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SUBSURFACE GEOTHERMAL STUDY IN THE CENTRAL PART OF THE NORTHERN WESTERN DESERT, EGYPT

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ABSTRACT

Geothermal investigation of the studied area was carried out using the bottom hole temperatures recorded in deep wells drilled for petroleum exploration. The study revealed interesting data regarding the geothermal gradient distribution, depth of potential petroleum source rocks, and throws some light on the petroleum accumulation in the investigated area.

INTRODUCTION

The present study implies a detailed geothermal investigation of the sedimentary sequence penetrated in deep wells drilled in the central part of the Northern Western Desert of Egypt and its significance to petroleum exploration. The studied district attains about 22000 Km^2 (Figure 1) located between:

Latitudes 30° 00′ and 31° 30′ N and
Longitudes 26° 00′ and 29° 00′ E.

It is generally accepted now that one of the most critical factors in the transformation of organic matter into petroleum is the temperature to which the rocks have been subjected (Karweil, 1956; Philippi, 1965; Louis and Tissot, 1967; Vossoyevich *et al*, 1970; Lopatin and Bostick, 1973; Bostick, 1973, 1974; Castano and Sparks, 1974; Connan, 1974; Deroo *et al*, 1977). Temperatures below 50°C (122°F) cannot lead to the beginning of the main phase of petroleum generation (Karweil, 1969; Lopatin, 1969; Vossoyevich *et al*, 1970).

Limited previous attempts have been made, using the geothermal data, for oil and gas exploration in the Western Desert of Egypt, of which those of Urban *et al* (1976) and Zein El-Din *et al* (1980) can be mentioned. Urban *et al* (1976) studying the relaionship of present-day bottom-hole temperatures to the vitrinite reflectance at total depth, regardless of unconformities or geologic age, of the Mesozoic in the Western Desert of Egypt concluded that present-day temperatures are thought to indicate the maximum temperatures, these sediments have experienced. Zein El-Din *et al* (1980) studied the geothermal gradients using the bottom-hole temperature data from oil wells drilled in the Wadi Natrum area, and revealed some relation to the hydrocarbon accumulation in the Jurassic rocks.

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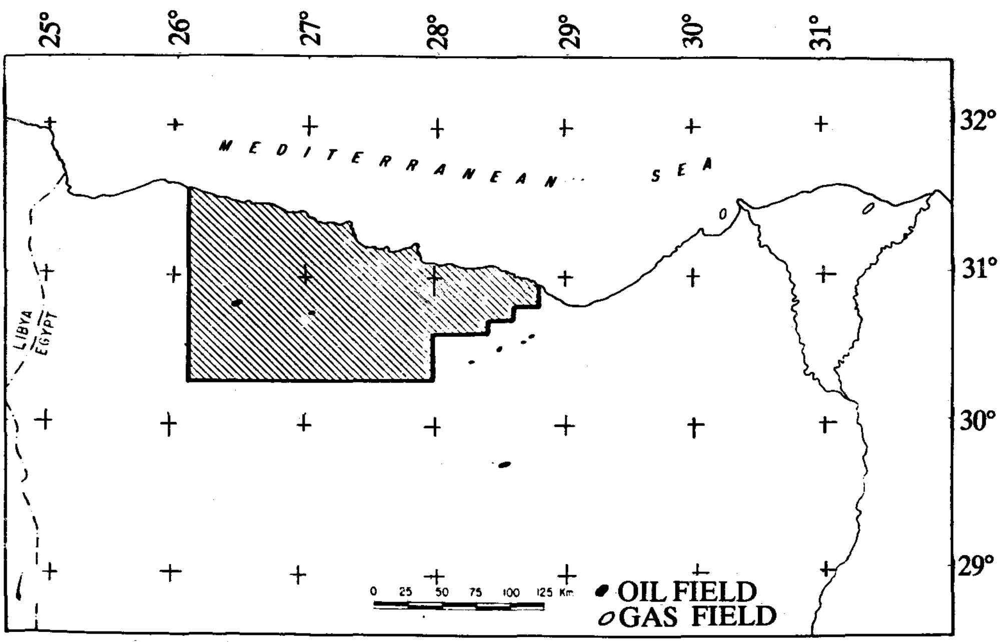

