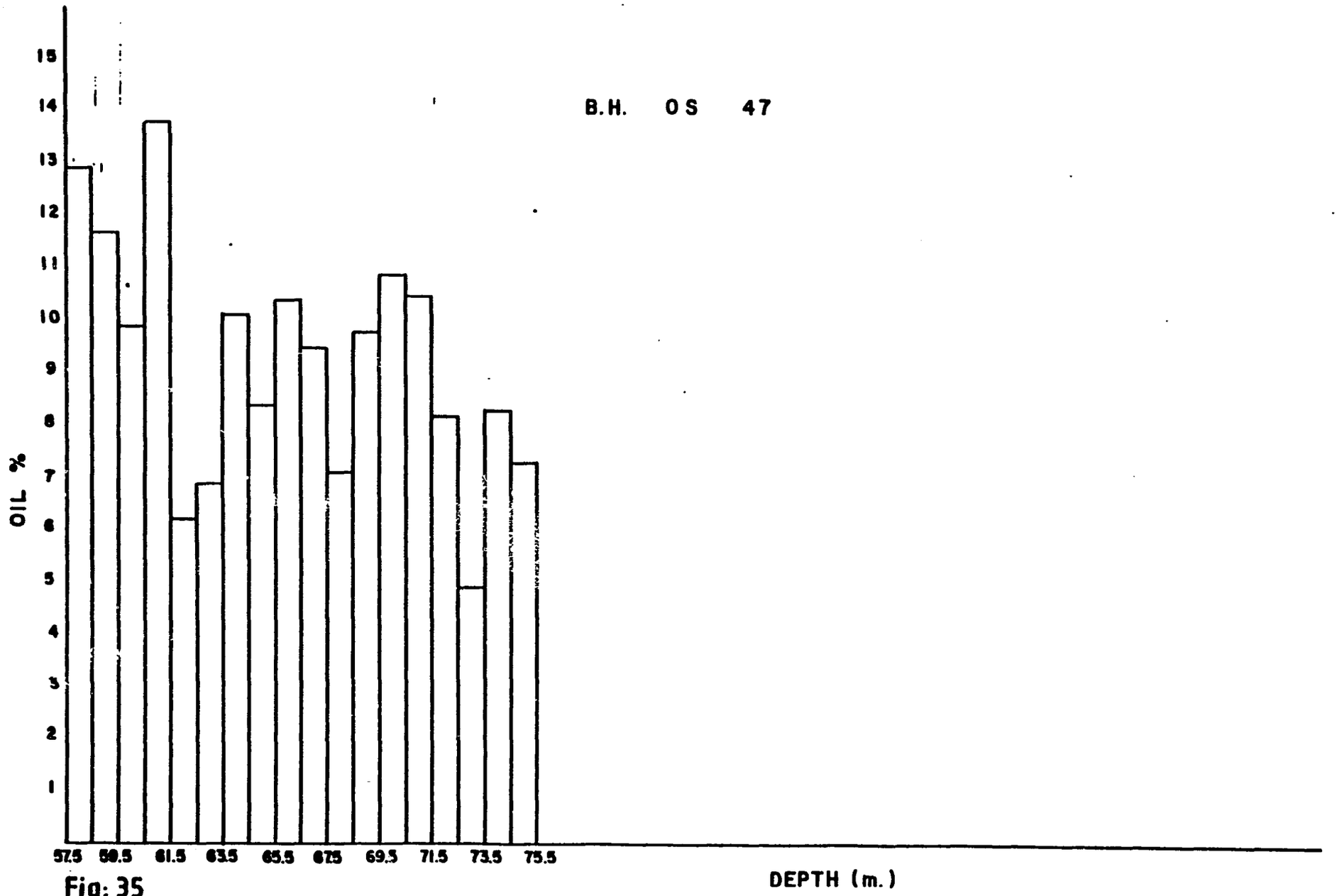
B.H. OS 47
OIL %
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
57.5
59.5
61.5
63.5
65.5
67.5
69.5
71.5
73.5
75.5
DEPTH (m.)

Fig: 35

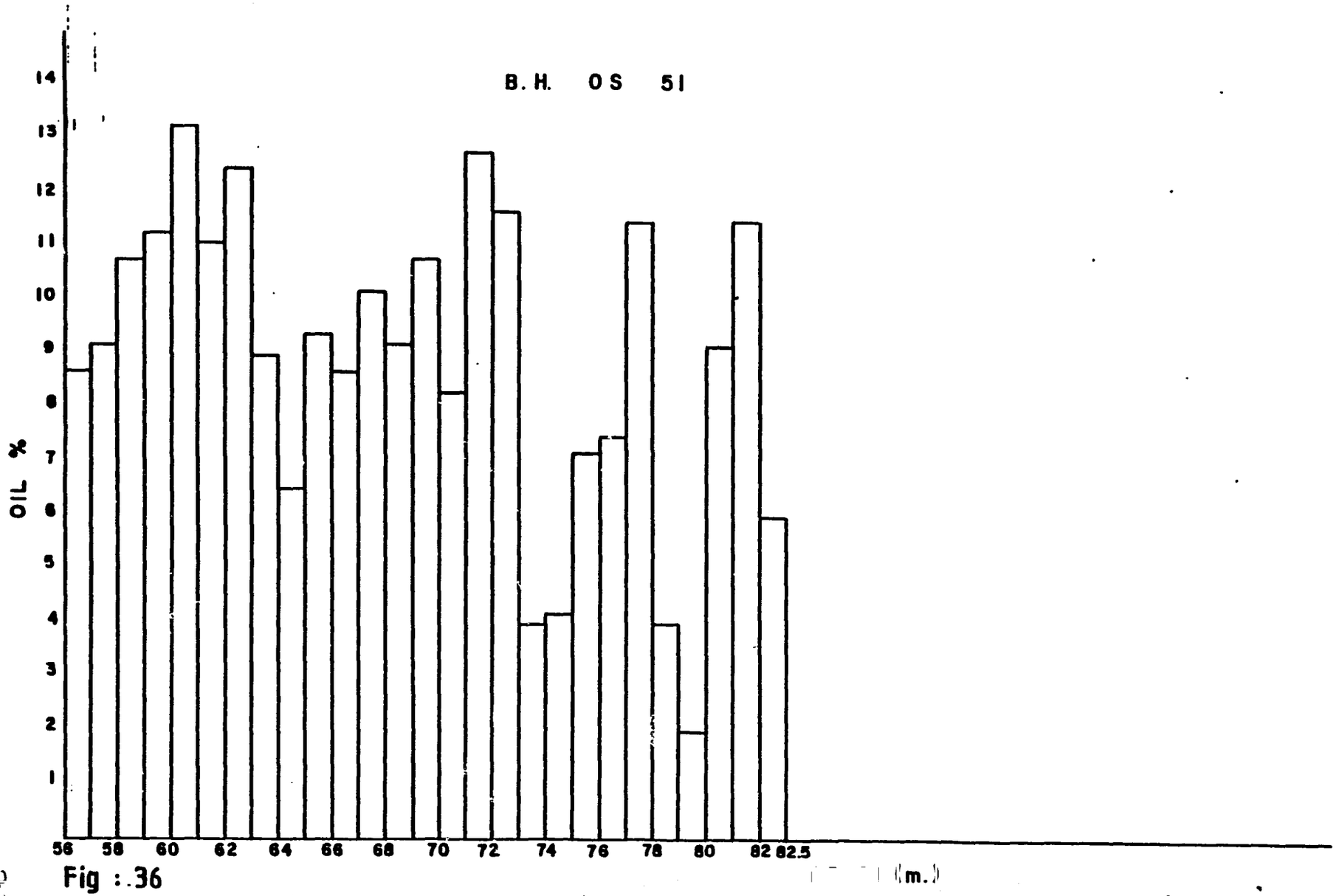
B. H. OS 51
OIL %
14
13
12
11
10
9
8
7
6
5
4
3
2
1
56
58
60
62
64
66
68
70
72
74
76
78
80
82
82.5
(m.)

Fig :.36

Apendix 1

(OS 27 A)

37.5-42.0	Bituminous Marl , grayish to dark brown , laminated .
42.0-46.5	Bituminous Marl , grayish to dark brown , light gray & dark brown thin layers .
46.5-48.5	Bituminous Marl , grayish to dark brown , with traces of fossils & calcite .

(OS 27 B)

34.0-37.0	Bituminous Marl , brown , to brownish gray.
37.0-44.5	Bituminous Marl , gray to brownish gray , with dark brown and light gray thin layers .
44.5-49.0	Bituminous Marl , greyish brown to dark brown .
49.0-50.0	Bituminous Marl , gray to grayish brown , with Phosphate spots .
50.0-53.0	Bituminous Marl , grayish to grayish brown with thin bands of limestone , phosphate , dark brown and light gray , thin layers .

END OF B.H

(OS 28)

57.5-59.5	Bituminous Marl , gray to brownish gray traces of fossils .
59.5-63.5	Bituminous Marl , brownish to dark brown gray with alternating of limestone , gray to white and marly limestone , light gray .

63.5 - 68.25	Bituminous Marl , alternating of brownish gray to dark brownish gray .
68.25-73.5	Bituminous Marl , light gray to light brownish gray with white spots .
73.5 - 75.10	Bituminous Marl , alternating of dark gray to brownish gray .
75.10 -80.0	Bituminous Marl , alternating of dark brownish gray to brownish gray with black shale .
80.0 - 81.0	Bituminous Marl , brownish gray .
81.0 - 83.0	No Samples .
83.0 - 84.5	Bituminous Marl , dark brownish gray to gray, traces of calcite .
84.5 - 85.0	Bituminous Marl , brownish gray to light brown, phosphatic marl .

END OF B.H

(OS 32)

36.0 - 37.5	Bituminous Marl ; greyish brown to dark brown, phosphate spots .
37.5 - 39.0	Bituminous marl ; grayish brown to dark brown , with black shale and grayish band of limestone, calcite content .
39.0 - 42.0	Bituminous marl , grayish brown to dark brown with black shale , phosphate spots.
42.0 - 45.0	Bituminous marl , grayish brown to dark brown with black shale , light gray and dark brown bands .
45.0 - 55.5	Bituminous marl , brownish gray to dark brown .

- 64.0	Bituminous marl , grayish brown with traces of fossils .
- 68.5	Bituminous manl , grayish brown to dark brown .
- 70.0	Bituminous marl , grayish to grayish brown , some phosph..

(OS.33)

0.0 - 16.0	Chalk marl , light brown to creamy .
16.0 - 34.0	Chalk marl , clayey , brownish to creamy , soft .
- 36.0	Chalk marl , brownish to reddish , soft.
- 44.0	Clayey marl , brownish to creamy , chalky , some chert ,Lst.
- 62.0	Chalk marl , white to creamy , with some chert .
- 72.0	Chalk marl , brownish to brownish gray with brownish grey chert and Lst.
- 82.0	Chalk marl , white to light grey with brownish chert , marly Lst.
- 84.0	Marl , brownish grey , Lst.
- 98.0	Chalk marl , creamy to white , Lst .
- 108.0	Marl ; grey , chert ; black and brown , black shale with few Lst .

(OS.34)

0.0 - 2.0	(Gravels), Chert , Lst , Top soil .
2.0 - 10.0	Chalk marl , creamy to light tan ,soft .
10.0 - 39.0	Chalk marl , light brown to reddish , creamy .

39.0	- 52.0	Chalk marl , creamy to white .
52.0	- 60.0	Clayey marl , greyish to brownish .
60.0	- 62.0	Clayey marl , light grey . slightly bit .
62.0	- 69.0	Bituminous marl , brownish to light grey , traces of fossils and calcite white spots of phosphate 100% .
69.0	- 74.0	Bituminous marl , brownish grey to grey , white spots of phosphate, 100%.
74.0	- 74.2	Bituminous marl , brownish grey to grey , black chert at the bottom .
74.2	- 78.2	Chert , black with few brownish grey bit marl .
78.2	- 85.2	Chert , dark brown to black with brownish grey bit marl and greyish limestone .
85.2	- 91.2	Bituminous marl , brownish grey to dark brown , with few black chert phosphatic spots 100% .
91.2	- 94.0	Chert , dark brown to black with brownish gray bit , marl and some greyish limestone .
94.0	- 97.0	Bituminous marl , brownish grey with phosphatic spots 100% .
97.0	- 106.0	Bituminous marl , brownish grey , greyish & brown with few traces of fossils . 100% .
106.0	- 108.8	Bit , marl , grayish brown to brown , grayish chert . 100% .
108.8	- 110.8	Chert , black to dark brown , bituminous marly limestone .
110.8	- 113.8	Phosphatic marl , brown to greyish brown , with greyish chert and some limestone .

(OS 35)

0.0 - 4.0	(Gravels) , chert , brownish soil , Lst., marly Lst.,
4.0 - 11.0	Chalk marl , whitish to creamy , powder.
11.0 -17.0	Chalk marl , yellowish , creamy to white , soft .
17.0 -23.0	Chalk marl , yellowish to light brown .
23.0 -24.0	Chalk marl , whitish to creamy .
24.0 -34.0	Chalk marl , rosy to light brown .
34.0 -53.0	Clayey marl ,light grey , brownish and grey chert with bituminous marl ,
53.0 -58.5	Bituminous marl , brownish grey to grey ,with gray marl and black shale 95% .
58.5 -60.5	Chert , black ; very hard ,Lst., (core+cutting)
60.5 -83.0	Bit marl , light to dark grey , chert;black, very hard and some phosphate spots , traces of calcite (core + cutting) .
83.0 -87.0	Bit marl, brownish to light grey with some phosphatic marl (core + cutting).
87.0 -92.7	Phosphatic marl ; brownish grey , chert ; greyish to brownish .

(OS 36)

0.0 -6.0	Chert , greyish to greyish brown , greyish Lst., soil .
6.0 -26.0	Chalk marl , light brown , with dark brown and grey chert .
26.0 -36.0	Chalk marl , creamy to yellowish , powder .
36.0 -37.0	Chalk marl , light brown to brownish .
37.0 -45.0	Chalk marl , light brown at the top then creamy and yellowish .
45.0 -52.0	Chalk marl , alternations of brownish, creamy and yellowish .
52.0 -53.0	Chalk marl , brownish to reddish , powder .

53.0-77.0	Chalk marl , alternations of creamy ,brownish light brown greyish brown and grey , some chert & Lst.,
77.0-84.0	Clayey marl , brownish grey to light grey with some calcite frag , slightly bitumen at last meter .
84.0-97.2	Bituminous marl , brownish grey to grey and dark grey , some black chert nodules and white spots 100% .
97.0-106.2	Bit marl , bit limestone , alternated , grey to dark grey with bit black chert .
106.2-118.2	Bituminous chert ; black , and bit. marl , bit. Lst., dark grey to grey .
118.2-121.2	Bit. marl , bit.Lst, gray to light grey with some black chert .
121.2-127.7	Bit. marl , grey to brownish grey , white spots 100% .
127.7-128.0	Marly Lst., brownish grey to brown , hard , slightly bitumen .100% .
128.0-139.0	Clayey marl , white to creamy , with some bit marl and Lst. .

(OS 37)

0.0-1.0	(Gravels) chert , Lst., soil .
1.0-4.0	Clayey marl , light brown , chalk, some chert, Lst.
4.0-17.0	Chalk marl , yellowish to creamy , soft .
17.0-19.0	Chalk marl , reddish to brown , soft .
19.0-40.0	Chalk marl , yellowish , grayish and light brown to creamy .
40.0-55.0	Chalk marl , light brown , some chert ; brownish grey .
55.0-64.0	Clayey marl , light brown , some chert ,Lst.
64.0-80.0	Phosphatic marl , light grey to creamy , clayey marl , light brown .
80.0-91.0	Phosphatic marl , grayish to yellowish , phosphatic chert , greyish , Lst. , whitish .

(OS 38)

0.0-1.0	(Gravels) , chert ,Lst., marl , brown soil .
1.0-4.0	Chalk marl , soft , white .
4.0-9.0	Chalk marl , rosy soft .
9.0-30.0	Chalk marl , yellowish to creamy , white .
30.0-43.0	Chalk marl , rosy , light rose to creamy .
43.0-55.0	Chalk marl , light grey , med. hard some black chert at last meter,Bit. marl , brownish gray .
55.0-66.0	Bituminous marl , gray to dark gray and light gray 100% .
66.0-68.0	Bit. marl , gray , bit. phosphate , with some black chert .
68.0-78.0	Chert , black , bituminous marl ; light gray and brownish gray .
78.0-87.6	Bit. marl , brownish gray to dark brown , greyish , traces of calcite , some phosphatic spots .
87.6-89.6	Chert ; dark brown to black with brownish grey bit . marl .
89.6-90.6	Bit. marl , brownish to brownish grey with black chert .
90.6-93.6	Bit. marl , brownish to brownish gray with traces of fossils,phosph. spots 100% .
93.6-103.2	Bit. marl brownish grey with traces of calcite , fossils,phosph. spots,chert 100% .
103.2-108.2	Phosph. marl , gray to brownish grey , chert and phosph .

(OS 39)

0.0-3.0	(Gravels) , chert , white limestone , brownish soil , marl .
3.0-20.0	Chalk marl , white , yellowish to creamy soft.
20.0-21.0	Chalk marl , rose .

21.0-32.0	Chalk marl , light brown , yellowish to creamy.
32.0-52.5	Clayey marl , grey to light grey , chert .
52.5-53.5	Bituminous marl , greyish to greyish brown with light grayish clayey marl and few chert.
53.5-54.20	Bituminous marl , greyish to brownish grey 100% .
54.20-55.0	Bituminous limestone , greyish 100% .
55.0-57.20	Bituminous marl grey to dark with black chert 100% .
57.20-59.20	Chert , dark brown to black with few bit.marl greyish to greyish brown .
59.20-59.70	Bituminous marl , greyish with dark brown to black chert , phosph. spots .
59.70-64.90	Chert , dark brown to black with greyish brown bit .marl .
64.90-70.25	Bituminous marl , greyish to greyish brown , chert and phosph.
70.25-73.25	Chert , black with brownish to greyish brown bit. marl .
73.25-75.25	Bituminous marl ; brownish to greyish brown with black chert 100%.
75.25-85.25	Bituminous marl; greyish to greyish brown 100% .
85.25-89.25	Bituminous marl , greyish to dark brown , chert & phosphate spots.
89.25-90.25	Chert , dark brown to black with grayish to greyish brown bit. marl .
90.25-91.25	Bituminous marl , greyish to brownish grey with black chert .
91.25-92.25	Chert dark brown to black with brownish grey bit. marl .
92.25-93.25	Marly limestone , greyish with dark brown chert .
93.25-94.25	Chert dark brown to black and grayish marly limestone .
94.25-95.25	Bituminous marl brownish to greyish brown with dark brown to black chert .

95.25-97.25	Chert , dark brown to black with greyish marly limestone , greyish bit.marl slightly phosphate .
97.25-98.25	Bituminous marl , with dark brown chert , phosphate .
98.25-99.25	Chert , dark brown to black , with bit.marl and marly limestone , phosph.
99.25-102.25	Phosphatic marl , limestone with black chert .
102.25-103.25	Marl , greyish with black chert , greyish limestone and black shale .
103.25-106.25	Phosphatic marl , greyish , few limestone and chert .

(OS 40)

0.0-3.0	(gravels) ; chert , brownish soil , marl .
3.0-37.0	Chalk marl , white , creamy , brownish to light , soft .
37.0-42.0	Chalk marl ,clayey marl , light grey to pale.
42.0-54.0	Clayey marl , brownish to light brown with traces of fossils .
54.0-55.0	Clayey marl , greyish , bit.marl , brownish to brownish gray
55.0-69.2	Bit.marl , grayish to brown , traces of fossils 100% .
69.0-70.0	Bit.marl light grey with black chert .
70.0-71.0	Bit.marl , grey to dark gray 100% .
71.0-72.0	Bit.marl , grey to light with black chert.
72.0-72.3	Bit marl very dark grey .100% .
72.3-72.3	Bit. marl , grey , black chert .
73.3-73.5	Bit. marl , light to brownish grey 100% .
73.5-77.5	Bit.marl , grey to dark grey with black chert .
77.5-82.0	Bit.marl , dark grey to grey 100% .
82.0-82.5	Bit. limestone very light grey . 100% .
82.5-91.3	Bit. marl , brownish grey to grey . 100% .
91.3-93.3	Black chert dominant , bit.marl brownish grey with brownish marl , some brown chert .

93.3-94.3	Bit.marl , brownish grey to grey , bit. black chert .
94.3-98.0	Bit. limestone , dark grey with bit. marl 100%.
98.0-103.0	Bit. marl dark grey to brownish dark grey 100%.
103.0-105.65	Bit. phosphate , with bit marl , light grey 100%.
105.65-107.65	Bit. phosphatic , bit. marl , grey with some black chert .
107.65-110.65	Phosphatic , slightly bit , grey marl , some chert , white marly limestone .

