Three Dimensional Representation of basement Surface Features for rub Al Khali Area, NE Yemen, by using Spectral Analysis Technique on Gravity data

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Abstract:

Two dimensional power spectral analysis techniques have been applied on gravity data for AR Rub' Al Khali region to estimate the depths to basement structures. The studied region is located in NE Yemen where little information about the deep geology is available. The estimated depth values are ranging between 3.5 to 9.5Km. The western and eastern parts have the deepest values while the middle part has an elevated basement features.

The distribution style of deep and shallow structural features reflect the orientation of graben and horst structures with lateral displacements. The graben structures with great depths and with large areal extent highlight the importance of this region for possible oil accumulation, since most Yemen oil fields are located within graben structures. The deduced shapes, trends, and depths of these structures and their three dimensional representation are so useful and encourage the future oil exploration in this part of Yemen territory.

Key words: Basement Depth Estimation, Rub Al Khali, Power Spectral Analysis.

Introduction:

The depth estimation of gravity sources may be carried out with the help of models, by comparing computed field values derived from models with observed field values. The spectral methods of analysis have been employed increasingly for depth estimation. In these methods, the characteristics of the observed anomalies are studied by transforming the data from space domain to the frequency domain and then analyzing their frequency characteristics [1].The energy spectrum and the autocorrelation function formulae of the magnetic anomalies related to different bodies have been derived by [2]. The log power spectrum and spectral techniques have been used to estimate the depth of basement [3, 4, 5, 6, 7] and deep geologic sources within the crust [8, 9]. Two straight lines of different slopes in a power spectrum may be interpreted as being of sources at different depths [10].

Mishra and Naidu [11] computed the depth to magnetic sources from aeromagnetic map data by dividing the map into a number of blocks, and calculating the radial spectrum for each block. The error in source depth prediction is related closely to the window size. For gravity field, a window of six times the source depth is required for <10% information loss [12]. Pal [4] suggested that a 95% minimal accuracy level demands a profile length exceeding five to six times the depth to center of the cylinder and digitization spacing less

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than one fourth this depth and width of the body from amplitude spectrum. However, before the computation of power spectrum, the gravity data are subjected to cosine tapering. The power spectrum, when the amplitude (average over circle in the wave number domain) is plotted on a logarithmic scale versus a lines scale for the frequency, produced estimates of two dimensional power as a function of wave number or spatial frequency intervals. This function has linear characteristic decreases with increasing spatial frequency. The slope of the straight line is proportional to the depth of the top of the body.

GEOLOGY OF THE AREA:

The study area is located in northeast Yemen Fig. (1) Where most of the surface is covered by sands. It is representing the southern part of Rub Al-Khali basin and the northern flank of the regional Hadramawt arch, forming the southern margin of the basin. It includes blocks number 11,12, 29, 30, 34, 36 and 54 according to division given by Petroleum Exploration and Production Authority of Yemen. The Rub Al-Khali basin constitutes a huge structural downwarp area originating an intracratonic sag within the wide Gondwana shelf of the early Paleozoic. It was becoming more differentiated as a subsiding platformal basin formed later during the Paleozoic and Mesozoic [13, 14].

All Paleozoic and early Mesozoic sedimentary sequences pinch out into south towards Hadramawt arch, northward into the basin. The northern flank of the Hadramawt arch slopes gently but in a step like manner. The sedimentary column thickness was found to be about 2km near the crest of the Hadramawt arch to over 4km towards north of the study area.

Hadramawt arch had remained as a positive elevated feature for much of the Paleozoic and was rejuvenated in the early Mesozoic and was remained as an effective barrier until Cretaceous time. In early Carboniferous, processes of uplift have been occurred as a result of Hercynian Orogeny which associated with normal faulting. In upper Jurassic, the rejuvenation of tectonic movements in the region began with the initial differentiation of the wide platform shelf, ultimately leading to accentuated subsidence and rifting of the graben areas including Rub Al-Khali [15].

On some seismic lines, flower structures can be discerned at the shallow levels, indicating that transpressional regimes were operated during phases of horizontal movement on the Najd system. These flower structures show a decrease in relief with depth, suggesting disharmony with the basement or a detachment surface at InfraCambrian levels [15, 16].