Figure 1. Location Map

SOURCE OF DATA AND TECHNIQUE

Bottom-hole temperatures (BHT) recorded at different depths while logging in wells drilled in the study area (39 wells) for petroleum exploration were used in this study to calculate the formation temperature and the geothermal gradients (especially Induction Log, because it gives the lowest temperature). Points above 2000 feet deoth were neglected in calculations as they are usually anomalously hot.

The geothermal gradients were calculated according to the following formula:

$$\text{Geothermal Gradient} = \frac{\text{BHT - MAST}}{\text{TOTAL DEPTH}} \times 100$$

The mean annual surface temperature (MAST) used is 80°F, and gradients were expressed in degrees Fahrenheit per 100 feet.
Unfortunately, temperatures read directly from wire-line logs do not represent true formation temperatures. This is because wire-line logs were usually run too soon after circulation was stopped and the well-bore did not have sufficient time to reach thermal equilibrium with the surrounding formation. Circulating drilling mud tends to cool the deeper portions of the well while at depths above 2000 feet the mud may actually be hotter than the surrounding formation. Le Roy (1951) suggested that a period of several weeks may be necessary for the well-bore and

surrounding formation to attain complete thermal equilibrium. Temperatures measured while logging in newly drilled holes are usually less than in undisturbed well. However, the gradients calculated in this manner are in error by less than 10% (Harper, 1971; Evans and Coleman, 1976). Consequently, in the present work, possible systematic error in the calculated geothermal gradients is less than 10%.

The formula used, in this study, to get formation temperature at any depth is:

$$\text{Formation Temperature} = 80 + \frac{\text{BHT-80}}{\text{TOTAL DEPTH}} \times \text{Formation depth}$$

INTERPRETATION OF THE GEOTHERMAL DATA

The average geothermal gradient in the studied area was found to be 1.22°F/100 feet as calculated fom 39 wells in which data was available (Figure 2). A maximum gradient of 1.48°F/100 feet was calculated in Barakat-1 well, while the minimum is 0.90°F/100 feet in Aghar-1 well. The gradients higher than 1.2°F/100 feet are classified in this study as "hot" whereas those lower than 1.2°F/100 feet are considered "cold".