(OS 41)

0.0-4.0	(gravel) chert , limestone , brown to creamy.
4.0-34.0	Chalk marl , light brown , reddish to creamy.
34.0-50.0	Clayey marl , creamy , brown to light .
50.0-51.0	Bit.marl light grey to brownish grey .
51.0-55.35	Bit.marl grey to dark grey 100% .
55.35-56.00	Bit marl , light grey , phosphatic marl with bit. chert .
56.00-58.0	Bit.marl , dark gray to gray 100% .
58.0-59.3	Bit. marl , brownish gray to gray , phosphatic marl 95% .
59.3-60.8	Bit. marl , gray with bit black chert .
60.8-61.0	Bit. marl dark gray .100% .
61.0-63.5	Marl , slightly bit. , bit . chert .
63.5-63.8	Bit . marl , grey to light gray , black chert , bit. 100% .
63.8-68.8	Bit. chert , black chert , phosphatic marl , slightly bit .
68.8-78.0	Bit.marl , gray to brownish gray , with traces of fossils and at the end dark brown to black chert 100% .
78.0-81.0	Chert dark brown to black with dark brown bit. marl .
81.0-82.0	Bit. marl brownish to dark gray with black chert.
82.0-90.0	Bit. marl brownish to brownish gray with traces of fossils and phosphate spots 95% .
90.0-93.0	Phosphatic marl , yellowish to brownish gray chert, limestone , some calcite (fossils) .

[OS.42]

0.0- 6.0	(Gravel). light brown soil with dark brown chert, limestone silicified limestone, light gray to gray marl.
6- 19.0	Chalk marl, yellowish to light grayish, white to light brown with black chert.
19- 20.0	Light gray to white limestone, marly limestone, dark brown to black chert .
20- 25.0	Chalk marl, light brown with slightly light greyish, limestone concr with some chert.
25- 26.0	Grayish marl with some greyish to brownish chert and limestone.
26- 38.0	Chalk marl light brownish, light greyish limestone, dark brownish to pinkish, chert, limestone.
38- 39.0	Clayey marl, brownish with few dark brown chert.
39- 56.0	Marl, grayish with limestone, dark brown chert.
56- 65.0	Limestone, greyish to light greyish, chert.
65- 72.0	Chalk marl, white to creamy.
72- 80.0	Chalk marl, yellowish to light tan. Phosphatic chert, yellowish to light grey.
80- 96.0	Chert, brownish to light grey, white marly limestone.

[OS.43]

0.0- 4.0	(Gravel); brownish to greyish chert, limestone and soil.
4- 7.0	Marl, light grey with chert and limestone.
7- 60.0	Chalk marl, brownish to pinkish, whitish to yellowish, creamy marly limestone, chert concr.

60- 73.0 Marl, light gray to grey, dark brown chert, limestone, clayey.

73- 77.0 Chalk marl, light grey to creamy with few grey chert.

77- 96.0 Clayey marl, grayish to light brown with yellowish brown marl plastic.

96-100.0 Clayey marl, yellowish brown, grey and tan with Iron content and calcite.

[OS.44]

0.0- 4.0 (Gravel), brownish to greyish limestone, chert, marl, soil.

4- 17.0 Chalk marl; soft whitish to yellowish, few chert, limestone and marly limestone.

17- 37.0 Marly limestone, light grey to grey with few chert and limestone concr. some what bit.

37- 44.0 Marl, greyish, brownish, some what bit. smell.

44- 46.0 Bit. marl, grey to dark grey.

46- 50.0 Bit. marl, dark grey. 100%.

50- 51.28 Bit. marl, dark grey with few phosphate. 100%.

51.28- 51.46 Bit. limestone, greyish slightly phosphate. 100%.

51.46- 54.50 Bit. marl greyish to greyish brown, grey to dark grey. 100%.

54.50- 56.0 Bit. marl, greyish to dark greyish with black chert.

56.0 - 58.5 Bit. marl, brownish grey to dark, white spots of phosph;band of lst. 100%.

58.5 - 65.5 Bit. marl, light to dark grey, limestone black chert is dominant.

56.5 - 76.5 Bit. marl, brownish to dark grey, light to dark grey, traces of calcite. 100%.

76.5 - 79.5 Bit. marl, brownish to light grey.

79.5 - 85.5 Bit. marl, brownish to dark grey, band of limestone. 97.5 %.

85.5 - 87.0 bit.marl dark grey, white, spots of phosph. 100%.

87.0 - 90.0 Phosphatic marl, slightly bit. yellowish to greyish, limestone, some balck chert. 95%.

[OS.45]

00 - 4.00 (Gravels), chert, brownish soil, some white chalk.

4.00 - 37.00 Chalk marl, whitish to yellowish. creamy, light brown.

37.00 - 60.5 Chalk marl, pinkish to yellowish, brown, phosphatic chert, chert, slightly bit.

60.5 - 69.5 Bit. marl, dark grey, traces of calcite. 100%.

96.5 - 78.0 Bit. marl, brownishgrey to darkgrey and light grey, some phosphatic marl. 100%.

78.0 - 81.5 Phosphatic marl, silghtly bit, chert, (Phosphorite Unit).

[OS.46]

0.0 - 4 Chert, grey, brownish Lst and silt stone (gravels).

4 - 12.0 Marl; gray and brownish, with white Lst, chert.

1[illegible].0 - 17.0 Chalk marl, white and light brown.

1[illegible].0 - 23.0 Chalk marl , white,soft, chert grey to light grey.

2[illegible].0 - 33.0 Chalk marl, grey, light grey chert.

3[illegible].0 - 39 Marl, white, dark to light grey chert.

39 - 41.0 Lst; brownish, grey marl, dark grey chert.

- 42 Marl; slightly bitnminous, some chert.

4[illegible].0 - 45.0 Bit. marl; brownish grey, light grey and dark grey, traces of calcite, 80cm band of bit. Lst.

45.0 - 50.5 Bit. marl; alternating of light to dark grey, some white spots of calcite.

50.5	- 51.5	Bit. marl; light to dark grey, some chert.
51.5	- 57.3	Bit. marl; brownish to dark grey.
57.3	- 60.0	Phosphatic marl; slightly bit. some black chert.

[OS.47]

0.0	- 2.0	(Gravels) ; chert, brownish to dark grey, limestone, chalk marl creamy.
2.0	- 10.0	Chalk marl yellowish to reddish, some chert.
10.0	- 50.0	Chalk marl white to reddish, creamy to light tan.
50.0	- 52.0	Chert black, limestone, chalk marl.
52.0	- 57.0	Chalk marl creamy light tan, limestone, some chert.
57.0	- 57.5	Bit. marl light greyish.
57.5	- 71.0	Bit. marl brownish to dark grey, lightgrey. 95%.
71.0	- 72.5	Bit. marl brownish to dark grey, white spots of phosphate. 95%.
72.5	- 75.5	Phosphatic marl, bit, limestone, some black chert. 90%.

[OS.48]

0.0	- 1.0	(Gravels), soil, brown chert, limestone.
1.0	- 35.0	chalk marl, creamy, white to yellowish.
35.0	- 47.0	Marl, clayey marl, greyish to light brown, chalk marl.
47.0	- 50.0	Chalk marl creamy to white.
50.0	- 58.0	Chalk marl light tan with some limestone and dark brown chert.
58.0	- 65.0	Chalk marl, brownish grey to grey with some brownish marl.
65.0	- 72.0	Clayey marl, light grey to grey, some limestone, traces of brownish chert.

[OS.49]

0.0	- 2.0	(Gravel) soil, brown chert, white limeston, marl.
2.0	- 9.0	Chalk marl, light to creamy with dark grey chert.
9.0	- 19	Chalk marl, yellowish to creamy powder.
19	- 49	Chalk marl, light, creamy to yellowish.
49	- 51.0	Chalk marl, rosy, soft.
51.0	- 55.0	Chalk marl, white to creamy. Soft.
55.0	- 70.0	Chalk marl, rosy, yellowish to creamy.
70.0.	- 81.0	Chalk marl, yellowish to creamy, powder.
81.0	- 86.0	Clayey marl, greyish brown, marly lst, chert dark brown with some phosphatic chert. 100%.
86.0	- 90.5	Bituminous marl, light to greyish brown. 100%.
90.5	- 93.5	Bituminous marl greyish brown, traces of calcite. 100%.
93.5	- 97.5	Bituminous, greyish brown to dark brownish grey. 95%.
97.5	-103.5	Bituminous,marl limestone, grey to light grey, with black chert. 100%.
103.5	-115.5	Bituminous,marl dark to brown grey with black chert.
115.5	-118.5	Bituminous,marl dark to brownish, marl; creamy to white.
118.5	-122.5	Bit. marl brownish to dark brown, marl; creamy to white with black chert.
122.5	-125.5	Bit. marl, brown to light, Bit. marl; creamy to yellowish traces of gypsum.
125.0	-129.0	Bit. marl; grey to light brownish grey. 100%.
129.0	-131.0	Bit. Limestone; grey. 100%.
131.0	-132.5	Bit. Marl brownish grey to grey, with white spots of marly limestone. 100%.
132.5	-134.5	Phosphatic marl, slightly bit. marl; brown, marl; yellowish to white. 100%.

[OS.50]

0.0 - 1.0	Gravel; Chert, clay, soil, light brown.
1.0 - 3.0	Chalk marl, some chert, limestone light brown to creamy.
3.0 - 4.0	Chalk marl, brownish to reddish.
4.0 - 6.0	Clayey marl, some chert, light brown.
6.0 - 28.0	Chalk marl, white to creamy, greyish to whitish.
28.0 - 52.0	Clayey marl reddish to brownish with greyish to light and chalk; reddish to brown.
52.0 - 59.0	Clayey marl, dark tan to brown, some chert.
59.0 - 67.0	Clayey marl, creamy; light tan to creamy, light to dark green.
67.0 - 85.0	Chalk marl, white, to creamy, traces of calcite.
85.0 - 88.0	Marly limestone brownish grey to light tan.
88.0 - 90.0	Limestone, chalky white and marly limestone brownish grey to grey. Marly limestone brownish grey to grey, marl with some white limestone.

[OS.51]

0.0 - 4.0	Chert, brownish grey to grey limestone, light grey to light brown soil (Gravel).
4.0 - 6.0	Chalk marl; greyish to light brown with brownish to brownish grey chert and limestone.
6.0 - 45.0	Chalk marl; brownish, yellowish to creamy bowder, some chert at the end.
45.0 - 52.0	Clayey marl; yellowish to light brown.
52.0 - 55.0	Chalk marl with chert. limestone.
55.0 - 56.0	Clayey marl, slightly bitumen, light grey.
56.0 - 75.5	Bitumineous marl, brownish to dark grey. 100%.

75.0 - 78.5	Bitumineous marl, light to dark grey with phosphatic marl and some chert. 100%.
78.5 - 80.5	Phosphatic marl, slightly bit, chert and limestone.
80.5 - 82.7	Bitumineous marl, light to dark grey, some phosphatic marl. 95%.
82.7 -100.7	Phosphatic marl, chert, limestone, slightly bit.

[OS.52]

0.0 - 2.0	(Gravel) chert, brownish grey, limestone, soil.
2.0 - 28.0	Chalk marl, brownish to light brown, creamy to light with chert.
28.0 - 32.0	Chalk marl, brownish to rosy brown with brownish grey chert.
32.0 - 43.0	Chalk marl, greyish, creamy to light with some brownish grey chert. Sometimes creamy to yellowish brown.
43.0 - 48.0	Chert, light greyish to brownish grey limestone , hard chalk marl.
48.0 - 65.0	Chalk marl, greyish to light, yellowish with brownish to brownish grey chert and limestone.
65.0 - 68.0	Marl, greyish with greyish to brownish grey chert and limestone.
68.0 -103.0	Chalk marl, yellowish brown, creamy, white to light grey with chert and Lst.
103.0 -110	Marl, greyish to light brown with brownish to light grey chert and limestone with phosphat.

[OS.53]

0.0 - 2.0	(Gravel); chert, greyish to light greyish limestone, soil.
2.0 - 20.0	Chalk marl, light brown to creamy with dark brown chert.

20.0 - 35.0	Chalk marl, brownish to greyish brown, chert and limestone.
35.0 - 37.0	Marl, brownish to brownish grey with few chert and limestone.
37.0 - 61.0	Chalk marl, brownish to greyish, creamy to light with chert and limestone.
61.0 - 62.0	Bitumineous marl; greyish to light brownish grey with limestone and few chert.
62.0 - 85.0	Chalk marl, white , yellowish , soft.
85.0 - 97.0	Chalk marl, brownish grey to light grey with some balck chert and Lst.
97.0 - 99.0	Marl, brownish grey, slightly bituminous.
99.0 -101.0	Marl, light grey limestone with brownish grey chert.
101.0 -105.0	Limestone, whitish to light grey , chert brownish and greyish.

Sultani Oil Shale Deposit

B. H. No 03 - 27 A

Apendix 2

Item	Depth (m)	Moisture %	$CaCo_3$ %	Carbon Total %	Sulphur Total %	Inorg. S %	Organic S %	Oil %
1	37.5-38.5	1.4	21.22	10.07	2.64	2.55	7.52	6.24
2	38.5-39.5	1.3	13.92	9.81	3.22	1.67	8.14	6.76
3	39.5-40.5	1.2	14.94	10.71	3.75	1.79	8.92	7.40
4	40.5-41.5	1.3	14.44	8.93	2.97	1.73	7.20	5.98
5	41.5-42.5	1.3	14.04	9.71	3.11	1.68	8.03	6.66
6	42.5-43.5	1.3	14.13	10.89	3.90	1.69	9.20	7.64
7	43.5-44.5	0.8	15.01	10.12	3.85	1.80	8.32	6.90
8	44.5-45.5	0.9	19.23	12.71	5.62	2.31	10.40	8.63
9	45.5-46.5	0.8	14.50	13.41	4.82	1.74	11.67	9.69
10	46.5-47.5	0.5	40.97	18.51	3.80	4.92	13.59	11.28
11	47.5-48.5	0.6	37.68	15.64	3.07	4.52	11.12	9.23

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Apendix 2

Sultani Oilshale Deposit

P. H. N. OS - 27 B

Item	Depth (m)	Moisture %	$CaCO_3$ %	Total Carbon %	Total Sulphur %	Inorg. C %	Org. C %	Oil %
1	34-35	1.3	30.90	11.47	2.33	3.71	7.76	6.44
2	35-36	1.4	17.89	12.13	5.16	2.15	9.98	8.28
3	36-37	1.9	41.72	10.91	2.28	5.01	5.90	4.89
4	37-38	1.8	38.68	12.09	2.17	4.64	7.45	6.18
5	38-39	1.7	15.80	11.26	4.83	1.92	9.34	7.75
6	39-40	2.0	20.86	12.15	5.32	2.50	9.65	8.01
7	40-41	1.6	15.10	10.54	3.41	1.81	8.73	7.24
8	41-42	2.1	19.58	9.42	3.71	2.35	7.07	5.87
9	42-43	2.1	16.48	9.37	2.59	1.97	7.40	6.14
10	43-44	2.3	13.19	10.54	3.58	1.58	9.06	7.52
11	44-45	1.3	32.78	19.17	4.93	3.93	15.24	12.65
12	45-46	1.7	32.46	16.24	4.35	3.89	12.35	10.25
13	46-47	1.4	37.04	17.74	4.16	4.52	13.22	10.97
14	47-48	1.3	38.61	15.56	4.01	4.63	10.93	9.07
15	48-49	1.4	45.62	18.25	4.85	5.47	12.78	10.61
16	49-50	0.8	45.74	12.12	2.35	5.49	6.63	5.50
17	50-51	0.6	50.55	9.67	1.69	6.07	3.60	2.99
18	51-52	0.9	51.05	11.73	2.33	6.13	5.60	4.65
19	52-53	0.6	25.20	11.85	2.08	3.02	8.83	7.33

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Sultani Oilshale Deposit

B. H. No OS - 28

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inog %	C Org %	Oil %
1	57.5-58.5	2.0	48.02	12.31	1.05	5.76	6.55	5.9
2	58.5-59.5	1.3	50.07	14.60	1.27	6.01	8.59	7.0
3	59.5-60.5	1.6	63.38	9.07	0.36	7.61	1.46	1.2
4	60.5-61.5	0.3	79.74	11.91	0.38	9.57	2.34	1.8
5	61.5-62.5	0.8	59.87	18.54	1.98	7.18	8.36	8.3
6	62.5-63.5	1.1	56.81	15.95	1.06	6.82	9.13	7.5
7	63.5-66	1.2	44.21	19.70	2.85	5.31	14.39	11.8
8	66-67	1.3	49.46	16.12	2.06	5.94	10.18	8.4
9	67-68	0.9	48.86	18.18	2.37	5.86	12.32	10.1
10	68-69	0.8	60.52	16.83	1.78	7.26	9.57	7.8
11	69-70	1.0	67.66	15.02	1.34	8.12	6.90	5.5
12	70-71	0.6	57.67	18.44	2.25	6.92	11.52	9.4
13	71-72	0.8	52.54	16.72	1.96	7.14	9.58	7.9
14	72-73	0.9	47.46	19.60	2.93	5.70	13.90	11.4
15	73-74	0.9	48.15	18.90	2.68	5.06	13.84	11.4

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Sultani Oilshale Deposit

B . H. No OS - 28

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
16	74-75	1.3	54.29	15.80	1.87	6.51	9.29	7.5
17	75-76	0.4	74.26	11.48	0.68	8.91	2.57	2.1
18	76-77	0.5	68.64	11.85	0.89	8.24	3.61	2.9
19	77-78	0.7	69.74	11.76	0.90	8.37	3.39	2.7
20	78-79	1.3	57.88	13.28	1.55	6.95	6.33	5.1
21	79-80	0.7	35.99	10.32	3.28	4.32	14.00	11.5
22	80-81	0.6	46.79	12.64	1.46	5.61	7.03	5.3
23	83-84	0.6	33.80	17.36	2.90	4.06	13.30	10.9
24	84-86	0.4	62.75	10.94	1.10	7.53	3.41	2.7

Sultani Oil[illegible] Do oil

B. H. No 08 - 32

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
1	36-37	1.2	42.23	16.34	3.61	5.07	11.27	9.2
2	37-38	0.5	16.71	8.53	1.75	2.00	6.53	5.5
3	38-39	1.1	57.24	12.38	2.18	6.87	5.51	4.5
4	39-40	0.6	37.67	18.90	5.44	4.52	14.38	11.8
5	40-41	0.9	49.25	15.04	3.10	5.91	9.13	7.5
6	41-42	0.7	46.47	12.65	3.00	5.57	7.08	5.8
7	42-43	0.7	35.45	9.00	2.33	4.25	4.75	3.9
8	43-44	0.7	54.59	15.89	3.89	6.55	9.34	7.6
9	44-45	0.5	41.67	13.31	2.11	5.00	8.31	6.8
10	45-46	0.6	60.05	18.64	4.60	7.21	11.43	9.3
11	46-47	0.7	31.41	12.3	3.0	3.77	8.53	7.0
12	47-48	1.0	33.22	17.09	4.20	3.98	13.11	10.8
13	48-49	1.4	38.15	16.87	4.52	4.57	12.3	10.1
14	49-50	0.7	42.87	19.46	5.01	5.14	14.32	11.8
15	50-51	2.0	23.58	17.54	5.45	2.83	14.71	12.1
16	51-52	2.7	21.74	14.11	4.71	2.61	11.5	9.4
17	52-53	2.4	32.32	11.45	3.23	3.88	7.57	6.2
18	53-54	3.4	22.53	11.56	4.13	2.70	8.86	7.3

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Sultani Oil Shale Deposit

B. H. No 08 - 32

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
19	54-55	1.9	21.07	10.8	3.84	2.53	8.27	6.8
20	55-56	3.5	21.19	10.3	3.49	2.53	7.77	6.4
21	56-57	4.7	15.54	9.98	3.91	1.87	8.11	6.6
22	57-58	4.5	14.16	9.91	3.96	1.70	8.21	6.7
23	58-59	3.2	18.37	10.34	3.92	2.20	8.14	6.6
24	59-60	3.7	17.24	10.14	3.73	2.07	8.07	6.6
25	60-61	2.7	17.80	8.93	3.59	2.13	6.80	5.6
26	61-62	2.3	23.36	8.76	3.48	2.80	5.96	4.9
27	62-63	1.4	28.24	10.2	3.59	3.38	6.82	5.6
28	63-64	1.4	23.75	10.77	3.77	2.85	7.92	6.5
29	64-65	0.7	31.50	19.33	5.45	3.78	15.55	12.8
30	65-66	1.0	35.91	19.91	5.66	4.31	15.60	12.8
31	66-67	1.3	33.64	17.61	5.74	4.04	13.57	11.2
32	67-68	1.0	37.58	14.79	4.22	4.51	10.28	8.4
33	68-69	0.6	45.81	13.45	3.61	5.49	7.96	6.5
38	69-70	1.2	49.72	10.56	2.24	5.97	4.59	3.1