In the eastern part (eastern portion of block 12, and the whole block 54), the InfraCambrian section is becoming thin to absent. There, the structures were found as a result of low relief antithetic, down to basin margin faults, generally terminating at the base of Jurassic unconformity. During late Jurassic, a rejuvenating movement was initiated along the old NW-SE faults which are following Najd fault system (beydoun 98, lan). The Alpine Orogeny was associated with normal faulting. This tectonic movement was represented by the very late NW-SE trending normal faults in the southern most portions of all four northern blocks.

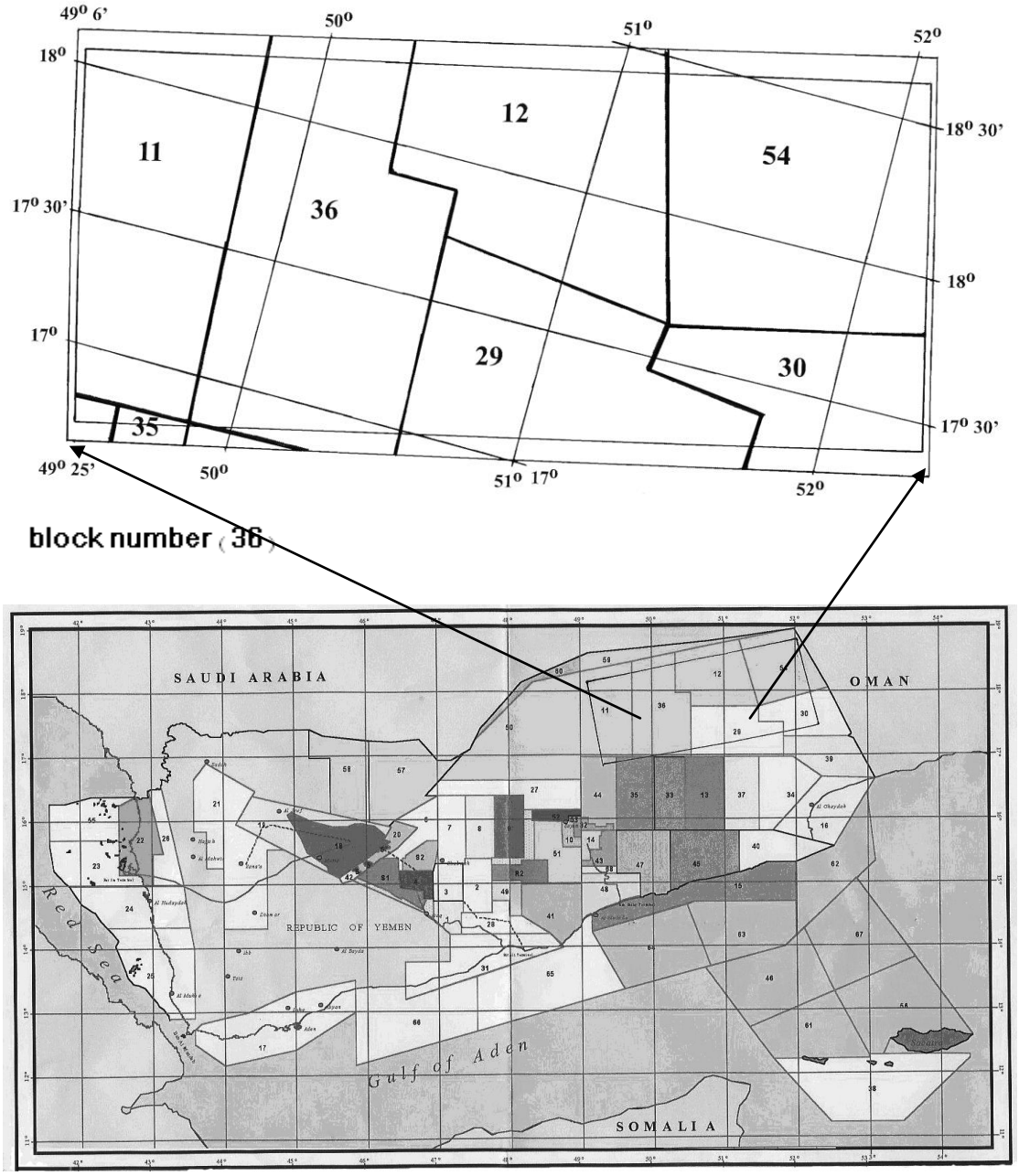
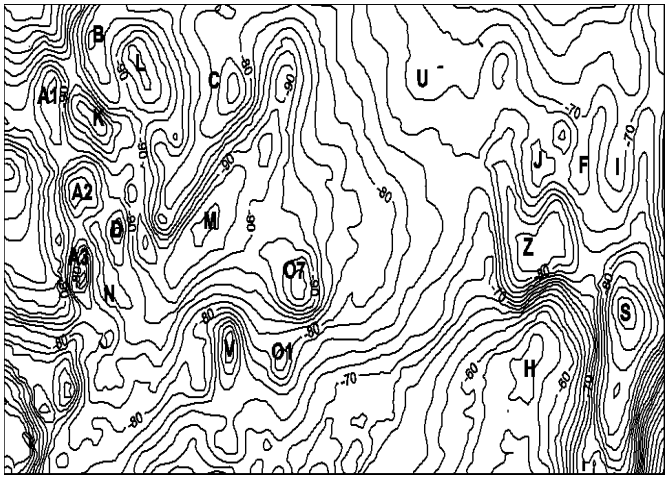