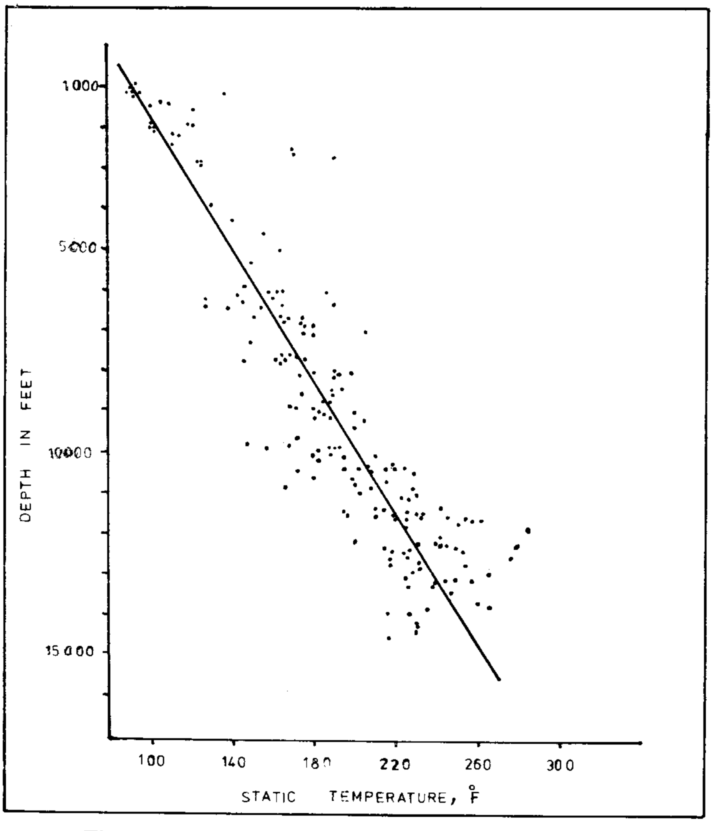

Figure 2. Geothermal Gradient in the Study Area.

The distribution of the geothermal trends in this area is illustrated on figure 3. This map shows the presence of an almost east-west trending high geothermal gradient region passing in the middle of the studied area.

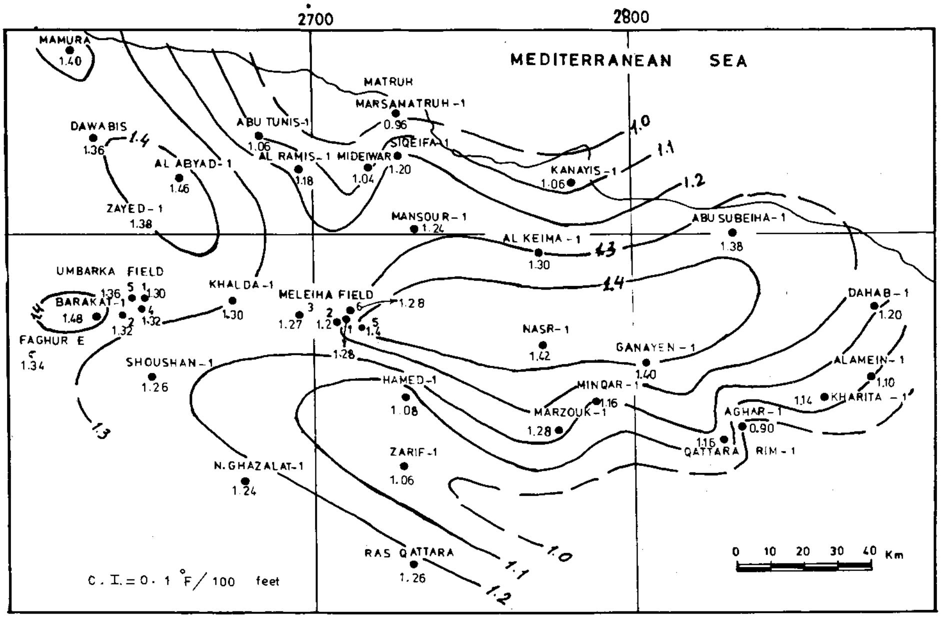

Figure 3. Geothermal Gradient Contour Map.

Granite basement encountered as shallow as 12,200 feet on the Umbarka Structure suggest that this east-west high geothermal trend may represent a basement high over which the sedimentary cover relatively thins. (may be less than 13,000 feet thick). The Matruh basin to the north has been estimated to build up about 25,000 feet of sedimentary rocks, while Abu-Gharadig basin to the south is known to have at least 15,000 feet of sedimentary rocks, reaching more than 18,000 feet along its axis. This may allow to conclude that temperature generally decreases with increasing depth to basement. Where the sedimentary section is relatively thick, the rocks act as a heat sink and dissipate the heat generated by radioactive decay in the basement rocks. Over the basement high, a smaller volume of saedimentary rocks exists, and temperature remains hotter.

Based on the work of Fletcher and Bay (1973), Hunt (1974) and Landes (1967), it is assumed that the minimum subsurface temperature needed for hydrocarbon generation from potential source rocks, in the Western Desert of Egypt, is 200°F. The depths at which 200°F occur in the area under study were calculated using the formula:

$$\text{Depth of 200°F geothermal temperature} = \frac{200 - \text{MAST, °F}}{\text{Geothermal Gradient}}$$

and are shown on the isotherm depth map (Figure 4). This isothermal surface is shallow in an area extending east-west in the central part of the study district and ranging in depth between 8500 to about 9500 feet depth, and gets deeper to the north and south, reaching a depth of about 14000 feet. Source rocks of younger age are expected in the central part of the area in contrast to older rocks in the north and south.