Sultani Oilshale Deposit

B. H. No OS - 34

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total C. %	Total S.%	Incrg. C.%	Org. C.%	Oil %
1	62-63	1.23	47.41	20.61	2.87	5.6	15.01	12.3
2	63-64	1.92	54.1	16.59	1.78	6.4	10.19	8.3
3	64-65	1.89	46.6	18.08	2.21	5.6	12.48	10.8
4	65-66	3.19	56.5	17.86	1.75	6.7	11.16	9.1
5	66-67	2.77	59.4	15.9	1.63	7.1	8.8	7.2
6	67-68	2.48	51.2	18.96	2.53	6.1	12.86	10.6
7	68-69	1.48	45.6	20.46	2.53	5.4	15.06	12.4
8	69-70	2.58	44.5	16.42	2.1	5.3	11.12	9.1
9	70-71	2.0	65.41	17.93	2.42	7.8	10.13	8.3
10	71-72	1.26	32.76	24.04	4.29	3.9	20.14	16.6
11	72-73	1.2	56.17	13.53	1.52	6.7	8.83	7.2
12	73-74	1.76	59.33	17.20	2.17	7.12	10.08	8.3
13	74-75	0.33	59.37	13.40	1.33	7.12	6.28	5.1
14	75-76	0.4	29.45	7.2	0.51	3.53	3.67	3.0
15	76-77	0.45	29.66	7.83	0.81	3.56	4.27	3.5
16	77-78	0.48	37.71	10.04	0.89	4.52	5.52	4.5
17	78-79	1.06	55.82	12.93	1.41	6.70	6.23	5.1
18	79-80	0.9	63.66	13.49	1.56	7.64	5.85	4.8
19	80-81	0.57	48.66	10.32	0.98	5.84	4.48	3.6
20	81-82	0.56	53.79	12.01	1.09	6.45	5.55	4.6
21	82-83	0.83	56.6	15.99	1.64	6.70	9.29	6.0
22	83-84	0.72	48.05	12.9	1.21	5.7	7.2	5.9
23	84-85	3.24	41.85	8.81	0.63	5.02	3.79	3.1
24	85-86	4.15	21.4	9.49	1.92	2.5	6.99	5.7
25	86-87	4.85	22.04	9.52	1.53	2.6	6.92	5.6
26	87-88	1.35	21.28	9.23	1.67	2.5	6.73	5.5
27	88-89	1.99	23.4	10.11	1.54	2.8	7.31	6.0
28	89-90	1.83	40.6	13.45	1.61	4.8	8.65	7.1

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Sultani Oilshale Deposit

B. H. No OS - 34

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total C. %	Total S.%	Inorg. C.%	Org. C.%	
29	90-91	1.31	20.4	9.73	1.69	2.4	7.33	
30	91-92	1.04	26.0	10.57	1.39	3.1	7.47	
31	92-93	0.79	24.4	8.85	1.16	2.9	5.95	
32	93-94	0.96	35.2	14.67	1.76	4.2	10.47	
33	94-95	1.07	34	17.37	2.52	4.1	13.27	1
34	95-96	1.09	44.32	17.92	2.77	5.32	12.6	1
35	96-97	1.28	44.24	19.88	3.15	5.31	14.57	1
36	97-98	1.83	30.21	17.29	3.72	3.62	13.67	11
37	98-99	1.88	26.70	4.46	0.75	3.20	1.26	
38	99-100	0.5	87.80	11.88	0.28	9.81	2.08	1
39	100-101	2.4	35.44	13.19	2.28	4.25	8.94	
40	101-102	2.29	28.86	16.23	2.03	3.46	12.77	1
41	102-103	1.15	42.61	16.07	2.87	5.11	10.96	
42	103-104	1.67	36.87	17.93	2.66	4.42	13.51	1
43	104-105	1.55	47.47	20.13	2.96	5.70	14.43	11
44	105-106	0.88	52.18	14.53	2.15	6.26	8.27	
45	106-107	1.58	42.58	12.71	1.42	5.11	7.60	6
46	107-108.8	4.01	53.41	12.07	1.25	6.41	5.66	
				average	1.85		8.99	

Sultani Oilshale Deposit

B. H. No OS - 34

Serial No.	Depth (m)	P_2O_5%
1	108.8 - 109.8	8.0
2	109.8 - 110.8	5.5
3	110.8 - 111.8	8.75
4	111.8 - 112.8	11.5
5	112.8 - 113.8	9.0

Sultani Oilshale Deposit

B. H. No OS - 35

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
1	53-54	2.68	42.45	19.92	3.52	5.09	14.83	12.2
2	54-55	2.93	67.34	12.46	0.76	8.08	4.38	3.6
3	55-56	3.88	60.33	12.26	0.86	7.24	5.02	4.0
4	56-57	4.32	42.96	19.29	2.28	5.15	14.14	11.6
5	57-58	3.26	59.03	18.88	1.91	7.08	11.8	9.7
6	58-59	6.15	58.87	14.73	1.23	7.06	7.67	6.3
7	59-60	0.71	23.68	9.57	1.12	2.84	6.73	5.5
8	60-61	1.51	41.88	16.12	2.32	5.02	11.10	9.1
9	61-62	1.11	44.08	15.82	1.89	5.29	10.53	8.6
10	62-63	1.18	33.86	11.76	1.26	3.99	7.77	6.8
11	63-64	3.72	47.89	13.65	1.54	5.75	7.90	6.5
12	64-65	1.83	32.59	14.82	1.64	3.91	10.91	8.9
13	65-66	9.17	13.70	8.328	1.67	1.64	6.69	5.5
14	66-67	7.8	22.74	10.28	1.47	2.73	7.50	6.1
15	67-68	5.84	17.33	8.74	1.31	2.08	6.66	5.5
16	68-69	2.69	29.53	15.21	1.86	3.54	11.67	9.6

Sultani Oilshale Deposit

B. H. No OS - 35

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
17	69-70	9.79	15.68	9.05	1.25	1.88	7.17	5.9
18	70-71	3.25	21.80	9.73	0.87	2.62	7.11	5.8
19	71-72	0.94	17.99	9.68	1.17	2.16	7.52	6.1
20	72-73	0.91	23.71	10.17	1.15	2.84	7.33	6.0
21	73-74	0.88	22.47	8.99	0.95	2.69	6.30	5.1
22	74-75	1.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
23	75-76	4.88	42.82	15.5	1.28	5.14	10.36	8.5
24	76-77	2.08	31.82	20.24	2.74	3.82	16.42	13.5
25	77-78	2.04	29.75	18.58	2.88	3.57	15.02	12.3
26	78-79	2.00	19.55	17.02	2.38	2.35	14.67	12.1
27	79-80	2.36	23.58	14.32	2.02	2.83	11.49	9.4
28	80-81	0.94	23.29	11.72	1.20	2.79	8.93	7.3
29	81-82	1.08	21.66	11.19	1.36	2.59	8.60	7.0
30	82-83	2.66	28.51	15.78	1.88	3.42	12.36	10.2
31	83-84	1.28	24.39	11.73	1.33	2.92	8.81	7.2
32	84-85	1.22	26.18	11.86	1.36	3.14	8.72	7.1
33	85-86	1.14	24.32	10.98	1.18	2.92	8.06	6.6
34	86-87	3.89	47.27	18.71	2.20	5.67	13.04	10.7

Sultani Oilshale Deposit
B. H. No OS - 35

S. No.	P_2O_5
B H-OS.35	
87-88	11.50
88-89	11.25
89-90	7.25
90-91	11.00
91-92	9.75
92-92.5	6.25

Sultani Oilshale Deposit

D. H. No 05 - 36

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
1	84-85	3.0	39.44	20.03	3.73	4.73	15.3	12.5
2	85-86	2.2	45.64	19.51	2.70	5.48	14.03	11.5
3	86-87	2.8	51.58	16.54	2.01	6.19	10.35	8.5
4	87-88	4.1	57.00	15.44	1.39	6.84	8.6	7.0
5	88-89	4.5	75.23	12.33	0.69	9.03	3.3	2.6
6	89-90	3.2	60.30	16.44	1.96	7.24	9.2	7.5
7	90-91	8.6	43.38	13.39	1.70	5.21	8.18	6.7
8	91-92	5.2	42.88	13.19	1.76	5.51	8.04	6.5
9	92-93	3.6	31.31	15.98	3.10	3.76	12.22	10.0
10	93-94	4.8	30.49	15.28	2.40	3.66	11.62	9.50
11	94-95	1.4	29.37	18.91	4.36	3.52	15.39	12.6
12	95-96	1.1	57.76	17.13	2.20	6.93	10.2	8.3
13	96-97	2.1	63.26	15.24	1.73	7.59	7.65	7.0
14	97-98	6.1	64.14	14.61	1.54	7.69	6.92	5.6
15	98-99	5.5	66.0	13.28	1.23	7.92	5.36	4.4
16	99-100	0.9	39.44	16.83	2.45	4.73	12.1	9.0
17	100-101	0.9	41.96	16.72	2.34	5.04	11.68	9.6

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Sullani Oilshale Deposit
B. H. No 08 - 36

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
18	101-102	5.0	62.25	11.35	0.88	7.47	3.88	3.1
19	102-103	0.6	42.62	14.62	2.13	5.12	9.50	7.2
20	103-104	0.8	48.65	14.74	1.87	5.84	8.90	8.1
21	104-105	0.7	38.97	9.95	1.04	4.68	5.27	4.3
22	105-106	1.1	25.75	6.76	0.67	3.08	3.68	3.0
23	106-107	1.2	32.94	7.81	0.64	3.95	3.86	3.1
24	107-108	0.7	82.42	14.21	1.81	3.89	10.32	8.4
25	108-109	1.2	41.1	11.64	1.52	4.9	6.74	5.4
26	109-110	5.6	27.92	8.60	1.34	3.35	5.25	4.2
27	110-111	10.9	20.79	7.10	1.30	2.49	4.61	3.7
28	111-112	5.3	19.78	7.31	1.18	2.37	4.94	3.9
29	112-113	1.6	18.91	7.33	1.00	2.27	5.06	4.1
30	113-114	3.2	17.53	7.65	1.33	2.10	5.55	4.5
31	114-115	1.4	21.2	9.66	1.21	2.55	7.11	5.8
32	115-116	0.84	22.3	8.59	1.12	2.67	5.92	4.8
33	116-117	1.0	28.36	11.82	1.56	3.40	8.42	6.9
34	117-118	3.0	26.01	11.21	1.58	3.12	8.09	6.6
35	118-119	1.41	38.40	14.72	1.88	4.61	10.11	8.3
36	119-120	1.4	31.82	13.81	1.90	3.82	9.99	8.2
37	120-121	1.80	29.26	14.91	2.40	3.51	11.4	9.3

Sultani Oilshale Deposit

B . H . No OS - 36

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Anorg %	C Org %	Oil %
38	121-122	6.0	19.28	14.64	3.63	2.31	12.33	10.1
39	122-123	6.2	17.11	12.78	3.60	2.05	10.73	8.8
40	123-124	6.8	18.39	9.32	1.95	2.2	7.12	5.8
41	124-125	6.6	13.71	10.50	2.10	1.64	8.86	7.3
42	125-126	10.4	14.60	15.27	2.49	1.75	13.52	11.1
43	126-127	4.1	42.48	12.24	1.40	5.09	7.15	5.9
44	127-128	9.9	44.28	9.14	1.80	5.31	3.83	3.1

Sultani Oilshale Deposit
B. H. No OS - 36

Sample No.	P_2O_5 %
BH.OS-36	
128 - 129	1.15
129 - 130	1.08
130 - 131	0.93
131 - 132	1.23
132 - 133	1.08
133 - 134	1.10
134 - 135	1.30
135 - 136	1.65
136 - 137	1.50
137 - 138	1.40
138 - 139	1.50

Sultani Oilshale Deposit

B. H. No OS - 38

Item	(m) Depth	% Moisture	% $CaCO_3$	% C total	% S Total	% Cinor	% Corg	% Oil
1	73-74	1.53	22.31	11.64	1.26	2.68	8.96	7.4
2	74-75	1.22	54.08	11.98	1.20	6.49	5.49	4.5
3	75-76	2.94	64.65	12.69	1.04	7.76	4.93	4.0
4	76-77	0.82	42.48	9.86	0.88	5.10	4.76	3.9
5	77-78	1.01	51.00	15.14	1.66	6.12	9.02	7.4
6	78-79	2.65	49.65	17.30	2.54	5.36	11.94	9.8
7	79-80	2.21	31.16	10.07	1.66	3.74	6.33	5.1
8	80-81	4.49	23.30	8.81	1.63	2.80	6.01	4.9
9	81.82	6.20	18.88	7.60	1.38	2.27	55.33	4.3
10	82-83	6.21	17.57	7.82	1.42	2.11	5.71	4.7
11	83-84	6.07	17.35	7.21	1.39	2.08	5.13	4.1
12	84-85	3.45	21.77	8.10	1.16	2.61	5.49	4.5
13	85-86	6.12	23.44	7.20	0.97	2.81	4.39	3.5
14	86-87	3.00	25.48	10.35	1.66	3.06	7.29	6.0
15	87-88	4.95	24.97	7.64	0.79	3.00	4.64	3.7
16	88-89	2.35	32.44	9.50	1.10	3.89	5.61	4.6
17	89-90	5.01	28.7[illegible]	9.11	1.28	3.44	5.67	4.6
18	90-91	2.29	35.36	15.75	2.40	4.24	11.51	9.4
19	91-92	1.43	35.00	18.79	3.17	4.20	14.59	12.0
20	92-93	1.46	31.06	19.07	3.14	3.73	15.34	12.6
21	93-94	1.72	24.36	15.93	3.33	2.92	13.01	10.7
22	94-95	1.53	41.06	11.49	1.42	4.93	6.56	5.4
23	95-96	2.09	25.20	11.67	2.23	3.02	8.65	7.1
24	96-97	1.73	34.33	14.90	2.26	4.12	10.78	8.9
25	97-98	1.45	40.13	15.77	2.58	4.82	10.95	9.0
26	98-99	1.44	41.58	15.12	2.57	4.99	10.13	8.3
27	99-100	1.50	49.86	19.26	2.44	5.98	13.28	10.9
28	100-101	3.63	53.24	11.97	1.25	6.39	5.58	4.6
29	101-102	1.71	53.14	12.14	1.25	6.38	5.76	4.7
30	102-103	2.16	40.14	13.10	2.16	4.82	8.28	6.8

Sultani Oilshale Deposit
B. H. No OS -38

Serial No.	Depth (m)	P_2O_5%
1	103.2 - 104.2	2.0
2	104.2 - 105.2	5.25
3	105.2 - 106.2	14.75
4	106.2 - 107.2	11.25
5	107.2 - 108.2	14.00

Sultani Oilshale Deposit

B . H . No 05 - 39

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total C. %	Total S. %	Inorg. C. %	Org. C.%	Oil %
1	53.5-54.5	1.2	67.32	13.03	1.03	8.07	4.96	4.1
2	54.5-55.5	0.8	73.61	12.58	0.73	8.83	3.75	3.1
3	55.5-56.5	3.5	52.9	15.38	2.30	6.35	9.03	7.4
4	56.5-57.5	6.9	27.42	17.61	3.71	3.29	14.32	11.7
5	57.5-58.5	0.7	20.31	8.78	1.68	2.44	6.34	5.1
6	58.5-59.5	0.9	43.09	12.76	2.22	5.17	7.59	6.2
7	59.5-60.5	1.4	43.45	15.23	2.51	5.09	10.14	8.3
8	60.5-61.5	1.0	9.97	11.19	1.81	1.19	10.0	8.2
9	61.5-62.5	0.7	41.49	11.26	1.99	4.98	6.28	5.1
10	62.5-63.5	0.9	40.67	15.1	2.46	4.88	10.22	8.3
11	63.5-64.5	0.9	40.80	16.05	2.37	4.90	11.15	9.2
12	64.5-65.5	3.0	38.91	9.06	1.31	4.67	4.39	3.6
13	65.5-66.5	10.5	22.34	7.7	1.25	2.68	5.02	4.1
14	66.5-67.5	7.8	12.52	6.95	1.55	1.50	5.45	4.5
15	67.5-68.5	8.6	14.95	7.57	1.49	1.79	5.78	4.7
16	68.5-69.5	9.7	14.08	6.89	1.22	1.68	5.21	4.2
17	69.5-70.5	4.8	24.33	10.32	1.94	2.92	7.40	6.0
18	70.5-71.5	4.1	27.08	7.52	1.2	3.24	4.28	3.5
19	71.5-72.5	3.9	23.51	8.59	1.1	2.82	5.77	4.7

Sultani Oilshale Deposit

B . H . No OS - 39

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total C. %	Total S. %	Inrog. C.%	Org. C. %	Oil %
20	72.5-73.5	1.3	44.90	10.28	1.01	5.38	4.9	4.0
21	73.5-74.5	1.2	44.33	13.53	1.8	5.32	8.21	6.7
22	74.5-75.5	2.8	38.67	14.36	2.32	4.64	9.72	8.0
23	75.5-76.5	2.3	34.88	17.98	2.89	4.18	13.8	11.3
24	76.5-77.5	2.1	25.95	19.15	3.53	5.15	14.0	11.5
25	77.5-78.5	3.9	32.22	16.06	2.96	3.86	12.2	10.0
26	78.5-79.5	3.3	17.79	15.0	4.35	2.13	12.87	10.6
27	79.5-80.5	4.7	39.5	9.02	1.01	4.7	4.32	3.5
28	80.5-81.5	3.4	19.9	10.42	2.11	2.4	8.02	6.5
29	81.5-82.5	9.8	19.35	10.96	2.04	2.32	8.64	7.0
30	82.5-83.5	1.5	19.16	17.47	2.69	2.29	15.18	14.2
31	83.5-84.5	4.3	40.81	14.53	2.36	4.89	9.64	7.9
32	84.5-85.5	2.4	36.88	16.30	3.27	4.43	11.87	9.7
33	85.5-86.5	2.4	48.42	20.53	3.39	5.81	14.72	12.1
34	86.5-87.5	2.7	52.6	17.98	3.03	6.31	11.67	9.6
35	87.5-88.5	4.1	52.96	10.15	1.28	6.36	3.79	3.1
36	88.5-89.5	0.5	42.61	11.82	1.51	5.11	6.71	5.5
37	89.5-90.5	0.9	35.21	9.96	1.28	4.22	5.74	4.6
38	90.5-91.5	1.1	33.53	9.83	1.63	4.02	5.81	4.7
39	91.5-92.5	1.5	27.33	7.71	1.08	3.35	4.36	3.7
40	92.5-93.5	0.4	67.36	9.39	0.36	8.08	1.31	1.0
41	[illegible]	0.4	27.63	5.66	0.68	3.32	2.34	1.8
42	[illegible]	5.5	16.48	5.89	1.28	1.98	3.91	3.1

Sultani Oilshale Deposit

B. H. No OS - 39

Sample No.	P_2O_5 %
BH. OS-39	
95.5 - 96.5	9.5
97.5 - 98.5	2.2
98.5 - 99.5	9.0
99.5 - 100.5	7.1
100.5 - 101.5	4.0
101.5 - 102.5	1.3
102.5 - 103.5	2.58
103.5 - 104.5	2.50
104.5 - 105.5	0.45
105.5 - 106.25	1.08

Sultani Oilshale Deposit

B . H . No OS - 40

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
1	55-56	2.15	54.57	19.53	3.38	6.55	12.98	10.1
2	56-57	3.23	58.20	19.95	3.24	6.98	12.97	10.7
3	57-58	2.08	65.42	16.75	2.27	7.85	8.90	7.3
4	58-59	3.23	57.30	17.52	2.37	6.88	10.64	8.7
5	59-60	4.64	58.89	17.40	2.21	7.07	10.33	8.4
6	60-61	1.77	54.65	20.33	3.23	6.56	13.77	11.3
7	61-62	4.61	41.84	17.80	2.82	5.02	12.78	10.5
8	62-63	2.17	38.96	19.00	3.20	4.68	14.32	11.7
9	63-64	3.84	46.31	19.74	3.24	5.56	14.18	11.7
10	64-65	4.75	71.66	13.46	1.12	8.60	4.86	4.0
11	65-66	9.00	60.38	15.42	2.00	7.25	8.17	6.7
12	66-67	7.30	56.63	14.71	1.79	6.80	7.91	6.5
13	67-68	7.17	54.44	18.68	2.53	6.53	12.15	10.0
14	68-69	4.10	52.04	17.61	2.52	6.24	11.38	9.3

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Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C Inorg %	C Org %	Oil %
15	69-70	2.20	42.68	12.00	1.46	5.12	6.88	5.6
16	70-71	3.24	31.06	14.47	2.61	3.73	10.74	8.8
17	71-72	1.75	43.48	14.43	2.14	5.22	9.21	7.5
18	72-73	1.32	34.37	14.62	2.36	4.12	10.50	8.6
19	73-74	1.40	45.14	13.90	2.15	5.42	8.48	7.0
20	74-75	0.90	35.85	11.20	1.55	4.30	6.90	5.6
21	75-76	1.18	42.39	13.44	1.85	5.09	8.35	6.5
22	76-77	2.30	40.0	13.72	1.79	4.80	8.92	7.3
23	77-78	3.77	42.33	18.78	2.93	5.08	13.70	11.2
24	78-79	2.61	26.96	19.46	3.71	3.24	16.22	13.3
25	79-80	9.87	22.06	9.74	1.87	2.65	7.09	5.8
26	80-81	7.0	26.85	9.92	1.64	3.22	6.70	5.5
27	81-82	8.37	19.36	9.60	1.90	2.32	17.04	14.0
28	82-83	7.96	24.85	10.23	1.78	2.98	7.25	6.0
29	83-84	9.14	12.19	8.10	1.87	1.46	6.64	5.4
30	84-85	9.0	12.75	8.36	1.87	1.53	6.83	5.5
31	85-86	9.17	11.81	8.37	1.92	1.42	6.95	5.7
32	86-87	7.54	19.07	9.78	2.00	2.29	7.49	6.[illegible]
33	87-88	10.98	11.17	7.25	1.64	1.34	5.91	4.8
34	88-89	8.0	16.47	9.41	1.72	1.98	7.43	6.0
35	89-90	10.5	19.87	8.22	1.29	2.38	5.84	4.7
36	90-91	6.75	18.94	9.94	1.78	2.27	7.67	6.3

