NEW OIL SHALE OCCURRENCES IN JIBAL GHUZAYMA AREA CENTRAL OF JORDAN

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Abstract

In its continued efforts to explore and exploit Oil Shale Resources in Jordan, the Natural Resources Authority "NRA" had initiated an exploration program to locate and asses these resources in Jordan, whereas, this study is part of these efforts. The results of Twelve "12" oil shale boreholes drilled in Jibal Ghuzayma area were evaluated and assessed. A total of 1387.5 meters were drilled by which 390 m were cored. The total depth of the boreholes ranged from 79 to 147 m. The oil shale thicknesses in the penetrated sections ranged from 5.5 to 119 m and the overburden thicknesses of 28 to 89.5 m. The oil content values determined by Fischer Assay Analysis were in the range of 3.5 -8.4% with an average of 6.4%. Calorific values were in the range of 1026-8750 J/g. The average of sulfur content for the whole area is 1.52%, while the average of bulk density at all samples was 1.48 g/cm^3

The mineralogical composition of the Oil Shale Deposits of the area was characterized by homogeneity and mainly of calcite and quartz with moderate amounts of Fluorapatite and Smectite. The geological reserves determined in the area are about 10.6 billion tons.

INTRODUCTION

Definition

Oil Shale is a marine sedimentary rock, characterized by fine grain size, containing organic matter called Kerogen. The Kerogen is an organic matter with hydrocarbons, including Nitrogen and Oxygen in its structure. The source of the Kerogen was the first plants (Algae) and the animals that were died and accumulated in a huge amounts in the open seas beginning from the upper Cretaceous to Paleocene and Eocene ages within reduction environment, then by the effect of temperature and pressure, the organic matter was changed to Kerogen, which was solidified forming the oil shale rocks, which occupied most areas in Jordan.

Location and Access

Jibal Ghuzayma area is situated approximately 146 Km south of Amman, The area is easily accessible; it can be reached by a four –wheel drive vehicle, 53 km distance to the east of AL Hisa Phosphate Mines, (Fig 1). It occupies an area of about 200km². The following coordinates define the area: (Palestine Belt)

	E	N
1	281000	1001000
2	269500	1001000
3	269500	1018000
4	281000	1018150

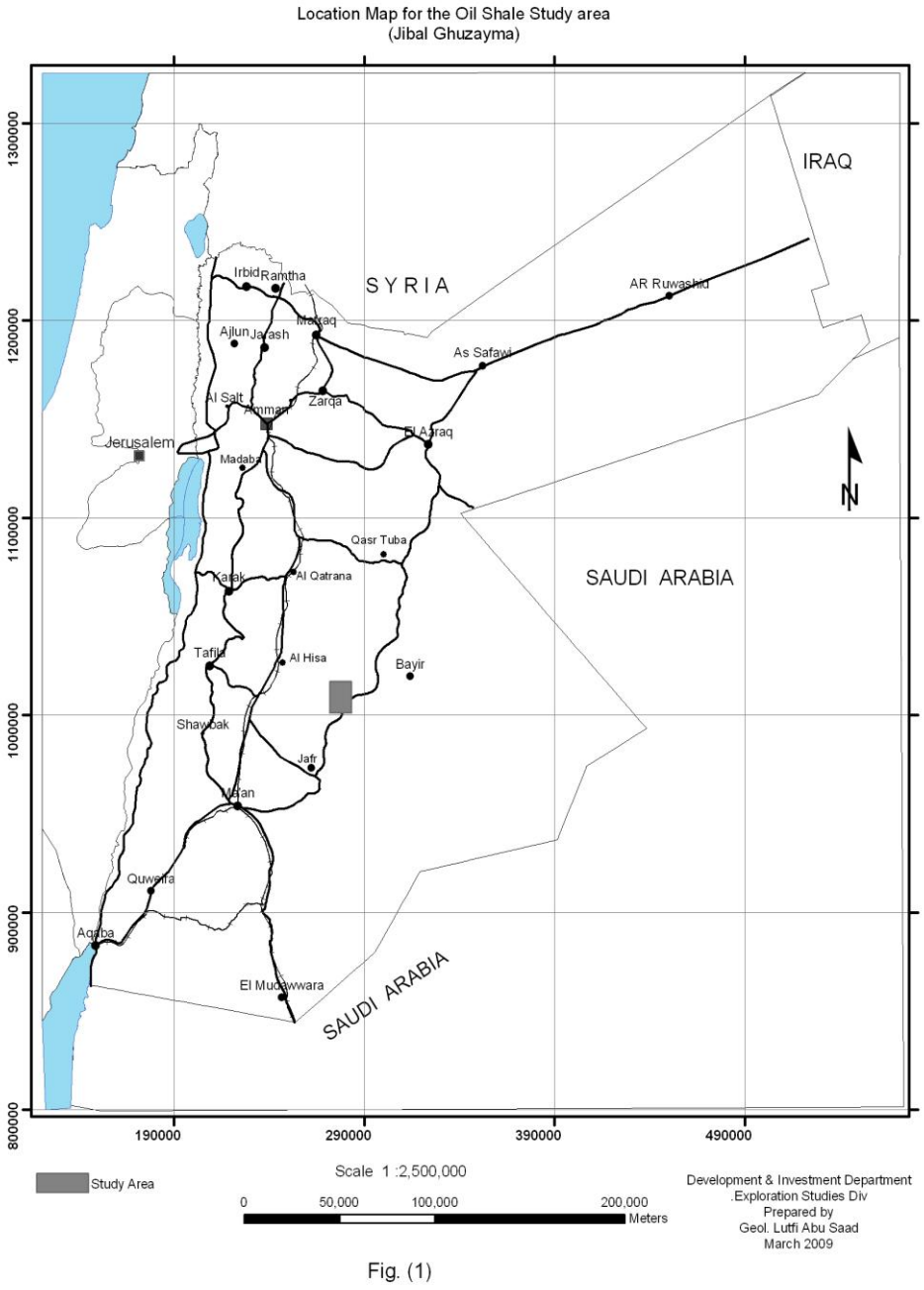

Fig. (1)

Fig. 1: Location map of the study area.