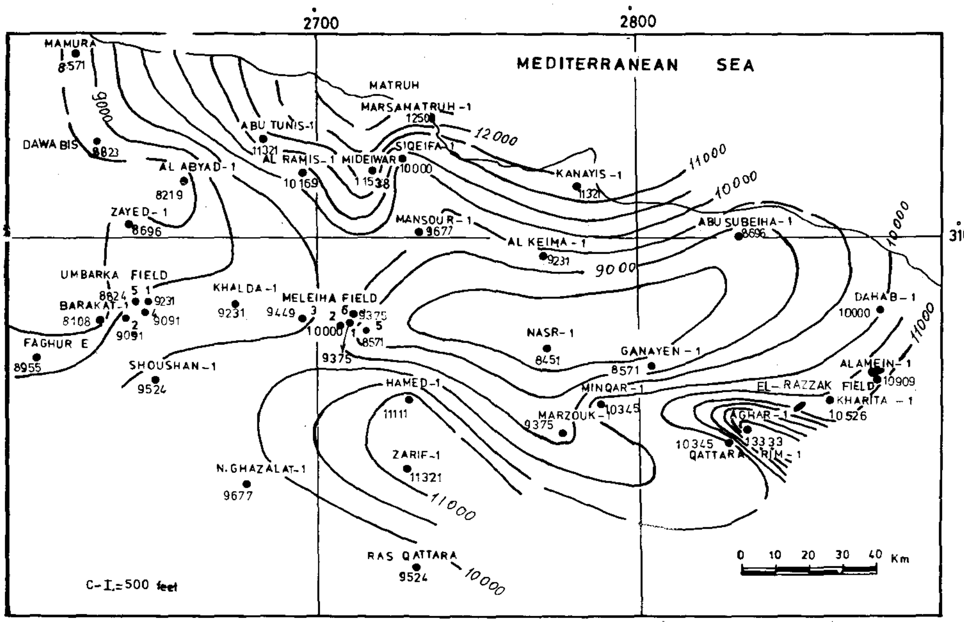

Figure 4. Isotherm Depth Map (200°F)

To illustrate the relationship between the geothermal gradient and the lithology of the penetrated section, figure number 5 was constructed. This map represents the distribution of the clastic ratio of the section penetrated in the studied wells from the surface (Moghra Formation of lower Miocene Age) to the base of the lower Cretaceous rocks (as most of the wells were bottomed in the lower Cretaceous). The similarity of distribution of the clastic ratio with the geothermal gradient is very striking. This map clearly shows that the geothermal gradient with the increase of the nonclastic and the decrease of clastic rocks in the section.

On the isotherm depth map (Figure 4) four oil fields, known in the studied area, are located. The Alamein field produces 18° to 34° API gravity oil from the Alamein Dolomite reservoir at a depth of 8300 feet. The estimated formation temperature at this depth is 171°F. Razzak field contains oil in both the Alamein Dolomite and Cenomanian rocks, where the deepest oil-water contact in this fied is at 7278 feet, and the estimated formation temperature at this depth is 160°F. The API gravity of the oil produced from the Alamein Dolomite ranges from 35.8° to 39°, while that of the Cenomanian oil is higher and ranges between 41° and 45° API gravity. The Meleiha field as 38° API gravity oil in a Cenomanian resrvoir at 5900 feet depth and an