Sultani Oilshale Deposit

B . H . No 05 - 40

Item	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	Stotal %	C Inorg %	C Corg %	Oil %
37	91-92	2.15	20.19	9.86	1.75	2.42	7.44	6.0
38	92-93	1.28	25.64	9.51	1.41	3.08	6.43	5.2
39	93-94	1.20	53.31	16.30	1.89	6.40	9.90	8.1
40	94-95	4.02	38.25	16.19	2.43	4.59	11.60	9.[illegible]
41	95-96	2.38	40.21	20.20	3.47	4.82	15.38	13.0
42	96-97	2.94	34.95	19.26	3.56	4.19	15.07	12.4
43	97-98	4.28	21.40	13.33	3.34	2.57	10.76	8.9
44	98-99	2.09	39.57	16.44	2.64	4.75	11.69	9.6
45	99-100	2.26	47.92	17.44	2.72	5.75	11.69	9.6
46	100-101	2.09	39.88	16.96	4.51	4.79	12.17	10.0
47	101-102	4.12	52.89	20.40	3.66	6.35	14.05	11.6
48	102-103	6.29	41.85	12.97	1.99	5.02	7.95	6.5
49	103-104	7.51	49.07	11.22	1.37	5.89	5.33	4.3
50	104-105	8.34	45.81	9.97	1.14	5.50	4.08	3.3
51	105-106	4.85	49.81	15.64	2.44	5.98	9.66	8.[illegible]
52	106-107	1.07	37.77	9.46	1.01	9.53	4.93	4.0
53	107-108	1.64	45.36	13.13	1.69	5.44	7.69	6.3
54	108-109	2.07	43.69	13.44	1.93	5.24	8.20	6.7
55	109-110.65	2.78	35.49	9.30	1.41	4.26	5.09	4.1

Sultani Oilshale Deposit

B . H . No OS - 41

Item	Depth(m)	Moisture %	$CaCO_3$ %	Total C %	Total S %	Inorg. C %	Org . C %	Oil %
1	51-52	1.36	38.89	20.01	4.80	3.89	16.12	13.38
2	52-53	1.20	55.57	19.85	3.85	6.67	13.18	10.94
3	53-54	1.96	58.10	14.06	1.48	6.97	7.09	5.88
4	54-55	4.15	65.87	10.19	1.06	7.90	2.29	1.90
5	55-56	2.62	62.65	17.19	3.19	7.52	9.67	8.03
6	56-57	2.40	60.32	14.97	2.76	7.24	7.73	6.42
7	57-58	2.10	49.02	20.81	4.45	5.88	14.93	12.39
8	58-59	2.03	52.23	18.65	4.13	6.27	12.38	10.28
9	59-60	2.87	49.89	11.47	2.49	5.91	5.56	4.61
10	60-61	0.71	38.12	14.33	2.85	4.58	9.75	8.09
11	61-62	1.37	29.58	20.33	8.66	3.55	16.78	13.93
12	62-63	1.30	66.54	12.87	1.87	7.99	4.88	4.05

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Sultani Oilshale Deposit

B . H . No OS - 41

Item	Depth(m)	Moisture %	$CaCO_3$ %	Total C %	Total S %	Inorg. C %	Org. C %	Oil %
13	63-64	0.87	37.85	11.06	1.95	4.54	6.52	5.41
14	64-65	0.56	20.12	6.95	0.95	2.41	4.53	3.76
15	65-66	0.60	29.31	7.22	0.69	3.52	3.70	3.07
16	66-67	0.71	43.83	11.79	2.42	5.26	6.53	5.42
17	67-68	1.02	42.32	11.40	1.99	5.08	6.32	5.25
18	68-68.8	1.50	50.02	12.12	2.25	6.00	6.12	5.08
19	68.8-70	3.3	39.49	8.69	1.2	4.74	3.95	3.2

Sultani Oilshale Diposit

B. H. No OS - 41

Item	(m) Depth	% Moisture	% $CaCO_3$	% C Total	% S Total	% Cinorg.	% Corg.	% Oil
20	70-71	7.03	20.98	8.41	1.75	2.52	5.89	4.8
21	71-72	7.55	13.36	7.62	1.53	1.60	6.02	4.9
22	72-73	9.21	13.43	7.30	1.49	1.61	5.69	4.7
23	73-74	3.65	18.18	9.36	1.92	2.18	7.18	5.9
24	74-75	8.79	21.51	7.43	0.97	2.58	4.85	4.0
25	75-76	4.58	13.89	6.71	1.14	1.67	5.04	4.1
26	76-77	3.92	18.16	7.91	1.11	2.18	5.73	4.7
27	77-78	1.95	22.71	11.64	2.05	2.73	8.91	7.3
28	78-79	1.01	29.76	9.71	1.17	3.57	6.14	5.0
29	79-80	0.76	25.34	10.27	1.45	3.04	7.23	5.9
30	80-81	0.82	30.67	9.95	1.46	3.68	6.27	5.1
31	81-82	0.83	27.88	8.44	0.96	3.35	5.09	4.1
32	82-83	2.18	38.72	15.72	2.14	4.65	11.07	9.1
33	83-84	1.47	26.94	19.93	3.72	3.23	16.70	13.7
34	84-85	2.11	25.06	17.84	4.32	3.01	14.83	12.2
35	85-86	3.10	18.15	12.18	2.60	2.18	10.00	8.2
36	86-87	2.96	19.53	13.19	2.30	2.34	10.85	8.9
37	87-88	1.00	36.00	17.30	2.56	4.32	12.98	10.7
38	88-89	1.89	37.33	15.25	2.55	4.48	10.77	8.8
39	89-90	2.60	40.43	19.41	2.72	4.85	14.56	12.0

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Sultani Oilshale Deposit

B . H . No OS - 41

Serial No.	Depth (m)	P_2O_5%
1	90.0 - 91.0	3.00
2	91.0 - 92.0	3.75
3	92.0 - 93.0	15.25

Sultani Oilshale Deposit

B.H. No OS- 44

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total Carbon %	Total Sulphur %	Inorg Carbon %	Org. Carbon %	Oil %
1	46-47	2.4	36.76	20.23	4.36	4.41	15.82	13.13
2	47-48	1.7	40.47	20.34	4.38	4.86	15.96	13.25
3	48-49	2.5	61.18	14.70	2.37	7.34	8 .36	6.94
4	49-50	4.2	75.06	11.91	1.03	9.01	2.90	2.41
5	50-51	3.0	70.76	13.11	1.46	8.49	3.62	3.01
6	51-52	2.5	70.78	14.80	1.89	8.49	6.31	5.24
7	52-53	5.4	46.28	19.92	4.70	5.55	14.37	11.93
8	53-54	4.8	64.99	14.48	2.12	7.80	6.68	5.54
9	54-55	2.3	39.64	15.23	2.61	4.76	10.47	8.69
10	55-56	6.6	39.34	16.59	3.99	4.72	13.87	11.51
11	56-57	1.0	44.91	16.35	3.25	5.39	10.96	9.10
12	57-58	2.0	40.84	11.92	1.26	4.90	7.02	5.83
13	58-59	0.8	53.48	11.59	1.40	6.42	5.17	4.29
14	59-60	3.5	34.31	18.88	5.27	4.12	14.76	12.25
15	60-61	2.0	42.32	18.23	3.11	5.08	13.15	10.91
16	61-62	1.0	34.30	18.69	3.66	4.12	14.38	12.09
17	62-63	1.6	43.74	11.94	1.67	5.25	6.69	5.55
18	63-64	1.6	49.60	12.40	2.18	5.95	6.45	5.35
19	64-65	1.5	28.17	10.92	1.86	3.38	7.54	6.26
20	65-66	10.0	19.82	9.61	2.35	2.38	7.23	6.00
21	66-67	7.9	35.91	8.47	1.21	4.31	4.16	3.45
22	67-68	10.0	14.66	7.72	1.70	1.76	5.96	4.95
23	68-69	9.4	18.61	9.46	2.01	2.23	7.23	6.00
24	69-70	5.1	15.69	8.09	2.30	1.88	6.21	5.15

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Sultani Oilshale Deposit

B . H . No OS- 44

Item	Depth (m)	Moisture %	$CaCo_3$ %	Total Carbon %	Total Sulphur %	Inorg. Carbon %	Org. Carbon %	Oil %
25	70-71	8.6	16.90	6.94	1.63	2.03	4.91	4.08
26	71-72	11.9	11.97	5.96	1.04	1.44	4.52	3.75
27	72-73	14.8	9.68	6.46	1.86	1.16	5.30	4.40
28	73-74	7.5	19.57	9.31	2.40	2.35	6.96	5.78
29	74-75	8.5	19.36	8.93	2.24	2.32	6.61	5.99
30	75-76	10.5	16.78	8.09	1.90	2.01	6.08	5.05
31	76-77	6.6	20.47	8.51	1.85	2.45	6.06	5.03
32	77-78	7.0	49.79	11.54	1.78	5.97	5.57	4.62
33	78-79	0.9	32.87	11.05	1.99	3.95	7.10	5.89
34	79-80	2.3	36.17	19.16	4.49	4.34	14.82	12.30
35	80-81	1.5	33.77	20.04	4.39	4.05	15.99	13.27
386	81-82	2.0	45.55	14.01	2.79	5.47	8.54	7.09
37	82-83	2.2	25.31	15.77	3.99	3.04	12.73	10.57
38	83-84	4.4	31.23	13.47	2.90	3.75	9.72	8.07
39	84-85	2.3	42.60	15.88	3.85	5.11	10.77	8.94
40	85-86	1.5	44.50	19.83	4.56	5.34	14.49	12.03
41	86-87	2.7	49.75	17.58	3.70	5.97	11.61	9.64
42	87-88	8.2	37.31	10.83	2.32	4.48	6.35	5.27
43	88-89	8.5	43.85	8.98	1.51	5.26	3.72	3.09
44	89-90	6.0	35.67	11.37	2.57	4.28	7.09	5.88

Item	Depth. (m)	Moisture %	CaCo3 %	Total C%	Total S%	Inorg. C %	Org. C %	Oil %
1	60.5-61.5	1.0	62.95	16.99	3.97	7.54	9.46	7.85
2	61.5-62.5	1.9	51.84	21.08	5.20	6.22	14.86	12.33
3	62.5-63.5	2.9	46.41	21.59	7.18	5.57	16.02	13.30
4	63.5-64.5	4.8	43.31	19.84	5.69	5.20	14.64	12.15
5	64.5-65.5	3.6	41.23	22.25	6.53	4.95	17.30	14.36
6	65.5-66.5	3.8	34.38	20.66	5.71	4.13	16.53	13.72
7	66.5-67.5	6.6	52.89	19.33	4.67	6.35	12.98	10.77
8	67.5-68.5	3.5	32.87	18.78	4.54	3.94	14.84	12.32
9	68.5-69.5	8.4	35.28	14.81	4.02	4.23	10.58	8.78
10	69.5-70.5	5.7	32.09	15.14	4.18	3.85	11.29	9.37
11	70.5-71.5	2.1	32.95	22.03	7.14	3.95	18.08	15.01
12	71.5-72.5	2.3	40.63	19.64	5.79	4.88	14.77	12.26
13	72.5-73.5	2.9	42.25	18.33	5.23	5.07	13.26	11.01
14	73.5-74.5	4.5	62.56	12.35	1.80	7.51	4.84	4.02
15	74.5-75.5	-	-	-	-	-	-	-
16	75.5-76.5	10.8	56.24	13.99	2.57	6.75	7.24	6.01
17	76.5-77.5	1.4	59.34	15.98	3.47	7.12	8.86	7.35
18	77.5-78.5	5.6	67.76	13.67	2.05	8.13	5.54	4.60
19	78.5-79.5	2.7	56.39	11.31	1.97	6.77	4.54	3.77
20	79.5-80.5	0.9	55.40	11.35	2.22	6.65	4.70	3.90
21	80.5-81.5	0.4	31.72	10.57	1.92	3.81	6.94	5.76

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Item	Depth (m)	Moisture %	CaCo3 %	Total C%	Total S%	Inorg. C%	Org. C%	Oil %
1	42-43	9.4	17.72	7.20	1.41	2.13	5.07	4.208
2	43-44	7.6	11.18	7.53	2.49	1.34	6.19	5.137
3	44-45	10.7	14.41	7.93	2.42	1.73	6.20	5.146
4	45-46	8.6	13.35	7.63	6.20	1.60	6.03	5.004
5	46-47	10.7	17.72	9.33	2.64	2.13	7.21	5.984
6	47-48	7.8	18.76	10.87	2.70	2.25	8.62	7.154
7	48-49	10.9	3.35	9.14	2.38	0.40	8.74	7.254
8	49-50	2.1	51.52	16.59	3.07	6.18	10.41	8.640
9	50-51	1.2	42.68	15.06	3.07	5.12	9.94	8.250
10	51-52	1.0	61.51	13.71	1.38	7.38	6.33	5.253
11	52-53	3.5	34.10	14.66	4.06	4.09	10.57	8.773
12	53-54	2.6	29.61	13.03	4.24	3.55	9.48	7.868
13	54-55	2.5	33.92	17.45	4.37	4.07	13.38	11.105
14	55-56	2.9	41.06	16.08	4.19	4.93	11.15	9.254
15	56-57	3.0	43.54	10.58	2.58	5.22	5.36	4.448
16	57-58	2.0	46.02	7.82	1.35	5.52	2.30	1.909
17	58-59	0.7	40.37	12.25	2.33	4.84	7.41	6.150
18	59-60	0.7	26.64	11.12	1.99	3.20	7.92	6.573

Sultani Oilshale Deposit

B.H . No OS - 47

Item	Depth (m)	Moisture %	$CaCO_3$ %	Total Carbon %	Total Sulphur %	Inorganic Carbon %	Organic Carbon %	Oil %
1	57.5 - 58.5	3.37	48.66	21.41	5.26	5.84	15.57	12.92
2	58.5 - 59.5	2.61	47.82	19.76	4.07	5.74	14.02	11.64
3	59.5 - 60.5	3.82	52.07	18.20	3.12	6.25	11.95	9.92
4	60.5 - 61.5	3.24	47.17	22.28	7.33	5.66	16.62	13.79
5	61.5 - 62.5	5.18	64.77	15.29	2.24	7.77	7.52	6.24
6	62.5 - 63.5	9.14	57.60	15.22	2.79	6.91	8.31	6.89
7	63.5 - 64.5	5.15	41.47	19.16	4.23	4.90	12.22	10.14
8	64.5 - 65.5	5.15	63.34	17.70	3.29	7.60	10.10	8.38
9	65.5 - 66.5	4.28	58.57	19.61	4.25	7.03	12.58	10.44
10	66.5 - 67.5	7.08	59.13	18.31	3.87	7.09	11.21	9.30
11	67.5 - 68.5	8.84	44.69	13.85	2.82	5.36	8.49	7.03
12	68.5 - 69.5	7.13	31.52	15.62	3.81	3.78	11.84	9.83

Sultani Oilshale Deposit

B . H . No 05 -47

Item	Depth (m)	Moisture %	$CaCO_3$ %	Total Carbon %	Total Sulphur %	Inorganic Carbon %	Organic Carbon %	Oil %
13	69.5 - 70.5	8.33	34.35	17.35	3.97	4.12	13.23	10.98
14	70.5 - 71.5	6.46	27.57	15.95	4.03	3.31	12.64	10.49
15	71.5 - 72.5	3.09	49.36	16.81	2.97	5.92	9.92	8.23
16	72.5 - 73.5	9.10	62.92	13.49	1.99	7.55	5.89	4.88
17	73.5 - 74.5	8.14	51.91	16.27	3.45	6.23	10.04	8.33
18	74.5 - 75.5	6.38	54.37	15.34	3.34	6.52	8.82	7.32

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Sultani Oilshale Deposit

B. H. No OS - 49

Item	Depth (m)	Moisture water %	Decomposition water %	Total water %	Ash Content %	Gas Loss %	Oi %
2	86-87	4.64	0.16	4.8	84.2	5.6	5.
2	87-88	1.71	1.69	3.4	84.4	4.2	8.
3	88-89	1.99	0.01	3.0	86.4	2.4	8.
4	89-90	2.57	0.83	3.4	80.4	7.4	8.
5	90-91	1.83	1.57	3.4	81.2	3.6	11.
6	91-92	5.53	1.80	7.4	77.6	4.0	11.
7	92-93	2.83	1.57	4.4	76.6	6.8	12.
8	93-94	3.37	1.43	4.8	77.0	6.6	11.
9	94-95	3.98	2.22	6.2	83.4	3.6	6.
10	95-96	3.47	0.93	4.4	84.4	4.6	6.
11	96-97	4.19	0.61	4.8	84.4	4.2	6.
12	97-98	3.19	1.21	4.4	80.4	4.4	10.
13	98-99	3.47	2.53	6.0	84.8	2.6	6.
14	99-100	5.07	0.53	5.6	79.8	4.2	10.
15	100-101	2.00	1.60	3.6	80.4	3.8	12.
16	101-102	2.97	0.43	3.4	78.0	6.0	12.
17	102-103	4.06	2.74	6.8	77.4	5.8	10.
18	103-104	2.09	1.51	3.6	84.2	4.0	8.
19	104-105	0.57	1.03	1.6	88.4	4.0	6.
20	105-106	0.69	0.51	1.2	90.0	2.4	6.
21	106-107	0.43	0.77	1.2	93.2	2.2	3.
22	107-108	0.47	0.53	1.0	91.8	3.6	3.
23	108-109	0.42	1.18	1.6	93.0	1.2	4.
24	109-110	6.69	0.91	7.6	82.4	4.0	6.
25	110-111	6.47	1.53	8.0	82.8	4.0	5.
26	111-112	7.25	3.35	10.6	82.8	3.0	3.6
27	112-113	14.32	1.68	16.0	77.2	2.8	4.0

./.

Sultani Oilshale Deposit

B . H . No OS - 49

Item	Depth (m)	Moisture %	Decomposition water %	Total water %	Ash Content %	Gas Loss %	Oil
28	113-114	10.66	0.94	11.6	81.4	4.4	2.[illegible]
29	114-115	9.18	0.82	10.0	83.6	3.0	3.[illegible]
30	115-116	7.65	1.35	9.0	85.2	2.4	3.[illegible]
31	116-117	2.14	0.86	3.0	89.6	2.8	4.[illegible]
32	117-118	4.06	0.34	4.4	87.2	3.4	5.[illegible]
33	118-119	2.91	1.09	4.0	84.2	4.2	7.[illegible]
34	119-120	5.5	0.7	6.2	82.2	4.0	7.[illegible]
35	120-121	3.25	3.15	6.4	80.8	4.6	8.[illegible]
36	121-122	5.67	0.73	6.4	81.2	4.2	8.[illegible]
37	122-123	4.13	1.27	5.4	84.2	3.2	7.[illegible]
38	123-124	6.05	0.75	6.8	83.4	2.6	7.[illegible]
39	124-125	8.73	0.27	9.0	79.6	3.0	8.[illegible]
40	125-126	7.45	0.95	8.4	81.6	3.0	7.0
41	126-127	5.01	4.19	9.2	82.4	2.4	6.0
42	127-128	6.87	1.13	8.0	81.4	3.0	7.6
43	128-129	0.84	0.16	1.0	85.8	4.8	8.4
44	129-130	1.18	0.22	1.4	86.0	4.4	8.2
45	130-131	2.75	1.65	4.4	82.2	4.4	9.0
46	131-132	2.49	1.11	3.6	81.0	3.8	11.6
47	138-138.5	2.40	1.6	4.0	80.2	3.6	12.2
		Average		5.4	83.2	3.9	7.3