GEOLOGY

Stratigraphy

The following formations are exposed in the study area (Fig. 2) after Kherfan A., 1986, from older to younger.

Muwaqqar Chalk Marl Formation (Maastrichtian – Paleocene)

This formation is considered the target of oil shale exploration, and exposed in the most of the study area. It consists of thin bedded light grey marl alternating with thick bedded of bituminous chalk marl, grey, dark grey.

Umm Rijam Chert limestone Formation (Late Paleocene to Eocene)

This formation is exposed in the center and east of the study area. The exposed 35 to 40 m of the formation consists of the alternating chalky limestone, thin beds of brown chert, and microcrystalline limestone.

Sand and gravel (Pleistocene)

Several meters thickness of Pleistocene sand and gravel, this is a deposit of variously sorted and unsorted, rounded and angular clasts predominantly of chert with some of limestone.

Volcanic Rocks (Neogene)

Basalt occurs as nine small plugs which are topographically prominent and possibly represent small eroded volcanic cones. These are aligned along NNW-SSE fractures in the NW part of the sheet.

Structural Geology

Dips throughout the region are gentle. The strongest structural expression is seen as the down faulted, elongated NNW-SSE, outliers of Umm Rijam Formation, which although geologically down faulted, are morphologically elevated. Faults are indicated by pronounced linear escarpments rather than by visible relative displacement of beds. The dominant fault trend is NNW-SSE with a less marked fault strike normal to this. Kherfan A., 1986. (Fig. 2)