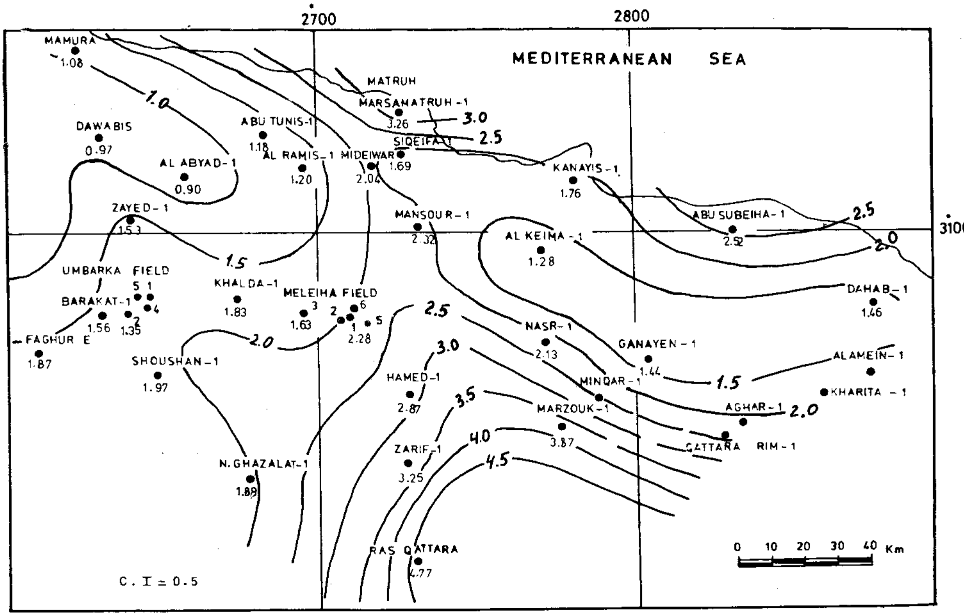

Figure 5. Clastic Ratio Map (of the section from surface to the base of lower

estimated formation temperature of 157°F. Umbarka field produces 38° to 48° API gravity oil from lower Cretaceous sandstones at a depth of 10700 feet. The estimated formation temperature at this depth is 219°F.

The relatively low temperature, shallow deoth of burial and moderate gravity of oil at Alamein, Razzak, and Meleiha oil fields suggest that the oil may have been generated in a deeper source (as indicated by the isotherm depth map), and migrated upwards to be trapped in these reservoirs. The higher API gravity oil in the Cenomanian reservoir higher than the Alamein Dolomite in Razzak oil field supports this assumption. On the other hand, Umbarka oil is thought to be generated from its own deep source - rock, at the same depth level, where it is accumulated.

CONCLUSIONS

1. The geothermal gradient anomalies in the area are classified into thermal high trends with geothermal gradients over 1.2°F/100 feet and thermal low trends with values less than 1.2°F/100 feet. An almost east-west trending high geothermal gradient region passing in the middle of the studied area. The influence of the basement depth is clearly reflected on the behaviour of the geothermal gradients in the area and has affected the generation of petroleum in the geothermal zones.

2. The isothermal surface of 200°F (the temperature suitable for petroleum generation) is shallowest in the central part of the area and gets deeper to the north and south.

3. The geothermal gradient distribution was found to be very related to the type of lithology. It increases with increasing of carbonates and decreasing of clastic rocks.

4. From this study, the petroleum accumulations in the study area were distinguished into those generated from their own sources (Umbarka Field) and those which have been generated in deeper horizons and accumulated as a result of vertial migration.

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دراسة حرارية تحت سطحية في المنطقة الوسطى من شمال الصحراء الغربية - مصر

محمود يسري زين الدين

يتضمن هذا البحث دراسة سطحية لتسجيلات درجات الحرارة في الآبار المختلفة التي تم حفرها في المنطقة الوسطى من شمال الصحراء الغربية بمصر . واستناد إلى البيانات الجيولوجية والحرارية تم استنباط معدلات التغير الحراري وأعماق درجات الحرارة المناسبة لتوليد وتواجد البترول والغازات بالمنطقة قيد الدراسة .