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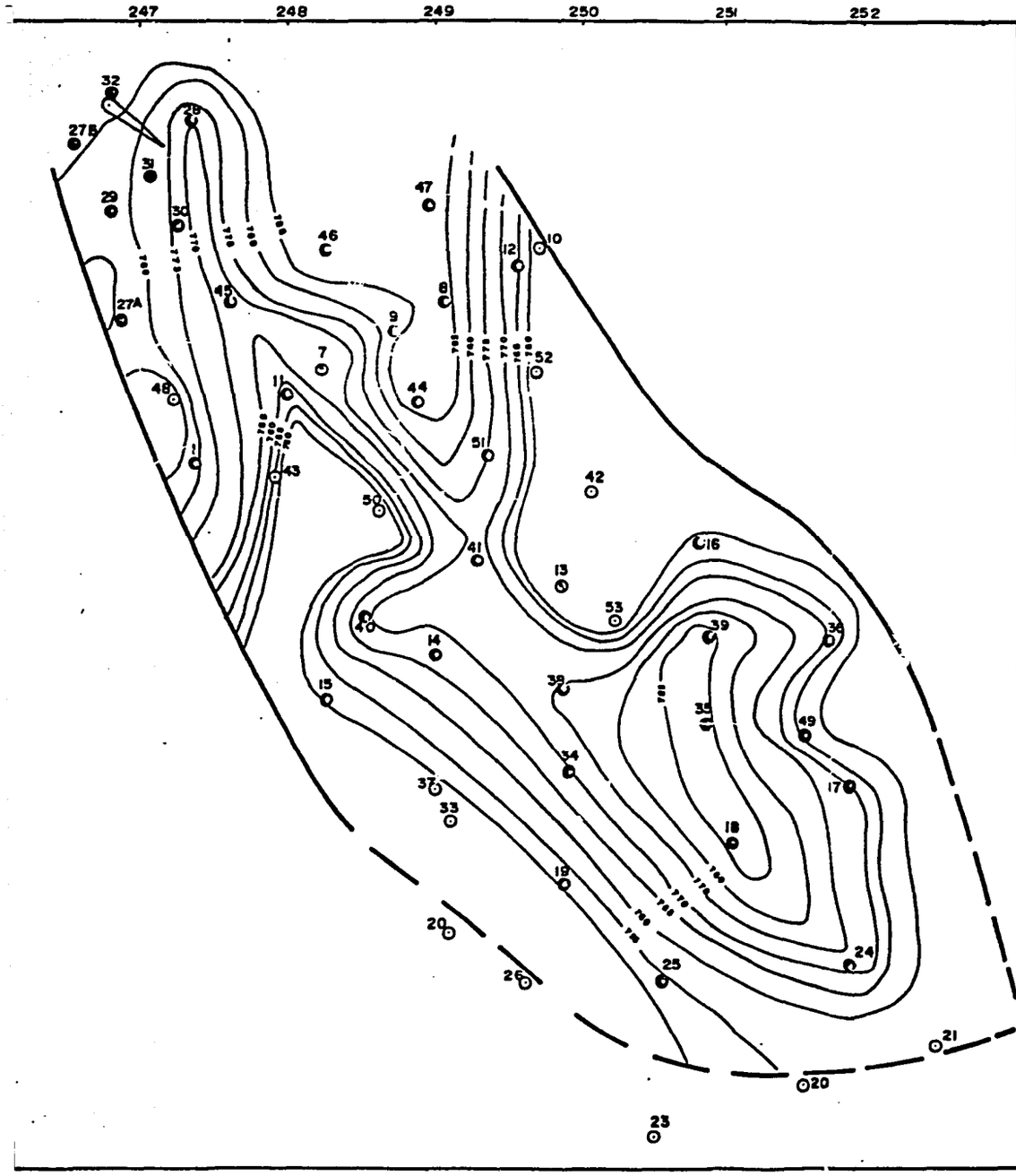
Sultani Oilshale Deposit

B . H . No OS - 49

S. No.		
B.H. OS.49		P2O5
	132.5 -133.5	8.50%
	133.5 -134.5	13.50%

B . H . No OS -51

tem	Depth (m)	Moisture %	$CaCO_3$ %	C Total %	S Total %	C inorg %	C org. %	Oil %
1	56-57	1.99	48.4	16.91	2.55	5.80	11.11	8.7
2	57-58	1.26	59.33	18.82	2.31	7.10	11.72	9.2
3	58-59	0.97	53.50	20.04	2.22	6.40	13.64	10.8
4	59-60	1.05	53.98	20.73	2.64	6.50	14.23	11.3
5	60-61	1.18	45.02	22.0	3.37	5.40	16.60	13.3
6	61-62	1.55	46.13	19.52	2.96	5.50	14.02	11.1
	62-63	1.76	49.40	21.60	2.69	5.90	15.70	12.5
8	63-64	1.44	53.05	17.71	1.87	6.30	11.41	9.0
9	64-65	1.90	53.08	14.72	1.09	6.37	8.35	6.5
10	65-66	2.73	56.40	18.57	2.30	6.70	11.87	9.4
11	66-67	2.81	58.40	18.09	2.30	7.01	11.08	8.7
12	67-68	1.78	50.83	19.02	2.79	6.10	12.92	10.2
13	68-69	2.73	52-45	17.90	2.39	6.29	11.61	9.2
14	69-70	2.27	36.54	17.98	3.01	4.39	13.59	10.8
15	70-71	3.72	39.14	15.19	2.23	4.70	10.49	8.3
16	71-72	1.40	37.36	20.53	3.67	4.48	16.05	12.8
17	72-73	1.69	41.35	19.62	4.43	4.96	14.66	11.7
18	73-74	1.55	67.73	13.43	1.45	8.13	5.30	4.0
19	74-75	2.15	67.74	13.75	1.47	8.13	5.62	4.2
20	75-76	1.25	59.11	16.32	1.90	7.09	9.23	7.2
21	76-77	3.44	57.10	16.42	1.71	6.85	9.57	7.5
22	77-78	1.07	47.63	20.12	3.40	5.72	14.40	11.5
23	78-79	0.63	46.64	10.94	1.54	5.60	5.34	4.0
24	79-80	1.14	55.49	9.57	0.72	6.66	2.91	2.0
25	80-81	0.71	44.38	17.05	1.98	5.33	11.72	9.2
26	81-82	0.53	38.19	18.94	3.31	4.58	14.36	11.5
27	82-82.5	0.54	61.24	15.11	1.84	7.35	7.76	6.0



THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY & MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

GEOLOGY DIRECTORATE

ECONOMIC GEOLOGY DIVISION

SULTANI OIL SHALE DEPOSIT

Structural Contour Map of the upper Oil shale surface.

Scale 1:25,000

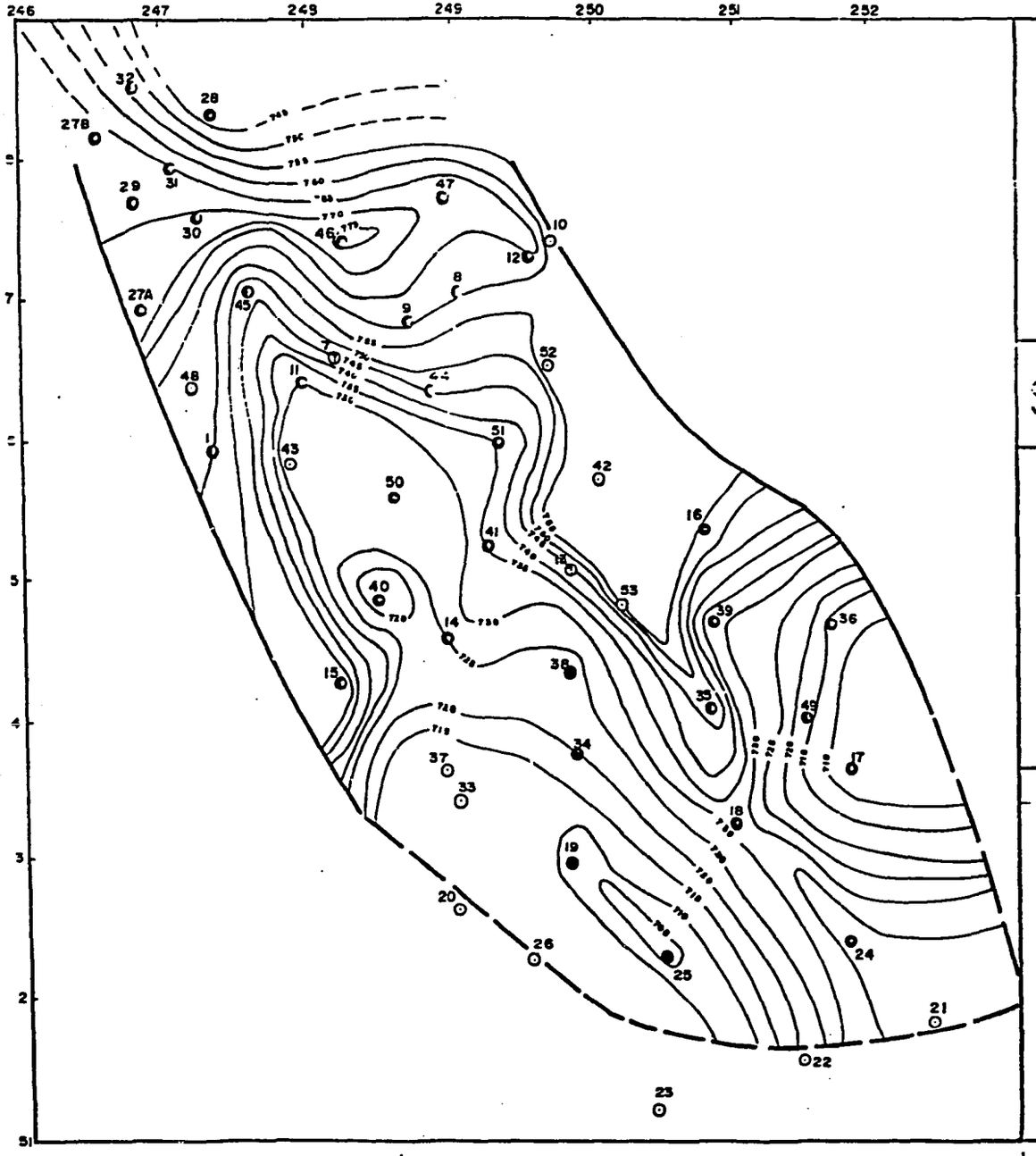
Prepared by: PROJECT STAFF.

Date: May / 1987

LEGEND

- ● POSITIVE
- ⊙ NEGATIVE
- INCOMPLETE

Fig. 4



THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY & MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

GEOLOGY DIRECTORATE

ECONOMIC GEOLOGY DIVISION

SULTANI OIL SHALE DEPOSIT

Structural Contour Map of the lower Oil shale surface.

Scale 1:25,000

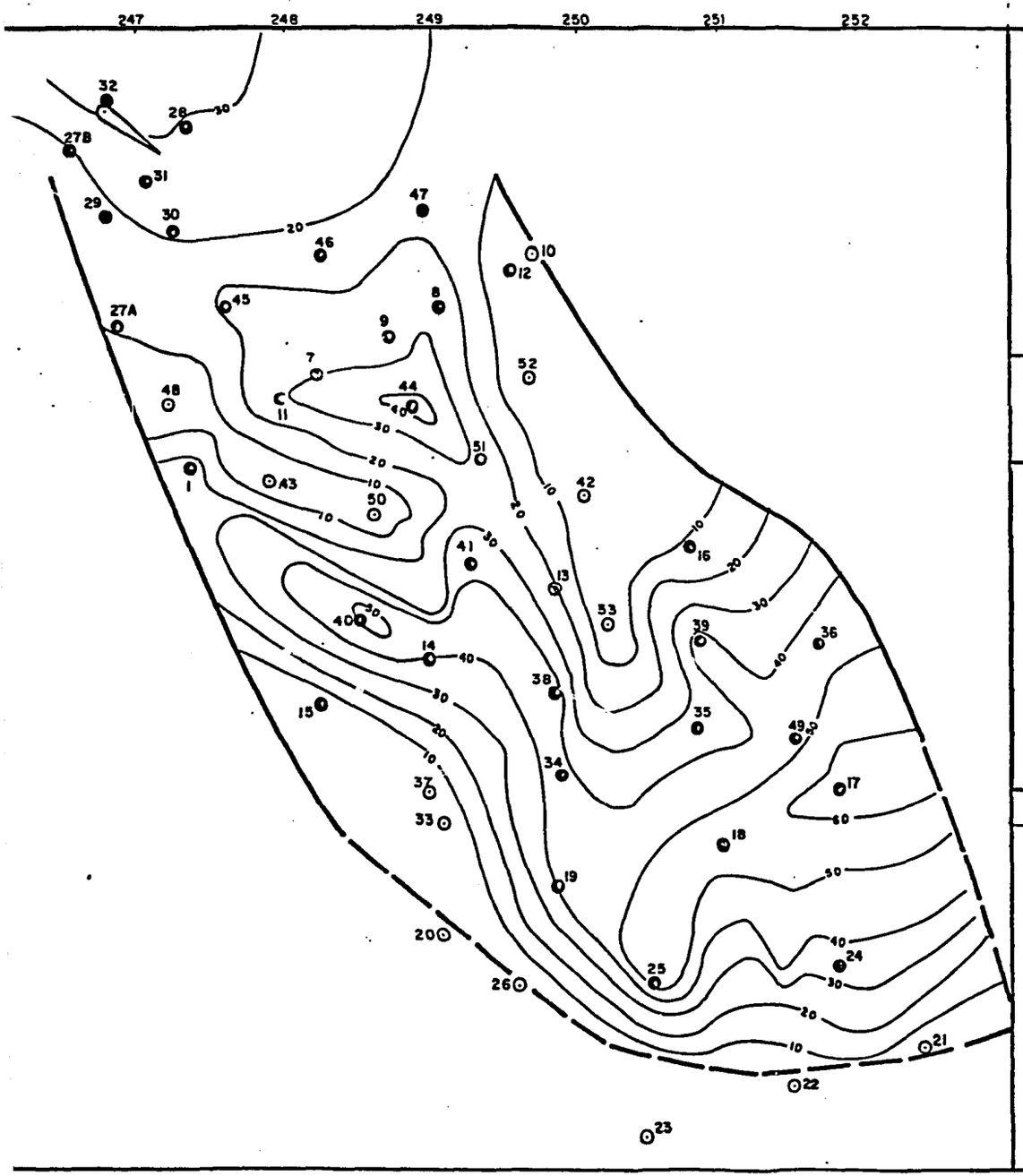
Prepared by: PROJECT STAFF.

Date: May / 1987

LEGEND

- POSITIVE
- NEGATIVE
- INCOMLETE

Fig.5



THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY & MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

GEOLOGY DIRECTORATE

ECONOMIC GEOLOGY DIVISION

SULTANI OIL SHALE DEPOSIT

Isopach Map of the Oil shale.

Scale 1 25,000

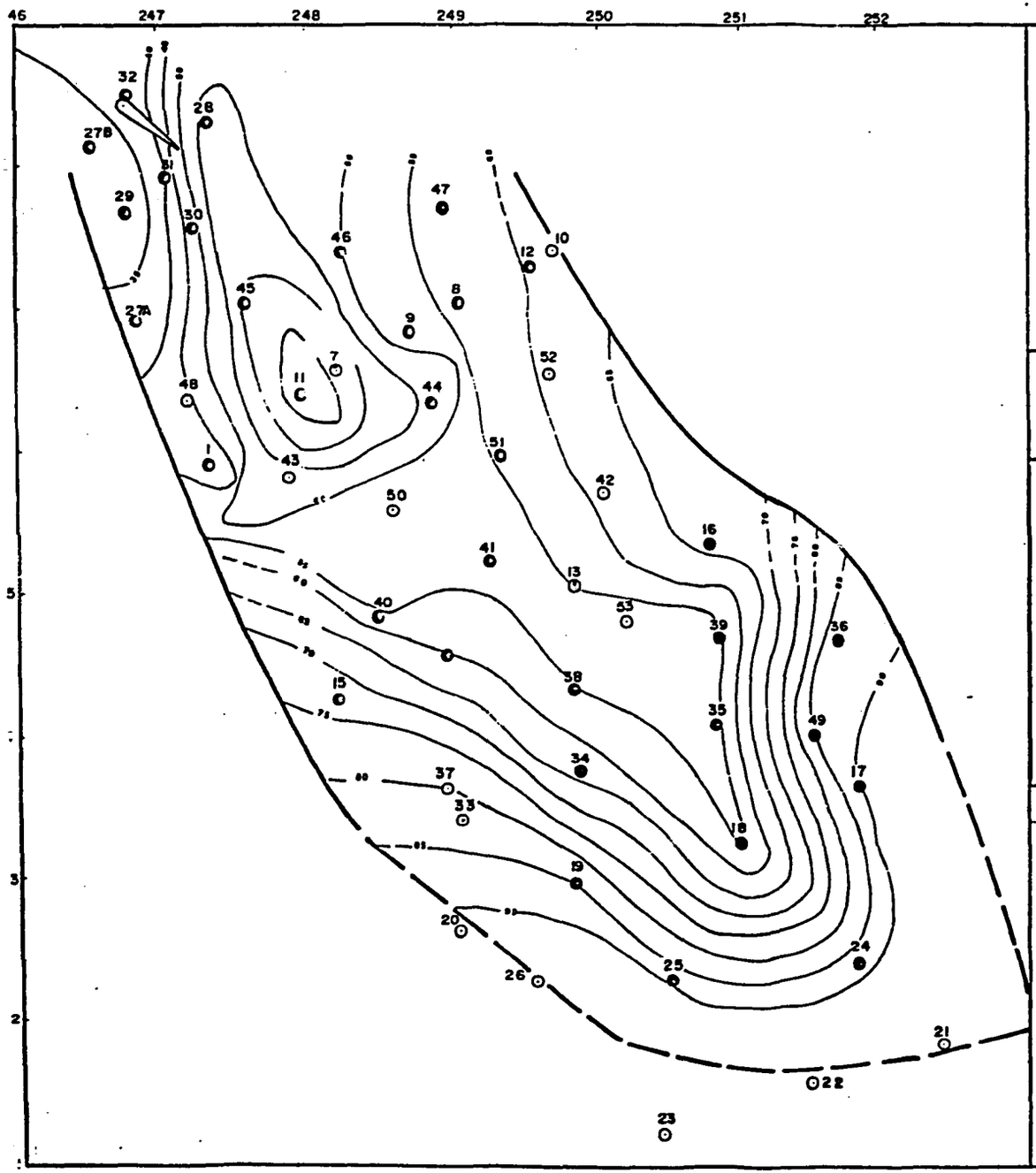
Prepared by: PROJECT STAFF .

Date: May / 1987

LEGEND

- POSITIVE
- NEGATIVE
- INCOMPLETE

Fig. 6



THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY & MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

GEOLOGY DIRECTORATE

ECONOMIC GEOLOGY DIVISION

SULTANI OIL SHALE DEPOSIT

Isopach Map of the Overburden.

Scale 1 25,000

Prepared by: PROJECT STAFF.

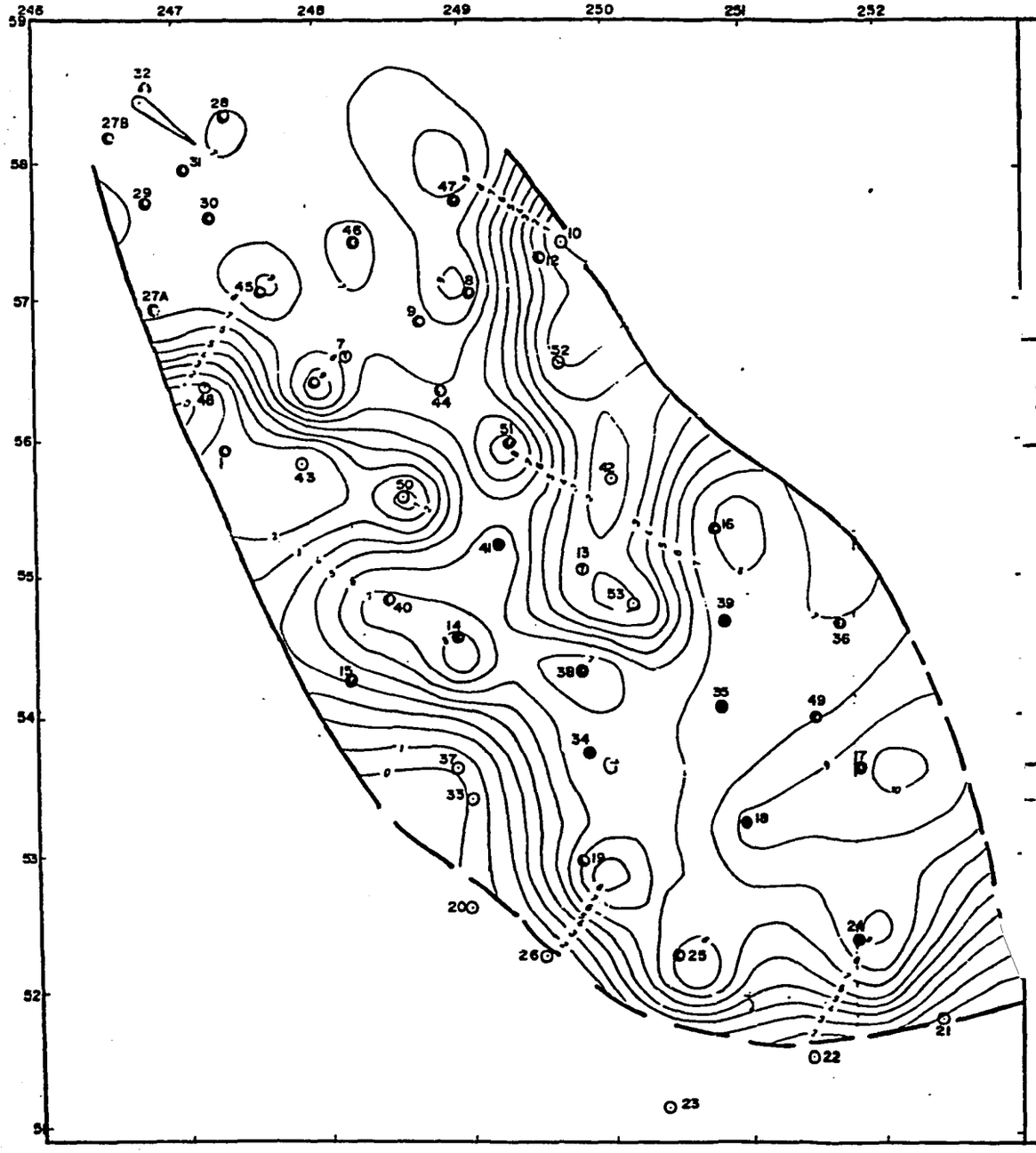
Date: May / 1987

LEGEND

- POSITIVE
- NEGATIVE
- INCOMLETE

Fig. 7

Fig. 7



THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF ENERGY & MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

GEOLOGY DIRECTORATE

ECONOMIC GEOLOGY DIVISION

SULTANI OIL SHALE DEPOSIT

Iso-Line Map of the Oil content %

Scale 1 25,000

Prepared by: PROJECT STAFF .