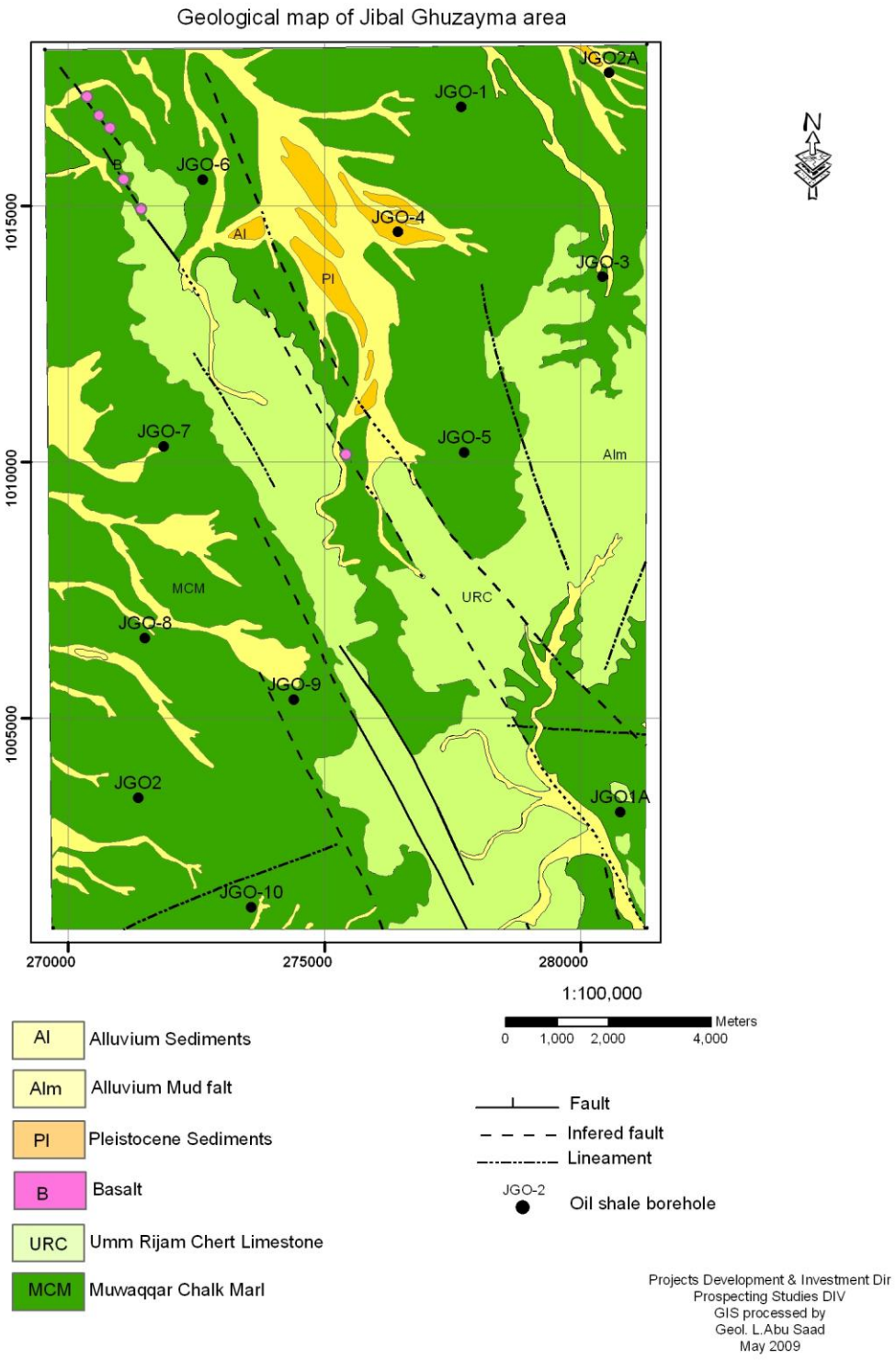

Fig. 2: Geological map of Jibal Ghuzayma area with boreholes location, after (Kherfan A., 1986)

FIELD ACTIVITIES

Drilling boreholes

The aim of the drilling was to study the oil shale deposit in order to determine its geometry parameters and to collect core and cutting samples from the boreholes for laboratory analyses, to asses the quality of oil shale in this area. Twelve boreholes were drilled, the spacing between the boreholes ranges from 2-6 km. The depth of boreholes ranges between 79m-168m, where the total meterage of the drilling was 1387.5m of which 390m out of them were cored and 997.5m was cutting (Tables 1, 2).

Table (1) Boreholes number, type of drilling and total depth

Borehole No.	Type of drilling		Total Depth(m)
	Cutting(m)	Core(m)	
J.G.O.1	144	---	144
J.G.O.1A	77	91	168
J.G.O.2	109	---	109
J.G.O.2A	75	33	108
J.G.O.3	28.5	118.5	147
J.G.O.4	78.5	8	86.5
J.G.O.5	88	46.5	134.5
J.G.O.6	90.5	10	100.5
J.G.O.7	75	21	96
J.G.O.8	69.5	9.5	79
J.G.O.9	79	14	93
J.G.O.10	83.5	38.5	122

(Table 2) shows Boreholes number, coordinates (Palestine Belt) and elevation (m).

Table (2): Boreholes number, coordinates and elevation (m)

B.H.NO.	East	North	Elevation(m)
J.G.O.1	277672	1016927	915
J.G.O.1A	280778	1003169	956
J.G.O.2	271375	1003450	880
J.G.O.2A	280557	1017594	939
J.G.O.3	280438	1013611	955
J.G.O.4	276440	1014490	912
J.G.O.5	277734	1010191	954
J.G.O.6	272632	1015513	903
J.G.O.7	271873	1010305	899
J.G.O.8	271506	1006563	898
J.G.O.9	274414	1005365	923
J.G.O.10	273575	1001312	952

Sampling and Logging

Sample for laboratory analysis were collected from both core and cutting.

The calcareous bituminous chalk marl, which was encountered in the boreholes, was sampled in the field. Cutting samples were preserved in polyethylene bags while the core samples were preserved in wooden boxes. Each sample represents cutting over a meter interval of the bituminous chalk marl and in some cases it represents les or more one meters after being mixed thoroughly. Each core was sampled at one meters interval for analysis in some cases more than one meter. Core samples were treated at the NRA laboratories.

Mode of occurrence

The thickness of oil shale deposit according to cut off grade 3wt% of oil content ranges from 5.5 meters in borehole number JGO-8 up to 119 meters in borehole number JGO-3, (Table 3). Table (3) shows the boreholes number, oil shale Thickness (m) and oil content average. Isopach map for oil shale thickness is constructed depending on the cut-off grade 3 Wt% is shown on (fig. 3). The oil shale thickness increasing toward east in the study area

Table (3): Boreholes number, Oil Shale Thickness (m) and oil content average wt%

B.H No.	Oil Shale Thickness (m)	Oil Content Average (Wt. %)
JGO-1	21	4.4
JGO-1A	91	6.3
JGO-2	52	3.5
JGO-2A	33	5.8
JGO-3	**119**	7.2
JGO-4	12	6.9
JGO-5	46	6.6
JGO-6	10	8.3
JGO-7	7	6.7
JGO-8	**5.5**	8.4
JGO-9	12.7	6.6
JGO-10	38.5	6.2

Cut off grade 3Wt% oil content has been assumed for the purposes of defining oil shale thickness.