Date: May / 1987

LEGEND

- POSITIVE
- NEGATIVE
- INCOMPLETE

Fig. 8

بسم الله الرحمن الرحيم

JORDAN ELECTRICITY AUTHORITY

سلطة الكهرباء الاردنية

Ref. : 5/8/7/23533

Date : 23/8/1988

File Jordan

incoming correspondence

Mr. W.H. Linton
Project Manager
Bechtel Western Power Company
P.O.Box 3965
San Francisco, Ca. 94119
U.S.A

cc. Kudlu
Marcor
Perkins
Butler
Gold

Subject: Oil Shale to Power
Pre-feasibility Study

Dear Mr. Linton,

We refer to your letter dated July 21,1988 which includes your comments on our previous communication, please find below our response:

AA- Background Data:-

1- Noted

2- New Borehole Assay Results:-

Please see attachment No 1. NRA comment indicating preliminary evaluation of the mining area at Sultani Mine.

3- Contract Mining Bids:-

Please note that informations provided to you on May 7th 1988 regarding the average mining costs are real and represent the commercial mining operation costs derived from Phosphate Mining Company.

You can consider them in your project economic analysis, however you may use different values (max. min and average) for the purpose of the sensitivity analysis.

4- Estimated Cost of Power:

a- The present average cost of producing power (sent-out) from all JEA's power stations is 15 fils/kwh using the international oil prices. The same cost using local oil prices is 17 fils/kwh.

b- Estimated present local purchase cost for motor gasoline is 180 fils/liter and for diesel fuel is 65 fils/liter. The international present purchase cost are for:

Diesel : 127 USD/ton
Gasoline: 188 USD/ton

You may consider two senarios, first to keep a/m value constant, and second to add 1% for annual escallation.

5- Labor Rates:-

a- The total labor rates provided to you includes all benefits burden but you may add 5% to cover unforseen costs in the future.

b- The social security and health insurance costs are already included in the total labor rates.

BB- General Comments:-

1- We have received the outline attached to your letter dated 21 July for the final report. Please find in attachment No. 3 our comments on this outline.

2- We agree that Pyropower base their boiler design to burn not less than 2000 BTu/Lb oil shale and we expect that blending at yard have been considered to meet the minimum design requirements.

3- We still consider that the combustor operating temperature of 870 °C is too high and Pyropower should reduce it to minimize the calcination and to improve the efficiency.

4- Noted

5- Noted

6- Noted

7- Noted

8- Noted

بسم الله الرحمن الرحيم

JORDAN ELECTRICITY AUTHORITY

سلطة الكهرباء الاردنية

Ref. : _____

Date : _____

الرقم : _____

التاريخ : _____

9- Please refer to the enclosed attachment No. 2 containing current up to date cost data for investment and operation requirements for recent oil fired power plant rated 130 MW at Aqaba for your consideration in the economic analysis.

10- Noted.

11- Noted.

12- Noted.

13- Noted.

14- Noted.

Sincerely yours

W. Daouni
Assistant Director General

OD/ha

cc. Ass. D. G

Attachment No.1

PRELIMINARY EVALUATION OF THE MINING AREA/SULTANI MINE

The Natural Resources Authority implemented a drilling programme in Sultani area for the development of the existing mine at Sultani.(Area 1 , marked green and red in the attached fig 1, and area 11 marked yellow in the attached fig. 2) .

The programme aims to study the quantity and quality of the oil-shale.

The programme included drilling of boreholes in both areas with spacing of 150 meters with some minor exception .

Calculation of the oilshale strata thickness is based on the lithological logs and chemical results of the drilled boreholes .

In most of the drilled boreholes the lower part of the oilshale strata which has an oil content less than (4%) was excluded from the calculated oilshale thickness in the attached tables (1 & 2) .

The overburden was penetrated by hammer drilling and the oilshale strata by core drilling .

Nine boreholes were drilled in area I and 16 boreholes were drilled in area II . Borholes MA6 and M 14 have negative results,so the area marked in red colour was excluded from area I .

Table 1 & 2 show borehole number, overburden thickness, oilshale thickness, total depth and average oil content of each borehole .

As a result the follwing calculations were made for both areas:

Area I marked Green Fig -1:

- Total area	135,000	m**2
- Average thickness of Overburden	30.64	m
- Average thickness of OilShale	18.57	m
- Overburden Volume	4,136,400	m***3
- Oilshale Volume	2,506,950	m***3
- Oilshale Quantity	4,512,510	ton
- Stripping Ratio	1 : 1.65	

Area II marked Yellow Fig -2:

- Total area	416,100**2	
- Average thickness of Overburden	42.72	m
- Average thickness of Oilshale	25.9	m
- Overburden Volume	17,775,792	m***3
- Oilshale Volume	10,776,990	m***3
- Oilshale Quantity	19,398,582	ton
- Stripping Ratio	1 : 1.6	

3/...

- N.R.A may continue the drilling programme to cover the area marked blue on your drawning (Bechtel M & M 3/24/88 preliminary draft) .
- In order to define the quantity and quality of the Oil Shale, over burden thickness and oilshale thickness in the North Pit area suggested by you, at least additional (42) borholes must be drilled in this area and the cost of these boreholes must be included in the evaluation of the feasbility study .

NOTES

- Calculation for area II was based on the influence area of boreholes as shown in fig [3] and table [3]
- Isopach map of oilshale, for Area 1 and Area II is attached .

AREA I

Item	B.H No.	Thickness Oilshale m	Thickness Overburden m	Shale Oil %	Total Depth m	Remarks . .
1	M1	0.5	30.	7.6	30.5	In Mine
2	MA1	19.	37.5	8.05	60.	3.5m Phosp
3	M5	17.	30.5	7.3	50.	2.5 "
4	MA17	19.	43.	7.05	65.	3. "
5	MA3	17.	37.	7.7	56.	2. "
6	MA2	12.	31.	7.3	48.	5. "
7	MA5	16.	36.	7.4	56.	4. "
	AVERAGE	18.57m	30.64	7.75%		

$$\frac{30.64}{18.57} = 1.65$$

Stripping Ratio= 1 :1.65

Table(1) Average Of Thicknesses and Shale Oil of sixteen drilled boreholes in NW site of SULTANI area.

AREA II

Item	B.H No.	Thickness Oilshale m	Thickness Overburden m	Shale Oil %	Total Depth m	Remarks . .
1	MA4	24.	44.5	8.3	76.5	8. m Pho
2	M13	21.	43.5	7.2	65.	0.5 "
3	MA8	15.	42.	7.3	61.	4. "
4	MA7	14.	36.	7.5	51.	1. "
5	M15	10.	36.	8.4	49.5	3.5 "
6	MA16	14.	40.	6.9	66.	12. "
7	MA9	31.5	40.	7.1	75.5	4. "
8	MA10	33.5	41.	7.4	76.	5. "
9	MA11	25.5	43.	7.5	70.5	2. "
10	M16	18.5	52.	7.6	73.5	3. "
11	M12	40.	40.	9.1	86.5	6.5 "
12	MA12	35.5	40.	7.9	80.	4.5 "
13	MA15	20.	54.	7.3	74.	Inprogre
14	MA14	39.	40.	8.	79.	"
15	MA13	25.	42.	8.	67.	"
16	M17	48.	49.5	8.5	101.5	3.5m Ph
	AVERAGE	25.9062 m	42.71875	7.75%		

57.5 ÷ 13 =
avg. 4.47
14.5 fo

$$\frac{42.7187}{25.9062} = 1.64$$

Stripping Ratio= 1 :1.64

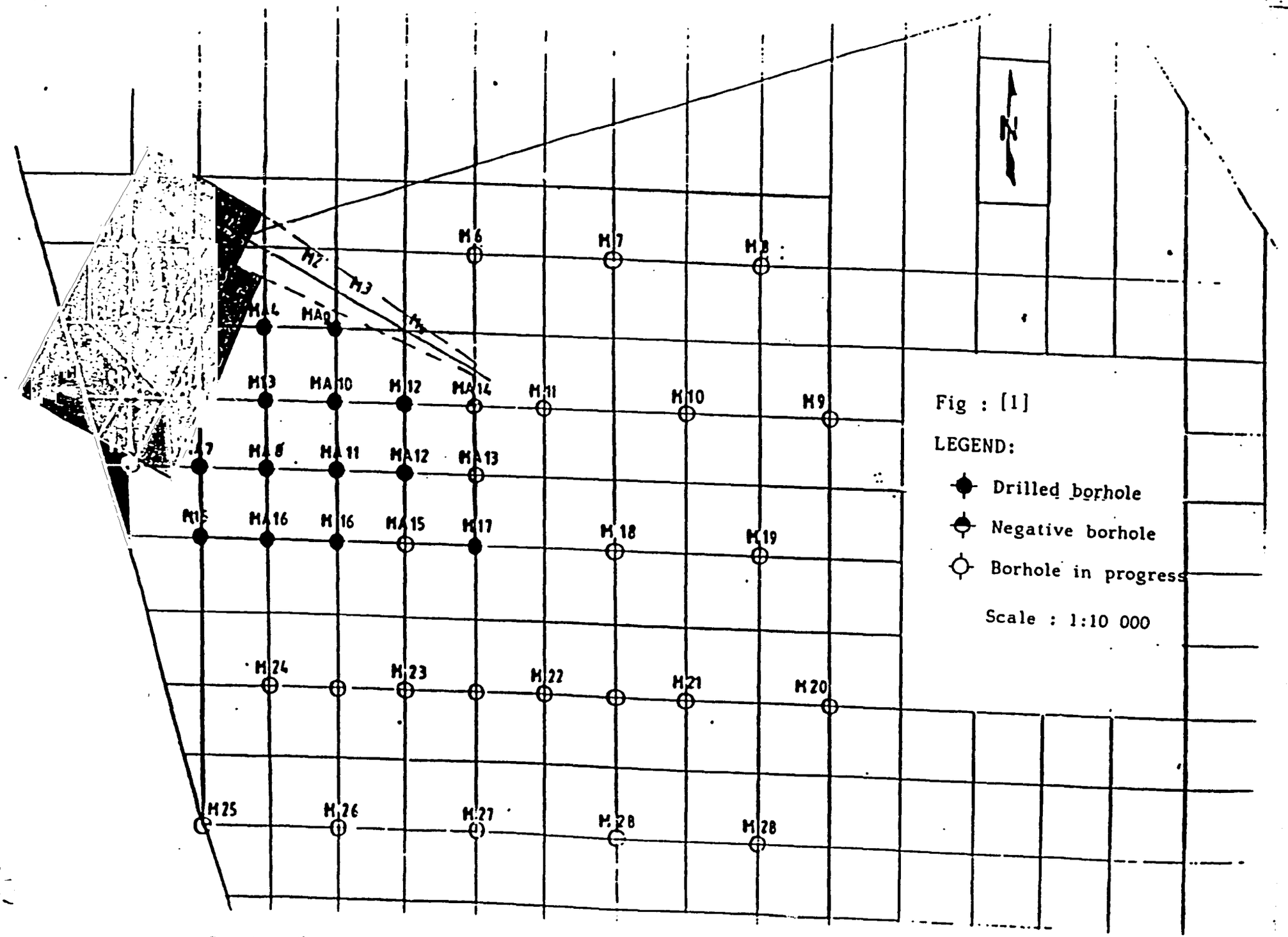
Table(2) Average Of Thicknesses and Shale Oil of sixteen drilled boreholes in NW site of SULTANI area.

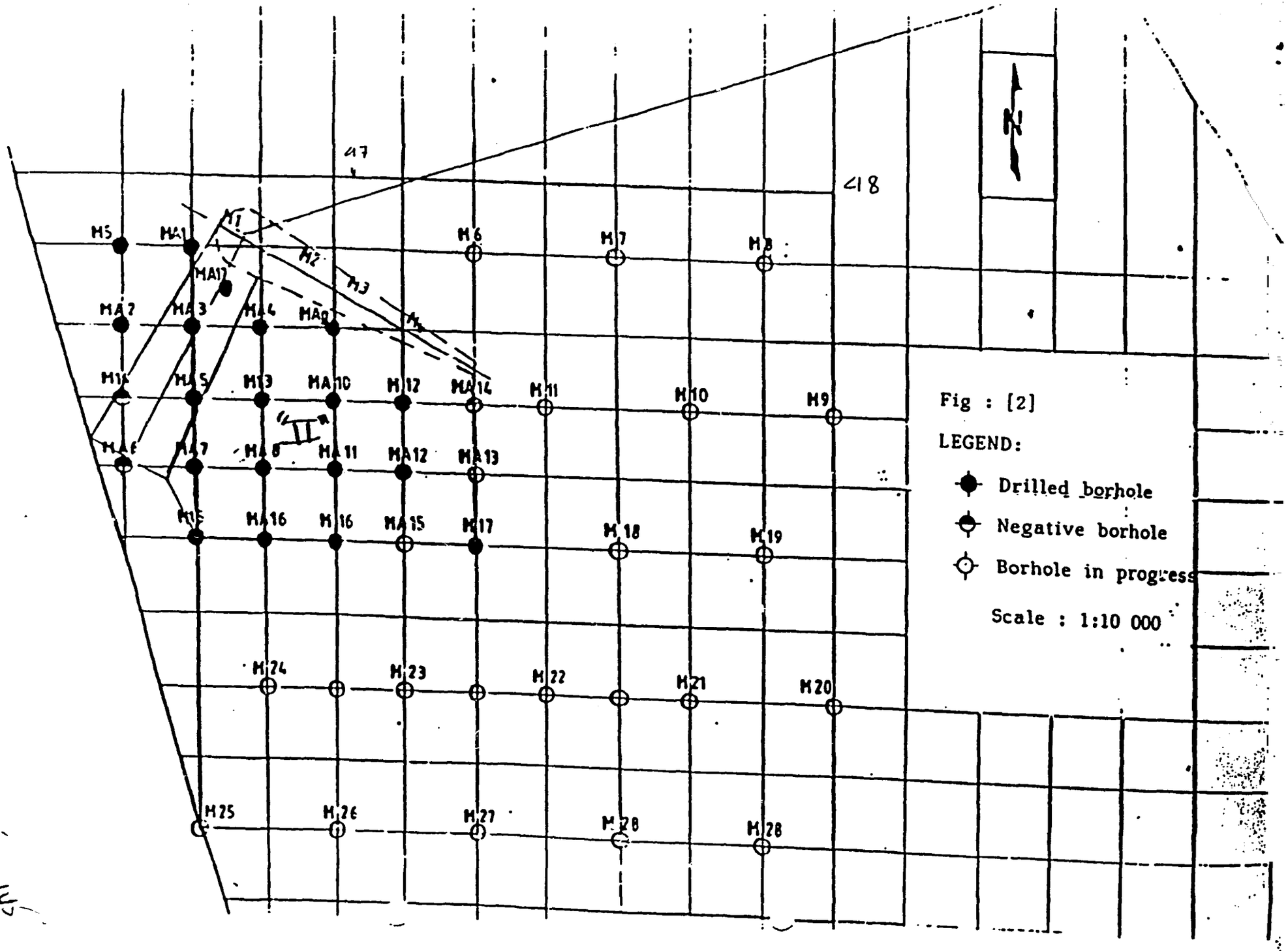
142

Item	B.H No.	Area of Influn. sq.m.E6	Thickn. Ore bod m	Oil conten. %	Thickn. Ov.burd m	OilShal. Ton. E6	Oil. Cont. to.E6	Ov.burd. cub.m E6
1	MA4	0.0450	24.0000	0.0830	44.5000	1.9440	0.1614	2.0025
2	M13	0.0337	21.0000	0.0720	43.5000	1.2752	0.0918	1.4675
3	MA8	0.0337	15.0000	0.0730	42.0000	0.9109	0.0665	1.4169
4	MA7	0.0056	14.0000	0.0750	36.0000	0.1416	0.0106	0.2022
5	M15	0.0056	10.0000	0.0840	36.0000	0.1011	0.0085	0.2022
6	MA16	0.0337	14.0000	0.0690	40.0000	0.8501	0.0587	1.3494
7	MA9	0.0337	31.5000	0.0710	40.0000	1.9128	0.1358	1.3494
8	MA10	0.0225	33.5000	0.0740	41.0000	1.3559	0.1003	0.9219
9	MA11	0.0225	25.5000	0.0750	43.0000	1.0321	0.0774	0.9669
10	M16	0.0225	18.5000	0.0760	52.0000	0.7488	0.0569	1.1693
11	M12	0.0337	40.0000	0.0910	40.0000	2.4290	0.2210	1.3494
12	MA12	0.0225	35.5000	0.0790	40.0000	1.4369	0.1135	0.8994
13	MA15	0.0225	20.0000	0.0730	54.0000	0.8095	0.0591	1.2142
14	MA14	0.0337	39.0000	0.0800	40.0000	2.3683	0.1895	1.3494
15	MA13	0.0225	25.0000	0.0800	42.0000	1.0119	0.0809	0.9444
16	M17	0.0225	48.0000	0.0850	49.5000	1.9428	0.1651	1.1131

Total Oilshale = 20.2708 *E6 ton
Total Oil Content = 1.5971 *E6 ton
Total Over burden = 17.9184 *E6 cub.m
Total Area = 0.4161 *E6 sq. m

Table(3)..Oilshle Reserve Of Area II NW Site
Of SULTANI OILSHALE DEPOSIT.


N
M6
M7
M8
M2
M3
M4
MA4
MA9
M13
MA10
M12
MA14
M11
M10
M9
MA8
MA11
MA12
MA13
MA16
M16
MA15
M17
M18
M19
M24
M23
M22
M21
M20
M25
M26
M27
M28
M28
Fig : [1]
LEGEND:
Drilled borhole
Negative borhole
Borhole in progress
Scale : 1:10 000


47
48
N
M5
MA1
M1
M2
M3
M4
MA17
MA2
MA3
MA4
MA9
M6
M7
M8
M15
MA5
M13
MA10
M12
MA14
M11
M10
M9
II
MA6
MA7
MA8
MA11
MA12
MA13
M14
MA16
M16
MA15
M17
M18
M19
M24
M23
M22
M21
M20
M25
M26
M27
M28
Fig : [2]
LEGEND:
Drilled borhole
Negative borhole
Borhole in progress
Scale : 1:10 000

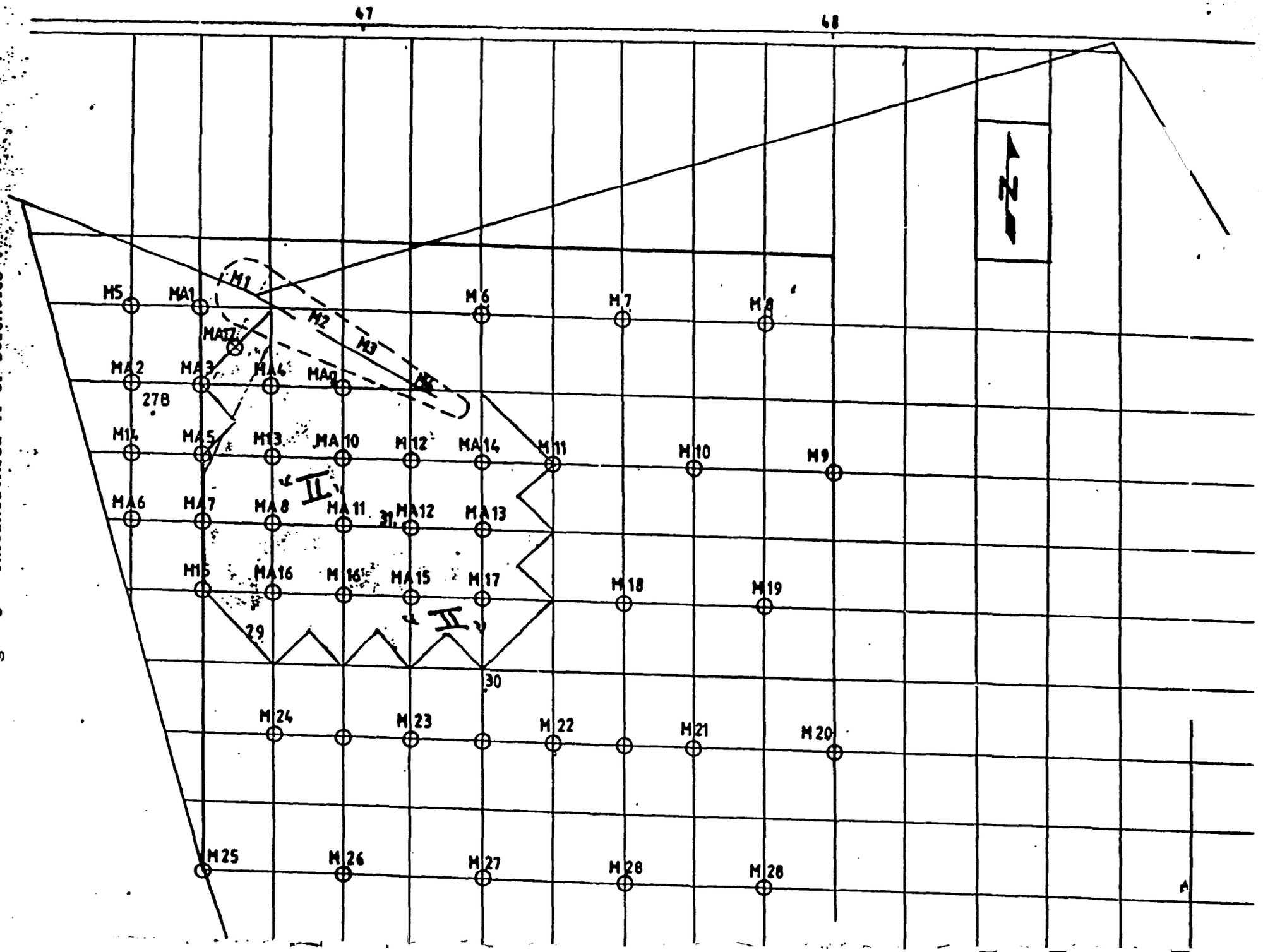
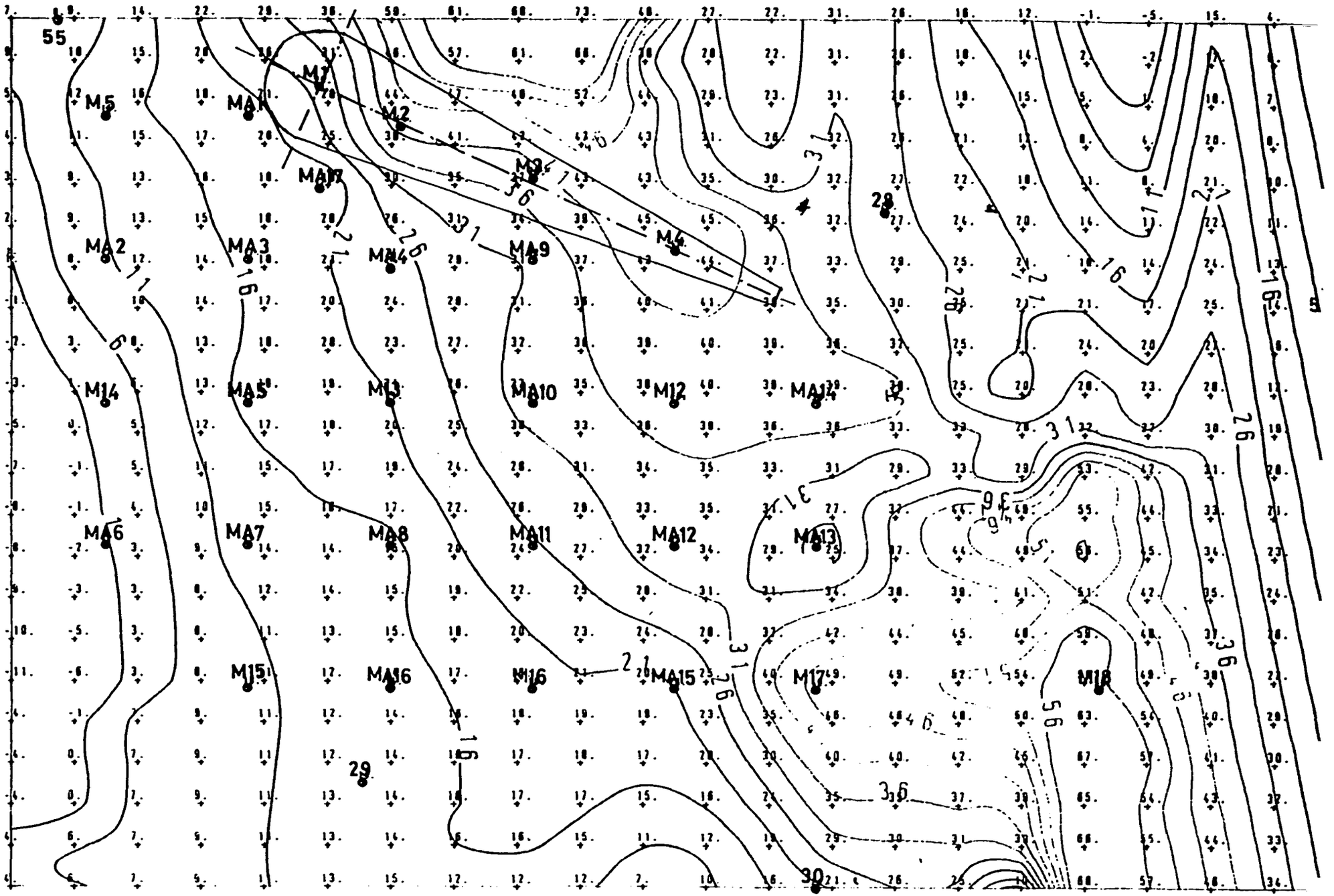


Fig - 3 - Influnce Area II of boreholes

SI 'A LSI E PRO. ECT

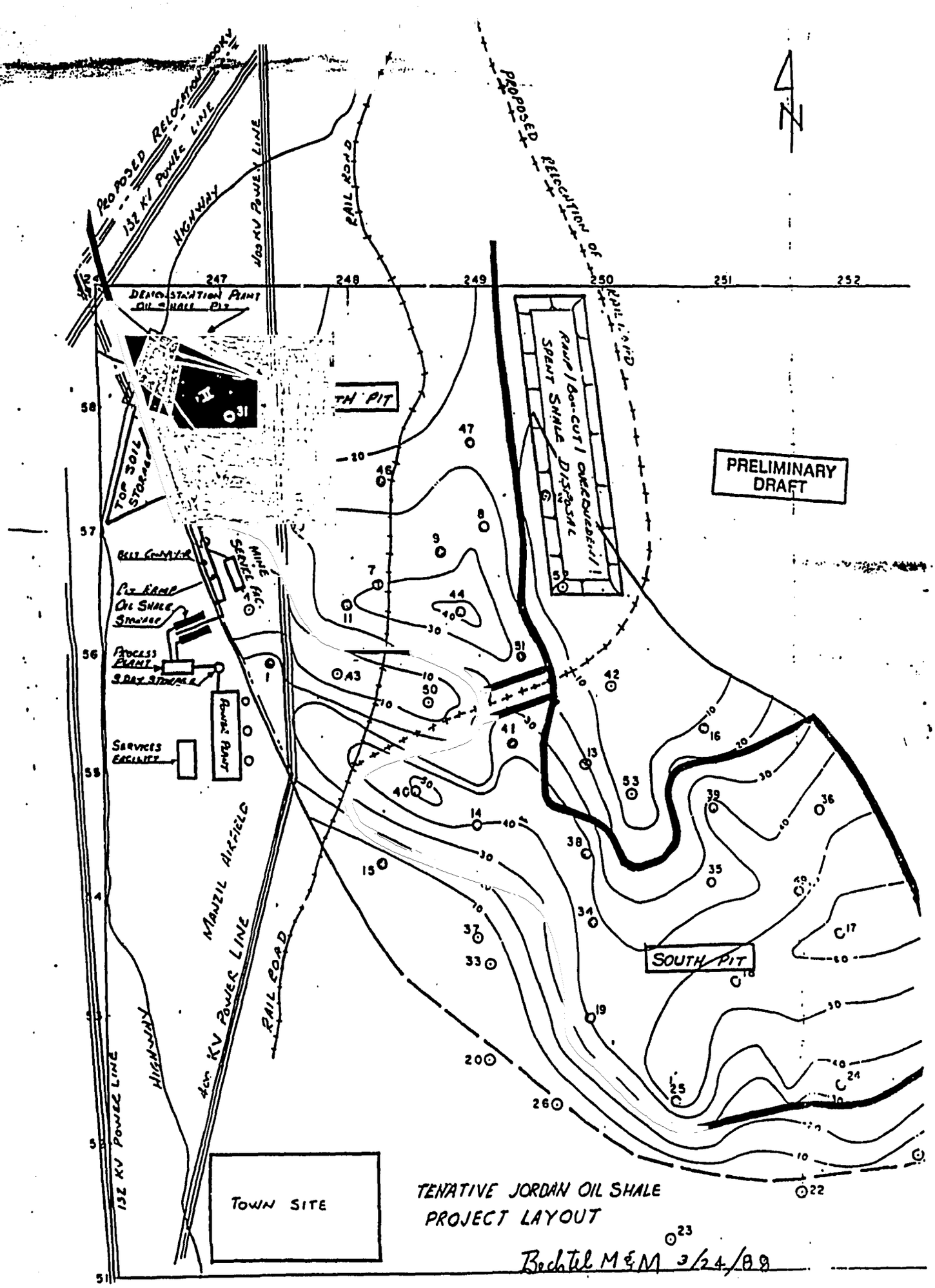


o Drilled Borehole
• Oilshale Thicknesses

OILSHALE ISOPACH MAP (NW-SULTANI AREA)

SCALE 1:3750

Prepared By: Eng. S.A
ining Dire lorate



TENATIVE JORDAN OIL SHALE PROJECT LAYOUT

Bechtel M&M 3/24/88

ATTACHMENT NO 2

FUEL OIL FIRED THERMAL POWER STATION 2X130 MW AT AQABA

Average annual production cost (fils/KWh) 1987

Alternative Costs	(Fils/Kwh)
DIESEL OIL	0.02
FUEL OIL	8.86
MAINTENANCE	0.27
OPERATIONAL COSTS	0.08
FIXED COSTS	
SALARIES	0.66
INSURANCE	0.07
ADMINISTRATIVE COSTS	0.02
DEPRETIATION (LIFE TIME 30 YRS)	2.28
TOTAL PRODUCTION COSTS GENERATED	12.25
TOTAL PRODUCTION COSTS SENT-OUT	13.60

Please note that the actual capital costs of the station is 318 JD/Kw installed.

* Additional 2 fils/kwh for loan interests and 2 fils/kwh for overheads and transmission losses shall be included.

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ATTACHMENT NO. 3

JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY

FINAL REPORT OUTLINE

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JORDAN OIL SHALE TO POWER
PREFEASIBILITY STUDY

SECTION 8.0 ECONOMIC ANALYSIS

A. BASE CASE

New 400 MW coal and oil fired power plant installed at AQABA 1995-2000.

Imported low sulfur, high heating value coal laid in at AQABA for:

A. U$50/Ton
B. U$70/Ton

Imported fuel oil at AQABA for:

A. U$ 70/Ton
B. U$ 90/Ton

B. OIL SHALE CASE STUDIES

Case 1	400 MW fully integrated shale fired power plant comprising 4x100MW boilers supplying steam for 4x100MW turbine generators.
Case 2	(Same as Case 1) but shale mining and ash disposal via contract operations.
Case 3	50 MW fully integrated shale fired power plant comprising 1x50 MW boiler and 1x50 MW turbine generator.
Case 4	(Same as Case 3) but shale mining and ash disposal via contract operations.
Case 5	20MW demonstration project based on contract mining and ash disposal.

C. OBJECTIVES

1. Develop Order of Magnitude Project Investment Costs and Operating Requirements.

2. Determine Years Required for Fuel Savings to Payout Incremental Investment for Oil Shale vs. Coal and fuel oil Fired Power Plants at Present Cost at Power in Jordan.

3. Determine Cost of Power at Several Alternative ROR on Required Project Capital Investment Costs for:

   A. Debt/Equity = 50/50
   B. Debt/Equity = 80/20

4. Identify Conditions That Make Power From Oil Shale Economically Viable.

   Define Subsidy Required for the 20 MW Demonstration Project.

5. Create Cash Flow Tables for Selected Key Case Studies.

6. Identify Area Needing Further Engineering Study and Testing.

APPENDIX 3

AHLSTROM PYROFLOW PROCESS BACKGROUND

AHLSTROM PYROFLOW PROCESS BACKGROUND

1.1 OPERATING EXPERIENCE

There are more than 60 Ahlstrom Pyropower units in operation or under construction worldwide with over 100 unit years of operating experience. Five (5) of the operating units are in the United States, with sixteen (16) more under construction in this country. Together, Ahlstrom and Pyropower offer the most comprehensive experience with CFB technology available in the world today.

This extensive operating history is of value to the customer because it saves money in terms of plant efficiency and operating cost. Ahlstrom Pyroflows are located in four of Ahlstroms own paper mills. This makes Ahlstrom unique among boiler suppliers - focusing our designs on user sensitivity. As a result of our experience, many improvements have been made to the Ahlstrom Pyroflow boiler to enhance reliability and to lower maintenance costs. The Ahlstrom Pyroflow has consistently demonstrated availabilities in excess of 95%, even in the most demanding operating situations such as pulp and paper mills, chemical plants, etc. No Ahlstrom or Pyropower unit has ever failed to delivery 100% of the rated steam conditions including those permitted in accordance with the strictest emission limits. A complete Pyroflow installation list as well as boiler availability data is presented at the end of this section. A summary of selected key projects is presented below:

Hylte Bruks - Hylte Bruk, Sweden

The Pyroflow boiler at Hylte Bruk (143,000 lb/hr) has been operating very successfully since its startup in August 1982. Hylte Bruk AB is one of Europe's major newsprint producers with an output of 540,000 tons of newspaper per year. This plant has two base loaded boilers, one fired with sulfite liquor and one with bark. The Pyroflow unit is used to carry the plant's load swings.

It is fired primarily with coal and supplemented with caustic de-inking sludges. The availability of the Hylte Bruk Pyroflow unit has been extremely high, averaging nearly 100% since its startup.

Kauttua Paper Mill - Kauttua, Finland

The Kauttua cogeneration plant has been in operation since June 1981, producing 200,000 lb/hr of steam and electric power for a paper mill. As an Ahlstrom owned unit, this boiler has been used for product development and demonstration tests. This unit has been tested at full power with 2.8% sulfur British coal and Swedish limestone as well as with petroleum coke containing more than 3% sulfur. High sulfur retention and low NO_x generation have been demonstrated with all of these fuels.

Kemira, Oy, Oulu, Finland

Kemira Oy, a major Finnish chemical producer, utilizes a 155,000 lb/hr Pyroflow unit which cogenerates steam and electrical power and also supplies district heat to a nearby town. This unit burns a mixture of coal, wood waste, Koppers-Totzek coal gasifier fines and peat. This unit has been operating extremely well since its start-up in December 1982.

Frantschach AG Pulp and Paper Mill - Frantschach, Austria

A 154,000 lb/hr Pyroflow unit was started up in mid-1983 in Frantschach, Austria. This unit burns high ash brown coal which is very similar to U.S. lignite. This unit has operated very satisfactorily since 1983.

OCI - Inchon, Korea

A 264,000 lb/hr Pyroflow boiler was commissioned in 1984 at the Oriental Chemical Company plant in Inchon, Korea. This unit is

designed to burn petroleum coke and coal separately or in any combination and to use limestone for sulfur removal.

CalMat Co. - Colton, CA.

In 1985, Pyropower Corporation furnished the Pyroflow CFB unit for the California Portland Cement divison of CalMat. The 191,3000 lb/hr unit burns Utah coal, and is part of 25 MW_e cogeneration project to provide steam for electrical generation. The project supplies all electrical power to the plant, and approximately 10 MW_e is sold to the local utility. No external air pollution control equipment other than baghouse is required for operation in one of the most stringent areas in the country in terms of air pollution control. The unit was commissioned in 1985.

B.F. Goodrich Co. - Henry, ILL.

A 125,000 lb/hr Pyroflow unit was started up at the B.F. Goodrich vinyl and specialty chemicals plant in Henry, Illinois in September 1985. The unit burns high sulfur Illinois coal, and utilizes Illinois limestone for sulfur retention. Actual emission levels have been significantly lower than design levels, and boiler performance tests were successfully completed in February 1986. The boiler is used to generate process steam for manufacturing.

General Motors Assembly Plant - Pontiac, MI.

The Pyroflow CFB for General Motors' Pontiac Motor Divisions burns high sulfur coal to generate 300,000 lb/hr of steam for process manufacturing space heating and electricity. Boiler erection was substantially complete by May1985, and first firing and boilout took place in July of 1986. The Pyroflow unit is designed to generate 27 MW_e through a turbine generator, as well as steam for manufacturing and heating of approximately 12 million square feet of the assembly plant.

Colorado-Ute Electric Association - Nucla, CO.

In 1984, Pyropower Corporation was awarded a contract to design and construct the world's first utility-scale CFB for the Colorado-Ute Electric Association's Nucla, Colorado plant. The application is a repowering of the refired Nucla Station, and the new Pyroflow unit produces 925,000 lb/hr of steam at 1510 psig and 1005°F to generate 110 $MW_{(e)}$ of electricity. The unit burns a Colorado bituminous coal with limestone. Erection of major components and hydrostatic testing was completed in September, 1986. The refractory was cured late in 1986 and boilout completed in mid-April, 1987. The boiler is currently in start-up, with generator outputs up to the 110 MW_e having been demonstrated. Performance and acceptance testing was completed in August 1988. The Electric Power Research Institute (EPRI) will conduct a 2 year test program to demonstrate the feasibility of CFB combustion for utility applications when acceptable testing is complete.

Gilberton Power Co. - Gilberton, PA.

In January of 1986, a Joint Venture agreement was finalized between subsidiaries of Pyropower Corporation, Bechtel and RiCorp Development, Inc. to build, own and operate a cogeneration power plant in Schuylkill County, Pennsylvania. Two Pyroflow units will supply 710,000 lb/hr of steam at 1500 psig and 955°F to generate 80 $MS_{(e)}$ of electricity and steam for a nearby coal drying plant. Steam blows were successfully completed in February 1988 and full power production is scheduled for latter half of this year.

Iowa State University - Ames, IA.

Pyropower Corporation received a contract award in April 1986 to design and construct two Pryoflow CFB boilers for the Ames Campus of Iowa State University. Each boiler will generate 170,000 lb/hr of steam for cogeneration of 15 MW_e for University use and for heating University facilities. Hyrostatic testing was completed in March of 1988 and commercial operation is expected in September of this year.

Air Products and Chemicals, Inc/Corn Products - Stockton, CA

In 1986 Pyropower Corporation was also awarded a contract to deliver a 500,000 lb/hr Pyroflow to Corn Products' Stockton, California corn wet milling CFB boiler plant. The cogeneration project will produce steam needed for the corn wetmilling process, and for generation of electricity, 49.9 megawatts of which will be sold to the local utility. First coal firing was successfully completed in February 1988 and the plant has operated at 100% MCR, producing 53 $MW_{(e)}$. Commercial operation is scheduled for July of this year.

J. A. Jones/Duke Power - Fort Drum, NY

A contract for 3 Ahlstrom Pyroflow units was awarded to Pyropower Corporation by J. A. Jones Construction Company who are building a cogeneration facility for the new light infantry development Army base at Fort Drum, New York. The cogeneration plant is owned by a limited partnership in which Pyropower and Ahlstrom Capital Corporation are both participating. The 3 Pyroflow boilers, rated at 175,000 lb/hr. of steam each, will supply 525,000 pounds of steam per hour to provide the U.S. Army with high temerature water for distribution at the base, and 49.9 megawatts of electricity for sale to the Niagara Mohaw Power Company. Construction of the cogeneration facility began in early 1987, and initial steam service to the Army will commence in the third quarter of 1988.

P. H. Glatefelter Co. - Spring Grove, PA

The first Pyroflow unit in the United States for use by the pulp and paper industry was contracted to Pyropower in late 1986 by the P. H. Glatfelter Company located in Spring Grove, Pennsylvania. The 400,000 lb/hr unit will cogenerate steam and power for uses at the pulp and paper mill. This is a multi-fuel unit designed for the combustion of coal in combination with wood waste, anthracite culm, fuel oil and sludge. The unit is scheduled for startup in early 1989.

University of North Carolina - Chapel Hill, NC

The University of North Carolina, Chapel Hill, contracted for two 250,000 lb/hr Pyroflow units in April of 1987. The units will generate steam for heating and power for the Chapel Hill Campus, including critical research and hospital facilities. The new system, to go on-line in the forth quarter of 1989, will refurbish the University's existing utility system.

Southeast Paper Manufacturing Co. - Dublin, GA

In October of 1987, Pyropower received a contract to deliver a 400,000 lb/hr Pyropower boiler to the Southeast Paper Mfg. Co. as part of a $300 million expansion of their Dublin, Georgia newsprint mill. The steam will be used in the newsprint production process and to generate electric power. The boiler will burn Eastern bituminous coal and suldge from the pulp-making process to generate the steam and approximately 65 $WE_{(e)}$ for use by the plant. Delivery of the pressure parts for this unit is scheduled for August 1988, with startup beginning in mid-1989

Boise Cascade/Rumford Cogeneration - Rumford, ME

In September, 1987, Boise Cascade awarded Pyropower a contract to furnish two(2) Ahlstrom Pyroflow boilers to the Rumford Cogeneration Company, a cogeneration project in which Boise Cascade is the general partner and an affiliate of Pyropower and Ahlstrom Capital Corporation is the lead limited partner.

The two boilers, each rated at 415,000 lb/hr of steam, will generate 85 $MW_{(e)}$ gross. The two CFB units are replacing three of four older oil-fired boilers at the plant and will fire coal, biomass and oil. Approximately 75 $MW_{(e)}$ will be purchased by the local utility, and Boise's Rumford pulp and paper mill will purchase steam for its process and heating needs. CFB combustion will improve air quality in the Rumford area by reducing emissions. Particulate emissions will be lowered by an estimated 60%, and SO_2 emission by about 40%. Pressure parts for the boilers will be delivered in late 1988, and commercial operation is scheduled for January of 1990.

Mt. Poso Cogeneration Co. - Bakersfield, CA.