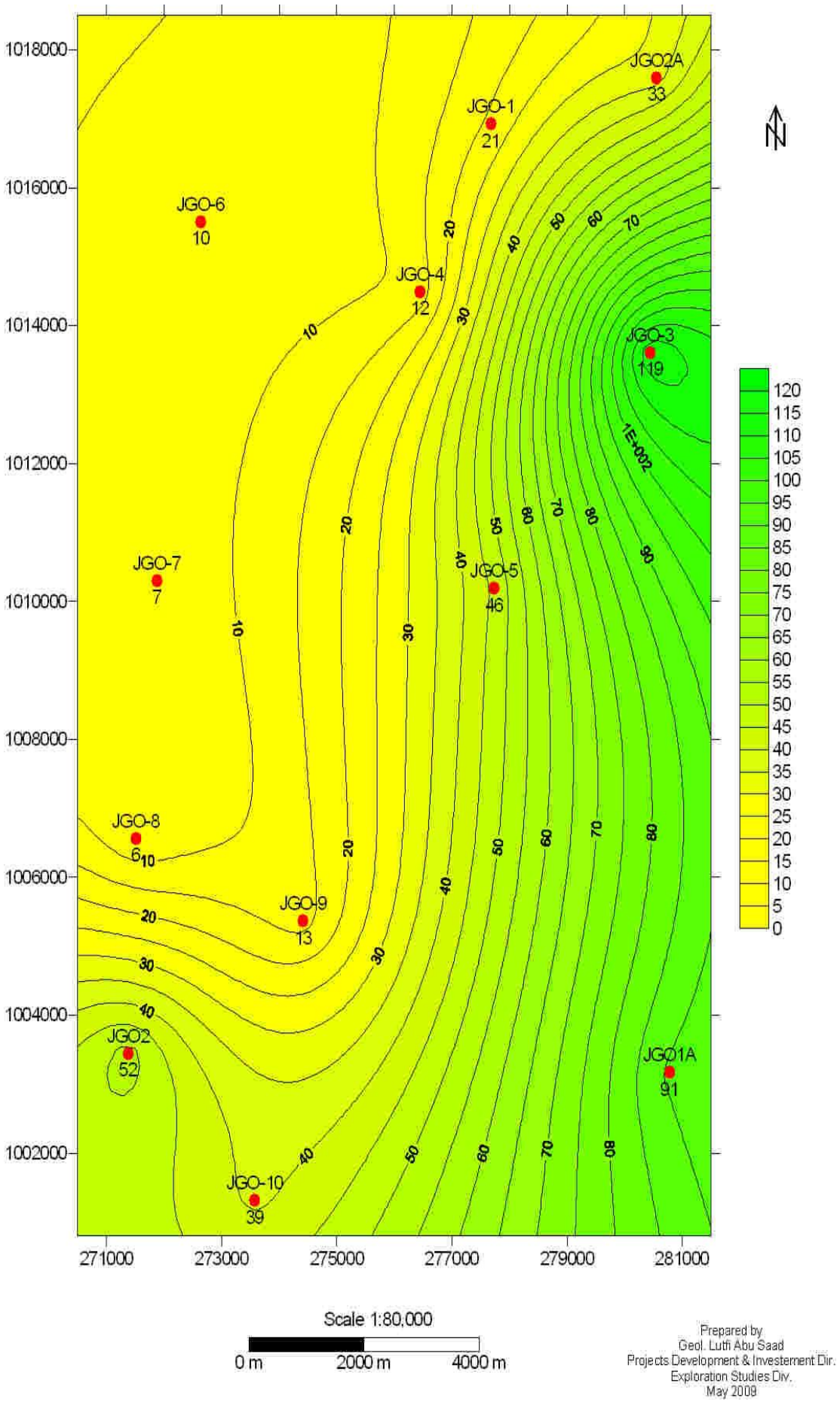

Fig. 3: Isopach map of oil shale thickness.

The rocks sequence overlying the oil shale is considered as the overburden which consists mainly of chert, brown to light brown, sharpness belong to Umm Rijam Chert Limestone formation. Chalk, chalky limestone, chalky marl, marl, marly limestone and limestone; belong to the upper part of Muwaqqar Chalk- Marl Formation. The thickness of the overburden of the twelve boreholes range between 28 m in borehole number JGO-3 and 89.5m in borehole number JGO-6, (Table 4).

Table (4): Boreholes number, overburden (m), oil shale thickness (m), and stripping ratio

B.H.NO.	Overburden (m)	Oil Shale Thickness (m)	Stripping Ratio OB/OS
J.G.O.1	77	21	3.66
J.G.O.1A	77	91	**0.85**
J.G.O.2	44	52	**0.84**
J.G.O.2A	75	33	2.3
J.G.O.3	**28**	119	**0.23**
J.G.O.4	74	12	6.1
J.G.O.5	85.5	46	1.8
J.G.O.6	**89.5**	10	8.9
J.G.O.7	72	7	10.2
J.G.O.8	61	5.5	11
J.G.O.9	73	12.7	5.7
J.G.O.10	83.5	38.5	2.2

Isopach map of overburden is constructed and can be seen in (fig. 4). The overburden increases in the center of the study area and towards northwest and southeast.

Stripping ratio decreases towards east of the study area as shown in borehole JGO-1A, JGO-3 and JGO-2; and increases towards west as shown in the others boreholes.

Stripping ratio isopach map is constructed shown in (fig. 5).

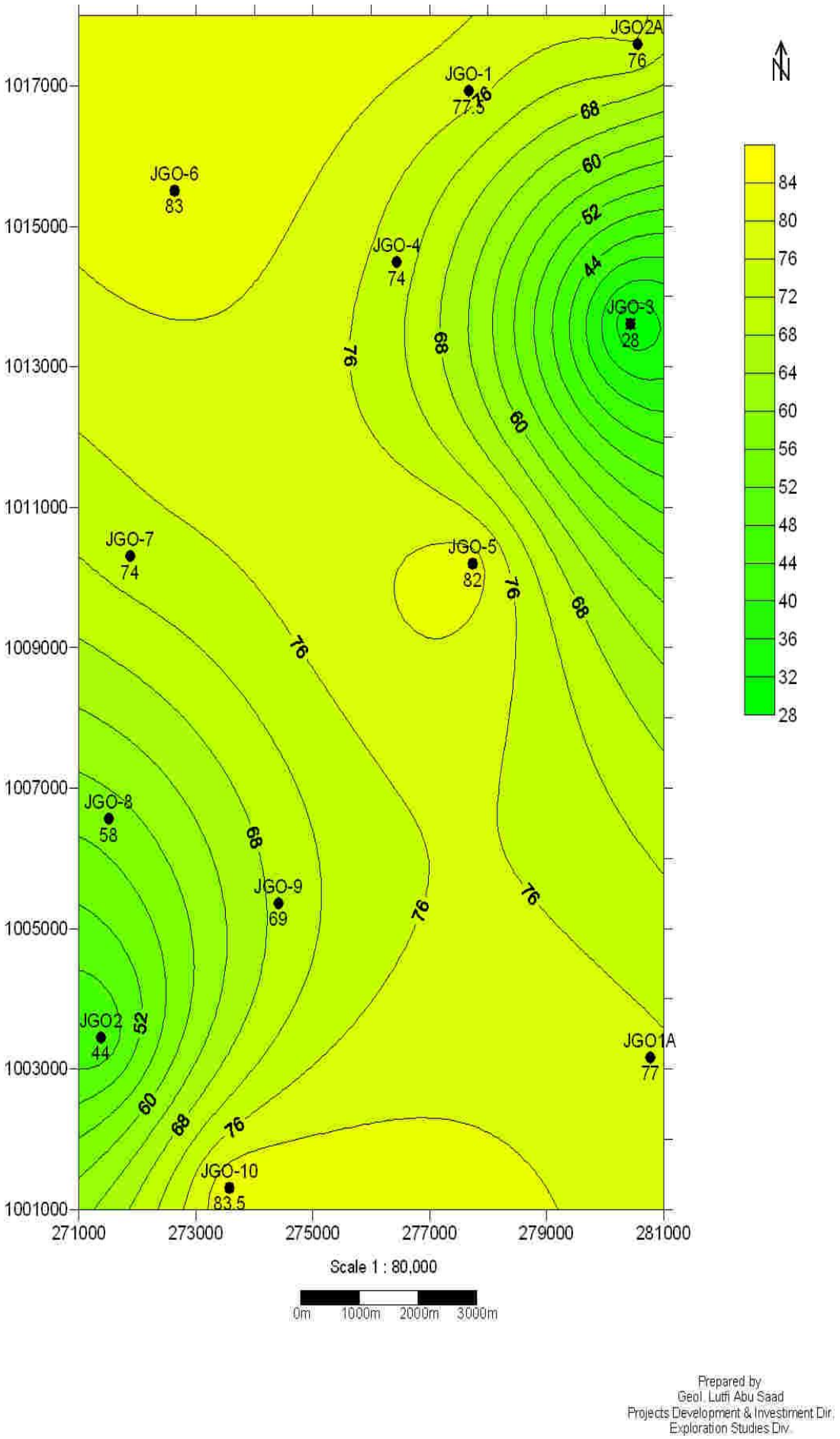

Fig. 4: Isopach map of overburden.