A contract for a 500,000 lb/hr Pyroflow unit was awarded to Pyropower in June of 1987 by the Mr. Poso Cogeneration Co. The Mt. Poso plant will be owned and operated by Pyropower Corporation, On-Site Energy, and Bechtel Corporation. The boiler will burn low sulfur coal to generate steam for supplement oil recovery from the Mt. Poso Field - West area and for generating 49.5 $MW_{(e)}$ of electricity for sale to the local utility. Construction is presently underway, and hydrostatic testing of the pressure parts has been completed. Commercial operation is expected in July of 1989.

ACE Cogeneration Co. - Trona, CA

In April of 1988, the ACE Cogeneration Company was formed to build, own and opearate a 96 $MW_{(e)}$ cogeneration demonstration facility near Kerr-McGee Chemical Corporation's Trona, CA., facility. An affiliate of Pyropower is a general partner in the $270 million project, and Pyropower is supplying the 910,000 lb/hr Pyroflow boiler. The ACE facility will provide an average of 60,000 lb/hr of steam for use within Kerr-McGee's Chemical complex and supply up to 96 megawatts of electricity to Southern California Edison Company.

1.2 COMPANY BACKGROUND

Pyropower Corporation is a U.S. corporation and a wholly owned subsidiary of the A. Ahlstrom Corporation. The A. Ahlstrom Corporation, established in 1851, is a multinational, privately owned, integrated industrial company headquartered in Helsinki, Finland. The company has been involved in fluidized bed combustion since the 1960s, when it began building FBC boilers for a variety of process applications. The company's business sectors are Engineering & Automation, Special Papers, Packaging and Converting, and Building Materials. Sales in 1987 exceeded $1.1 billion. The number of employees is approximately 12,000.

In the late '70s, A. Ahlstrom Corporation's executive management made a major decision to commit extensive resources to develop the American

market for their pulp and paper and energy products. This commitment involved the creation of four operating subsidiary companies. One of these companies - Pyropower Corporation - began as a joint venture in 1980 between GA Technologies of San Diego, California, and Ahlstrom to market Ahlstrom Pyroflow Circulating Fluidized Bed (CFB) combustion boilers in the U.S. Today, Ahlstrom is the sole owner of Pyropower, and the subsidiary company has achieved a high level of success in marketing the efficient and environmentally sound solid-fuel fired boilers to industrial process, cogeneration and electric utility customers for steam and/or electricity generation.

Since its establishment in 1980, Pyropower has booked in excess of $230 million in sales, including the world's first circulating fluidized bed boiler for a utility; Pyropower supplied a Pyroflow boiler for the Colorado-Ute Electric Association's refurbishment of its Nucla generating station. Pyropower has been awarded 38% of all CFB boiler contracts in the U.S. in the last five years, with the other 62% divided between 7 other competitors. This is a remarkable accomplishment for a company that had five employees in 1980. Pyropower employs about 220 at present. Along with the Pyroflow system, Pyropower also provides the U.S. market with the full range of boiler related services.

In addition ot its own facilities and personnel, Pyropower has complete access to Ahlstrom's testing facilities and personnel. This type of backup support is essential in the boiler supply field.

INSTALLATION LIST
AHLSTROM PYROFLOW UNITS IN OPERATION

CUSTOMER	FUELS	STEAM CONDITIONS	APPLICATION
1979			
Savon Voima Oy Suonenjoki, Finland	100% peat 100% oil	160 psig; 250°F hot water; 22MMBtu	Dist. Heating
Suomen Kuitulevy Oy Pihlava, Finland	100% peat 100% woodwaste	1230 psig; 970°F 45,000 lb/hr	Cogeneration- Retrofit
1981			
A. Ahlstrom Corp. Kauttua, Finland	100% peat 100% coal	1235 psig, 930°F 200,000 lb/hr	Cogeneration
Hyvinkaan Lampovoima Oy Hyvinkaa, Finland	100% coal 80% oil 80% peat	160 psig; 355°F hot water; 85MMBtu/hr	Dist. Heating
1982			
Hylte Bruk AB Hyltebruk, Sweden	100% peat 80% coal	960 psig; 840°F 143,000 lb/hr	Cogeneration
Skelleftea Kraft AB Skelleftea, Sweden	100% peat 100% oil	160 psig; 355°F hot water; 22MMBtu	Dist. Heating
1983			
A. Ahlstrom Corp. Varkaus, Finland	100% woodwaste	885 psig; 895°F 55,000 lb/hr	Cogeneration- Retrofit
Gulf Oil Exploration Co. Bakersfield, CA., USA	100% coal limestone 80% quality	2500 psig; 670°F 50,000 lb/hr	Enchanced Oil Recovery Once Thru Design
Kemira Oy Onlu, Finland	100% peat 80% coal	1305 psig; 960°F 155,000 lb/hr	Cogeneration
Oy Alko Ab Kosekenkorva, Finland	100% peat 100% oil	610 psig; 840°F 55,000 lb/hr	Process Steam
Zellstoff und Papierfabrik Frantschach AG Frantschach, Austria	100% peat 100% oil 67% brown coal limestone	1250 psig; 968°F 154,000 lb/hr	Cogeneration
1984			
Oriental Chemical Co. Inchon, Korea	100% petroleum coke 100% coal limestone	1580 psig; 970°F 264,000 lb/hr	Cogeneration

INSTALLATION LIST
AHLSTROM PYROFLOW UNITS IN OPERATION (CON'T)

CUSTOMER	FUELS	STEAM CONDITIONS	APPLICATION
1985			
B. F. Goodrich Co. Henry, ILL, USA	100% coal limestone	500 psig; 470°F 125,000 lb/hr	Process Steam
California Portland Cement Co. Colton, CA, USA	100% coal 100% woodwaste	650 psig; 825°F 190,000 lb/hr	Cogeneration
Central Soya Chattanooga, TN, USA	100% coal limestone	190 psig; 384°F 88,000 lb/hr	Process Steam
Kerava Energy Works Kerava, Finland	100% coal 90% peat	145 psig; 355°F 220,000 lb/hr	District Retrofit
Metsaliiton Teollisuus Oy Aanekoski, Finland	90% woodwaste 90% peat	1215 psig; 896°F 220,000 lb/hr	Cogeneration- Retrofit
Ostersunds Fjarrvarme AB Ostersund, Sweden	100% peat 100% wood chips 100% coal	160 psig; 355°F hot water; 85MM Btu/hr	District Heating
Papyrus Kopparfors AB Fors, Sweden	100% bark 100% peat	857 psig; 887°F 159,000 lb/hr	Cogeneration
1986			
Espoon Sahko Oy Espoo, Finland	100% coal limestone	145 psig; 355°F hot water; 237MMBtu	District Heating
General Motors Pontiac, MI, USA	100% coal plant wastes limestone	1460 psig; 955°F 300,000 lb/hr	Cogeneration
Kohler Papierfabrik Oberkirch, W. Germany	100% coal limestone	1667 psig; 955°F 220,000 lb/hr	Cogeneration
1987			
Colorado-Ute Elec. Assoc. Nucla Station, CO, USA	100% coal limestone	1510 psig; 1005°F 925,000 lb/hr	Electric Power
Kemira Oy Vuorikemi Pori, Finland	100% coal 90% peat limestone	1218 psig; 977°F 222,000 lb/hr	Cogeneration

INSTALLATION LIST
AHLSTROM PYROFLOW UNITS IN OPERATION (CON'T)

CUSTOMER	FUELS	STEAM CONDITIONS	APPLICATION
1987			
Lenzing AG Lenzing, Austria	100% brown coal 100% coal	1130 psig; 932oF 265,000 lb/hr	Cogeneration
KW Wactberg Wachtberg, W. Germany	100% borwn coal limestone	2582/551 psig; 986/797°F 386,000/394,000 lb/hr	Electric Power Reheat
Leykam Murztaler AG Gratkorn, Austria	100% coal	1755 psig; 968°F 364,000 lb/hr	Cogeneration
Solvay AG Ebensee, Austria	100% coal 50% woodwaste 70% oil, natural gas limestone	145 psig; 355°F 110,000 lb/hr	District
TWS Stuttgart, W. Germany	100% coal 50% gas limestone	1073 psig; 932°F 311,000 lb/hr	Cogeneration-
1988			
Corn Products Stockton, CA, USA	100% limestone	1550 psig; 955°F 500,000 lb/hr	Cogeneration
Gilberton Power Co. West Mahoney, PA, USA (Own/Operate)	100% anthracite waste	1500 psig; 955°F 2x355,000 lb/hr	Cogeneration
Iowa State University Ames, Iowa	100% coal limestone	410 psig; 750°F 2x170,000 lb/gr	Cogeneration

INSTALLATION LIST
AHLSTROM PYROFLOW UNITS UNDER CONSTRUCTION

CUSTOMER	FUELS	STEAM CONDITIONS	APPLICATION
1988			
Aluminium Pechiney Gardanne, France	100% coal limestone	2045 psig; 833°F 320,000 lb/hr	Cogeneration
Fort Drum Fort Drum, NY, USA	100% coal 100% anthracite 70% oil limestone, wood chips	1525 psig; 950°F 3x175,000 lb/hr	Cogeneration
Kuk Dong Oil Co., Ltd Seosan, Republic of Korea	100% petroleum coke 70% oil limestone	1566 psig; 968°F 264,000 lb/hr	Cogeneration
Kobe Steel, Ltd Chofu, Yamaguchi, Japan	100% coal & limestone	1323 psig; 932°F 119,049 lb/hr	Cogeneration
Omi-Kenshi Co. Ltd. Kakogawa, Hyogo, Japam	100% coal & limestone	882 psig; 905°F 77,162 lb/hr	Cogeneration
Somedith COF Marseilles, France	100% coal natural gas limestone	696 psig; 860°F 144,000 lb/hr	Cogeneration
Stadtwerke Pforzheim Power Pforzheim, W. Germany	100% coal limestone	2074/428 psig; 1004/995°F 198,000/184,000 lb/hr	Electric Rehea
Sunkyong Fibres Suwon, Rok, Korea	100% coke	1334 psig; 950°F 286,513 lb/hr	Cogeneration
Yuen-Foong-Yu Paper Mfg. Co. Taipei, Taiwan	100% coke 100% coal	1886 psig; 986°F 286,513 lb/hr	Cogeneration
1989			
Caledonian Paper Irvine, Scotland, GB	100% bark/coal 100% coal	363 psig; 436°F 143,653 lb/hr	Process Steam
Kajnuun Voima Oy Kajaani, Finland	100% peat, coal woodwaste, sludge mixture	1973 psig; 995°F 794,000 lb/hr	Electric Power
Lucky Yeochun, Rok, Korea	100% coal	1450 psig; 887°F 462,707 lb/hr	Cogeneration

INSTALLATION LIST
AHLSTROM PYROFLOW UNITS UNDER CONSTRUCTION (CON'T)

CUSTOMER	FUELS	STEAM CONDITIONS	APPLICATION
1989 (con't)			
Mt. Poso Cogeneration Bakersfield, CA, USA (Own/Operate)	Low sulfur Utah coal limestone	1550 psig; 955°F 500,000 lb/hr	Cogeneration
Nippon Steel Corp. Hirohata, Japan	100% coal & limestone	1522 psig;1060°F 551,155 lb/hr	Electric Power
PAMA Spring Grove, PA, USA	100% oil shale 50% culm, 50% oil limestone	624 psig; 950° 400,000 lb/hr	Cogeneration
Southeast Paper Mfg. Co. Dublin, GGGA USA	Low Sulfur eastern bitum. coal, de-inking sludge limestone	1300 psig; 950°F 400,000 lb/hr	Cogeneration
Sun Kyong Fibres Ulsan, Rok, Korea	100% coke	1624 psig; 950°F 441,278 lb/hr	Cogeneration
University of North Carolina Chapel Hill, NC, USA	100% coal 100% natural gas 80% oil limestone	1300 psig; 900°F 2x250,000 lb/hr	Cogeneration
1990			
Ace Cogeneration Project Kerr McGee Chemical Plant Trona, CA, USA	bituminous coal limestone	1525 psig/1005°F 910,000 lb/hr	Cogeneration
Kammerer Osnabruck, Germany	100% coal	1682 psig; 977°F 176,194 lb/hr	Cogeneration
KW Berrenrath Berrenrath, Germany	100% brown coal	1305 psig; 950°F 2x547,625 lb/hr	Electric Power
Rumford Cogeneration Co. Rumford, ME, USA	coal, biomass oil	1300 psig; 955°F 2x415,000 lb/hr	Cogeneration
1991			
Vaskiluodon Voima Oy Seinajoki, Finland	peat, bitum. coal, oil	2306/696 psig 1004°F/1004°F 881,848/767,472 lb/hr	Electric Power & District Heating Reheat

APPENDIX 4

NRA SULTANI BLENDED SAMPLE REPORT

APPENDIX 1

MINISTRY OF ENERGY AND MINERAL RESOURCES

NATURAL RESOURCES AUTHORITY

MINING DIRECTORATE

MINES DIVISION

SULTANI OIL SHALE

BLENDED SAMPLE REPORT

PREPARED BY

Eng. M. HADDAD

Eng . S. ABU - ALIM

NOVEMBER 7, 1987

SULTANI OILSHALE BLENDED

SAMPLE REPORT

In accordance with the agreement signed between Ministry of Energy and Mineral Resources and Pyropower Corporation, member of the AHLSTROM group, U.S.A. NRA had prepared and shipped (75) tons of crushed (25 mm. size) blended oilshale sample from Sultani open pit-mine with an oil content ranging between (7) to (8%) to karhula. This was based on the results of the average oil content of 18 boreholes drilled in Sultani Area. As shown in table 1.

1) Sample Site And Oilshale Characteristic.

NRA excavated a small open-pit-mine in Sultani Area. The excavations were carried out only in the overburden of the oilshale.

The sample was taken from the top layers of the oilshale. These layers are interbeded with low bituminized shale.

The upper part of the oilshale in Sultani Area (which is about 4 meters thick) was divided into sub-units- in order to take a sample representing this part. Samples were taken from these subunits for lab. analysis to determine mainly the oil content in these units. Table 2, shows the results of the lab analysis.

For the purpose of preparing a blended sample based on the results shown in table 2. The following quantities were collected.

Sub - Unit	Quantity
A_1	20 m3
A_2	20 m3
B_1	10 m3
B_2	20 m3

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Sub - Unit	Quantity
C_1	10 m3
C_2	20 m3
D_1	20 m3
D_2	10 m3

II) Sample Preparation.

According to the oil content in the sub-units, two heaps were collected from the above. as follows:-

$H_1 = A_1 + B_1 + C_1 + D_1$

$H_2 = A_2 + B_2 + C_2 + D_2$

H_1 = Black coloured heap represents the high grade oilshale.

H_2 = Brownish grey coloured represents the low grade bituminized shale.

III) Crushing And Screening.

Crushing and screening were carried out in an aggregate crushing plant located at about 30km. from the mine. Primary crushing was made by a jaw crusher with an opening size of 100 x 125 cm. In the secondary stage a hammer mill was used . Screening was done by a double deck vibrating screen. Crushing and screening were carried out at two stages.

First Stage: Primary crushing for H_1

The jaw crusher was set on 6" opening (reduction size 1:6) screening was done on 50 mm. screen, which is the smallest screen size available.

Second Stage: Secondary crushing was carried out for the plus 50 mm.

./.

The oversize was crushed and screened on stages using only the hammer mill, until the whole quantity passed the 50 mm. screen.

Results Of Crushing And Screening The H_1 Part:

The total losses were about 30% by weight as follows:-

a) For cleaning purpose the first truck (about 10cu.m.) was discarded after crushing.

b) Loading and transportation losses.

c) Crushing and screening losses.

Depending on the results of crushing and screening obtained and due to the fine nature of the H_2 part, this part was not crush and was discarded.

IV) Manual Crushing And Screening.

Three screens 150 x 100 cm. each, were manufactured at the N.R.A. workshop with 1" size decks. Hand screening was carried out on the two heaps H_1 and H_2 separately.

The oversize of H_1 is about 17% and that of H_2, about 30%. The oversize from H_1 was crushed by hand hammers and screened to pass 1" .

V) Analytical Control Analysis.

Several representative samples were taken from the H_1 part for chemical and size analysis. Results of these analysis are shown in the following:-

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H_1 - 1	10.8%	Oil Content
H_1 - 2	11.2%	=
H_1 - 3	9.6%	=
H_1 - 4	8.49%	=
H_1 - 5	7.2%	=
H_1 - 6	8.4%	=

According to these results the average oil content of the sample is 9.26% by weight.

Several trials were done to obtain the required range of oil content 7-8% .

Finally blending of the sample was made according to the average oil content of H_1 which is 9.26% and of H_2 which is 1.2%.

90% = By weight from H_1 part.
10% = By weight from H_2 part.

VI) Blending Procedure.

90 tons of H_1 and 10 tons from H_2 were mixed thoroughly by a loader. A representative sample was taken from the blended material. Three portions of the sample were analysed for oil content. The results are shown in the following:-

	Oil Content
US 1-1	8.4
US 1-2	8.6
US 1-3	8.6

VII) Packing And Shipment.

The blended sample was filled in 668 double layer plastic bags. The average weight of each sack is

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about 115 kg. The sacks were loaded in four containers. The capacity of each is 20 cu. ft. The containers were transported to Aqaba on 21.9.1987. Then the sample was shipped on 6.10.1987 to Helisinki Port in Finland.

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Table No. 1

The Oil Content Average each borehole and the head average of the 18 boreholes
the chemical analysis

EM	B.H.#	DATE	TOTAL DEPTH	ELEVA-TION	TOP OF OIL SH	PHOSPH.	COORDINATES EAST	NORTH	OV.B. THICK	OIL_SH THICK	OIL %	CACO3 %	ORG %	INORG %	S %	C %
1	OS-27A	1/87	48.50	821.91	784.41	773.41	469	569	37.50	11.00	7.86	19.93	9.46	2.28	3.51	11.86
2	OS-27B	1/87	53.00	821.55	787.55	768.55	466	581	34.00	19.00	7.31	31.00	9.03	3.70	3.54	12.75
3	OS-28	2/87	82.00	826.02	768.02	744.02	468	585	58.00	24.00	6.91	56.18	8.53	6.69	1.73	15.22
4	OS-32	12/86	79.00	824.03	788.03	745.03	469	585	36.00	43.00	7.72	33.40	9.32	3.94	4.11	31.44
5	OS-34	4/87	108.00	833.09	771.09	725.09	499	538	62.00	46.00	7.46	41.99	9.02	5.8	1.84	14.17
6	OS-35	2/87	87.00	839.67	786.67	752.67	509	547	53.00	34.00	7.38	39.35	9.08	4.80	2.1	13.9
7	OS-36	2/87	128.00	853.03	769.03	725.03	518	547	84.00	44.00	6.94	36.79	8.53	4.47	1.88	12.92
8	OS-38	3/87	103.00	831.00	758.00	728.00	499	542	73.00	30.00	6.54	35.46	7.96	4.18	1.79	12.17
9	OS-39	2/87	94.50	839.68	786.18	745.18	509	547	53.50	41.00	6.46	34.71	7.85	4.20	1.90	11.57
10	OS-40	2/87	83.00	824.66	768.66	741.66	485	549	56.00	27.00	7.26	37.38	8.73	4.48	2.70	13.21
11	OS-41	1/87	69.00	824.66	773.66	755.66	492	553	51.00	18.00	7.11	46.87	8.59	5.62	2.85	14.18
12	SO-41A	3/87	90.00	822.50	752.50	732.50	492	553	70.00	20.00	7.20	24.90	8.64	2.99	1.94	11.76
13	OS-44	1/87	90.00	836.23	790.23	746.23	489	563	46.00	44.00	7.26	37.38	8.73	4.49	2.65	13.21
14	OS-44A	3/87	68.00	838.30	784.30	770.30	489	563	54.00	14.00	7.57	21.08	9.64	2.53	2.27	12.22
15	OS-45	11/86	81.50	828.74	768.24	747.24	477	570	60.50	21.00	9.43	46.8	11.06	5.59	4.29	16.99
6	OS-46	2/87	60.04	836.23	790.23	776.19	482	575	46.00	14.04	6.54	30.41	7.85	3.65	2.92	11.55
7	OS-47	1/87	75.40	844.02	785.02	768.62	490	578	59.00	16.40	9.52	47.67	11.36	5.76	3.78	16.97
8	OS-51	3/87	83.00	836.23	780.23	753.23	493	560	56.00	27.00	8.44	50.99	11.31	6.13	2.37	17.43
VERAGE									54.9	27.4	7.5	37.4	9.2	4.5	2.6	13.7

(Table No. 2)

Sub-Unit	Moisture %	$CaCo_3$ %	In org. C. %	Total Carbon %	Total Sulfur %	Org. Carbon %	Oil %
A_1	2.30	17.5	2.10	22.44	4.89	20.34	15.0
A_2	6.09	30.33	3.64	6.49	1.92	2.85	1.2
B_1	0.70	38.42	4.61	26.71	4.93	22.10	15.4
B_2	7.02	26.67	3.20	4.63	1.72	1.43	1.2
C_1	2.25	43.92	5.27	13.78	1.44	8.51	5.8
C_2	6.26	36.33	4.36	11.99	1.77	7.63	6.4
D_1	2.76	36.92	4.43	11.83	1.00	7.40	5.2
D_2	3.40	41.17	4.94	10.63	1.59	5.69	5.0

Results of analys , of samples were taken from the upper part of oilshale in sultani mine .