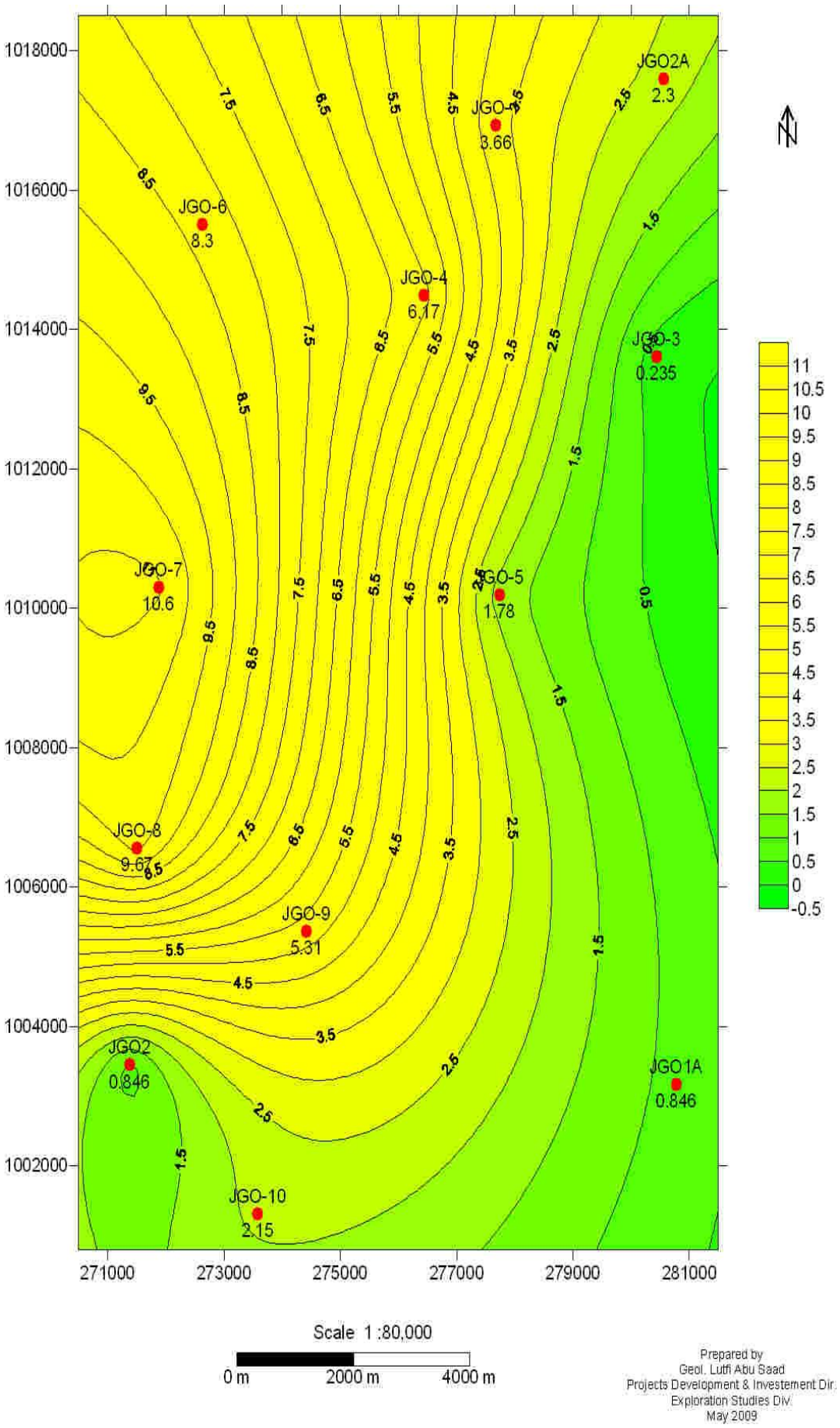

Fig. 5: Isoline map of stripping ratio.

LABORATORY ANALYSIS

307 samples were analyzed for Fischer assay, XRF, XRD, Heat value and Bulk density, more details about the collected samples and the type of analysis are shown in table (5).

Table (5): Boreholes number, Fischer assay, XRF, XRD, heat value and bulk density.

Borehole No	Fischer Assay	X.R.F	X.R.D	Heat Value	Bulk density
J.G.O.1	66	66	-	13	-
J.G.O.1A	23	23	12	4	7
J.G.O.2	41	41	-	7	-
J.G.O.2A	10	10	5	3	2
J.G.O.3	35	15	-	8	8
J.G.O.4	3	3	3	1	1
J.G.O.5	29	10	-	3	10
J.G.O.6	3	3	3	1	1
J.G.O.7	6	6	-	2	3
J.G.O.8	4	4	-	1	2
J.G.O.9	11	10	-	3	4
J.G.O.10	20	10	-	5	5

Fischer Assay Analysis

251 oil shale samples were tested for organic analysis to determine oil content, organic matter, spent shale, Gas loss, Calcite, calorific value and total sulfur, the analysis determined by using Fischer assay method. Results of Fischer assay analysis are presented in appendix C-1, and table (6) summaries the results of Fischer assay analysis.

Table (6): The Max, Min and averages of the samples

	Total Water Wt. %	Total Oil Wt. %	Spent shale Wt. %	Gas Loss Wt. %	T.C. Wt. %	T.S. Wt. %	$CaCO_3$ Wt. %	C inorg. Wt. %	C org. Wt. %	Calorific value J/g
Max.	5.6	14.46	96.92	14.28	32.6	4.28	79.12	9.49	18.17	8750
Min.	0	3.60	71.76	0.5	6.5	0.273	21.27	2.55	3.55	1026
Avg.	1.55	6.40	89.70	3.07	16.68	1.52	44.57	5.35	8.87	4071

Oil content

Fischer assay retorting procedure was used to determine the oil content. In calculating the oil shale sequence in each borehole, it was decided that a cut-off grade at 3% oil content to be adapted (as shown in table 7). This cut-off grade was taken into consideration for the whole sequence from the top and bottom layers of oil shale.

The average of oil content for the whole area is 6.41Wt %

Table (7): Boreholes number and average oil content Wt %

B.H No.	Oil Content Average (Wt. %)*
JGO-1	4.4
JGO-1A	6.3
JGO-2	3.5
JGO-2A	5.8
JGO-3	7.2
JGO-4	6.9
JGO-5	6.6
JGO-6	8.3
JGO-7	6.7
JGO-8	8.4
JGO-9	6.6
JGO-10	6.2

**Cut off grade 3Wt% oil content.*

Sulfur

The average content of sulfur for each borehole was calculated. Sulfur content ranges from 0.27% at depth (118-120m) in borehole JGO-10 to 4.28% at depth (124-125m) in borehole JGO-1. However, the average of sulfur content for the whole area is 1.52%.

Organic Carbon

Organic carbon contents ranges from 3.55% at depth (115-116m) in borehole JGO-1 to 18.17% at depth (124-125m) in the same borehole. However, the average of organic carbon content for the whole area is 8.87%.

Calorific Value

54 samples from all boreholes were sent for testing, the results of calorific value ranged from 1026 to 8750 J/g.

X-Ray Fluorescence Analysis (X.R.F)

To determine the major oxides, 201 samples were analyzed for complete chemical analysis using X-Ray fluorescence method. The average oxides of boreholes are shown in (Table 8).

Table (8): Min, Max and average of the major oxides

	Fe_2O_3%	MnO%	TiO_2%	CaO%	K_2O%	P_2O_5%	SiO_2%	Al_2O_3%	MgO%	Na_2O%	L.O.I.%
MIN.	0.53	0.001	0.019	15.3	0.04	1.81	3.37	1.2	0.36	0.06	18.1
MAX.	2.94	0.067	0.33	35.8	0.33	6.48	47.9	8.01	4034	1.95	41.6
AVG.	1.28	0.04	0.12	26.47	0.23	3.34	30.95	3.06	71.38	0.30	28.77

Ray Diffraction Analysis (X.R.D)

Mineralogical composition of oil shale beds were determined by the X-ray diffraction method, 23 samples from boreholes were analyzed. The main components of oil shale were found:

- Calcite in all samples as a major mineral.
- Quartz was detected as a trace mineral, but it was detected as a major mineral in sample number 001 from borehole JGO-4 and sample number 001, from borehole number JGO-6.
- Dolomite was detected as a trace mineral in some samples, but it was detected as a major mineral in sample number 002 at depth of 92-96m from borehole JGO-6, with MgO 7.73% and oil content 6.72wt %.
- Fluorapatite, Hematite and Smectite were detected as a trace mineral in some samples.

The results of analysis are shown in (Table 9).

Table (9): Results of X- ray diffraction analysis.

Sample No.	Q	Cc	F1	He	D	Sm
JG04/ 01	***	***	*	*	*	-
JG04/ 02	*	***	-	*	-	-
JG04/ 03	*	***	-	-	-	-
JG06/ 01	***	***	-	*	*	-
JG06/ 02	**	***	*	-	***	*
JG06/ 03	**	***	*	-	*	-
JG1A/ 01	*	***	-	-	-	-
JG1A/ 0 3	-	***	-	-	-	-
JG1A/ 05	-	***	-	-	-	-
JG1A/ 07	*	***	-	-	-	*
JG1A/ 09	*	***	-	-	-	-
JG1A/ 011	-	***	-	-	-	-
JG1A/ 013	*	***	-	-	-	-
JG1A/ 015	-	***	-	-	-	-
JG1A/ 017	*	***	-	-	-	-
JG1A/ 019	*	***	-	-	*	-
JG1A/ 021	*	***	-	-	-	-
JG1A/ 023	-	***	-	-	-	-
JG2A/ 0 2	*	***	*	-	-	*
JG 2A/ 04	-	***	*	-	-	-
JG2A/ 0 6	*	***	*	-	-	-
JG2A/ 08	*	***	*	-	-	-
JG2A/ 0 9	*	***	*	-	-	-

Where:

Q = Quartz Cc = Calcite Fl = Fluorapatite
D = Dolomite Sm = Smectite He= Hematite

Key: (Based on Relative XRD high peak Data):

Major : *** Minor : ** Trace : *

Bulk Density

38 samples were analyzed for bulk density, the range value of bulk density is from 1.04 at borehole JGO-3 to 2.62 at borehole JGO-8, the average of bulk density at all samples was 1.48 g/cm^3. The results of analysis are shown in (Table 10).

Table (10): borehole number, samples number, dry Gs, saturated Gs and Apparent Gs

BH.N0 Sample No	Dry Gs. g/cm^3	Sat. Gs. g/cm^3	App. Gs. g/cm^3
BH.1A/01	1.06	1.5	1.9
02	1.57	1.82	2.09
03	1.14	1.55	1.92
04	1.34	1.76	2.3
05	1.32	1.73	2.23
06	1.39	1.75	2.19
BH.2A/01	1.49	---	---
02	1.61	---	---
BH.3/01	1.04	1.42	1.66
02	1.27	1.68	2.15
03	1.21	1.61	2.03
04	1.16	1.56	1.92
05	1.75	2.01	2.38
06	1.3	1.69	2.14
07	1.2	1.6	1.99
08	1.41	1.77	2.19
BH.4/01	1.53	---	---
BH.5/ 01	2.07	2.24	2.48
02	1.42	1.82	2.38
03	1.38	1.76	2.24
04	1.30	1.78	2.49
05	1.38	1.75	2.19
06	1.54	1.91	2.44
07	1.40	1.75	2.17
08	1.32	1.66	2.01
09	1.37	1.75	2.22
010	1.41	1.75	2.15
BH.6/01	1.56	---	---
BH.7/01	1.58	1.77	1.95
02	2.20	2.38	2.70
03	1.81	2.17	2.81
BH.8/ 001	2.62	2.65	2.70
02	1.61	1.93	2.38
BH.9/01	1.45	1.83	2.34
02	1.31	1.71	2.19
03	1.49	1.82	2.25
04	1.30	1.64	1.97
BH.10/1	1.42	1.75	2.13
2	1.49	1.90	2.53
3	1.35	1.76	2.30
4	1.40	1.75	2.14
5	2.40	2.48	2.61

GEOLOGICAL RESERVES CALCULATION

The oil shale reserve was calculated depending on the results of 12 boreholes, covered an area of about 200 km^2. The thickness of oil shale beds were measured depending on the cut off grade 3wt% of oil content. The area of influence (polygons method was adopted); method was adopted for reserves calculation. The area of influence map with scale 1:100000 was constructed and consisted of a number of polygons around boreholes. Fig (6)
The reserve was calculated according to the following equation:

$$R = T*A* B$$

Where:-

R = Reserve.

T = Oil shale thickness, m.

A = Area of polygon, km^2.

B = Bulk Density.

The total indicated reserve of Jibal Ghuzayma oil shale deposit were about 10.66 billion tons. The assumed bulk density is 1.48 g/cm3
Results of calculation are shown in (Tables 11).
(Table 11) shows the borehole numbers, oil shale thickness (m), polygon area (km^2), and reserve in million metric tons.

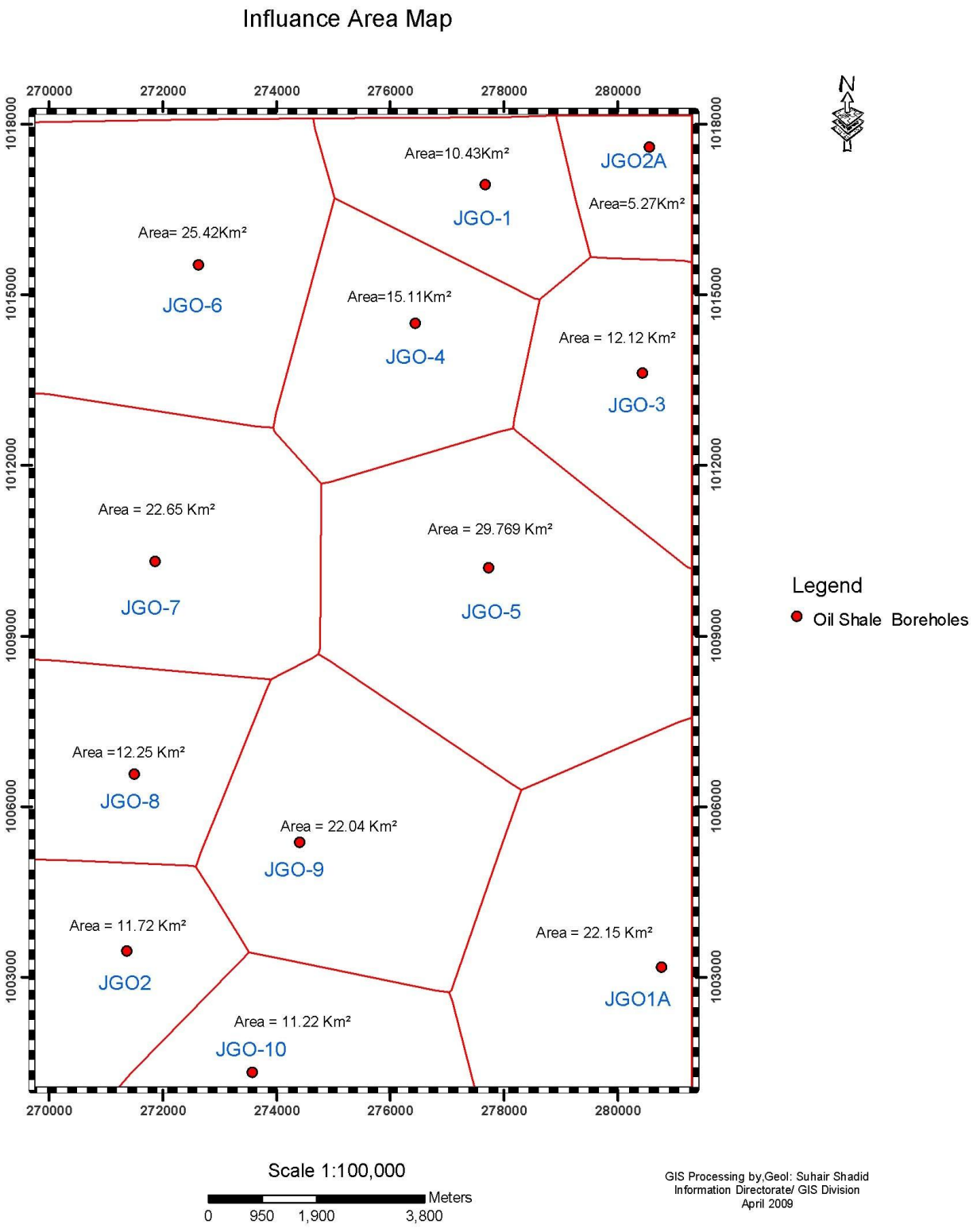

Figure (6): Area of Influence map for Jibal Ghuzayma.

Table (11): Borehole No, Oil shale Thickness (m), Polygon Area (Km^2) and Reserve

Borehole No.	T= Oil shale Thickness (m)	A= Polygon Area (Km^2)	R= Reserve (Million Metric Ton)
JGO-1	21	10.432276	324.23513
JGO1A	91	22.155588	2983.9145
JGO2	52	11.727699	902.5637
JGO2A	33	5.271143	257.44261
JGO-3	119	12.129586	2136.262686
JGO-4	12	15.114547	268.43434
JGO-5	46	29.771367	2026.834565
JGO-6	10	25.427578	376.32815
JGO-7	7	22.659822	234.75575
JGO-8	5.5	12.254788	99.753974
JGO-9	12.7	22.046701	414.38978
JGO-10	38.5	11.224519	639.573092
Total:			***10664.488277***

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1- Oil shale strata thickness increase towards the east direction in study area.

2- Overburden strata thickness increase in the medial of the study area and towards the north west and south east direction.

3- Best oil content wt % in the borehole number JGO-3 and JGO-1A.

4- The calculated reserve is about 10.6 billion tons.

5- The color of oil shale beds is gray, dark gray, greenish grey, greenish brown. The darker color always is of high oil contents and heat value.

RECOMMENDATIONS

As a result of the present investigation and on the basis of the available data the following recommendations are suggested:

1- More boreholes are recommended to be drilled in the eastern area, between borehole number JGO-3 and borehole number JGO-1A.
2- Eastern area very good for oil shale investment.

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