Fig. (1) Location map of the study area (After Petroleum Exploration and Production Authority, PEPA, 2003. Scale= 1: 4,000,000

The Paleozoic deposits in the study area were named and correlated well with Paleozoic deposits of Rub Al-Khali basin as a whole. They extended from Saudi Arabia in the north into northern Yemen. The information about the complete stratigraphic sequences on this area and their lithologic variation are available from many wells drilled in the area for oil exploration purposes.

THE GRAVITY MAP OF THE AREA:

Bouguer anomaly map of the study area (Fig. 2) is a part of the Bouguer anomaly map of People Democratic Republic of Yemen previously, with a scale of 1:1000,000 and contour interval of 2 mgal. This map was published by the Petroleum and Minerals Board in 1983, depending on gravity survey which has been carried out by Russian Company [17].



Scale 1:1,500,000 . C.I.= 2 mgal.

Fig (2) Bouguer anomaly map of the study area [17].

The gravity map of the study area may be separated into eight zones of different anomalous characters, and these are giving symbols (A, B, C, D, H, K, L, M) on the map. The eastern part of the map is characterised by two large negative anomalies (S, Z) with irregular shapes. These are representing parts of a large negative anomaly covering the area with a amplitude of (-8,-18) mgals respectively. Anomaly (S) is trending (N-S) and anomaly (Z) has nearly a circular shape. These anomalies suggested the location of low density rocks. The circular shape is suggesting a local intrusive body or a local thickening of the sedimentary succession.

The western part of the gravity map, region (C), is characterised by continuous positive anomalies, trending in a (N-S) direction. The area comprises many isolated positive anomalies within the large one. Such anomalies suggested a possible basement blocks protruded from the main basement surface as suprabasement structures. Region (H) is characterised by a large positive anomaly with an amplitude of (20) mgals. This anomaly is attributed to the metamorphic rocks of high density of Hadramawt arch located to the south of the study area. The high gradient between anomaly (S) and anomaly (H) indicates fault zone trending nearly in (N-S) direction and another trend (NW-SE) between anomaly (Z) and anomaly (H). The same source can create positive anomaly (G).

One of the main features of the gravity map is the area covered by a huge gravity low in the middle area. It has a large negative zone (M) across the study area with irregular shape. The positive anomaly (Q) at the NE corner of the map could be due to sources with in the basement. Analysis of the gravity map has revealed the general structural and tectonic trends of the main features. These features are affected by block faulting systems, leaving graben structures [18].

The Bouguer anomaly map is digitized at a grid interval of 2.5Km, the values being taken to the nearest milligal. The 2.5 Km interval is chosen because the analysis is concerned with deep feature studies. The array of the data is becoming (128 X 64) data points.

Two Dimensional Basement Depth Estimation using power Spectrum analysis.

Gravity data for Rub Al Khali area are used to estimate the depth of basement

through the application of two dimensional power spectral analysis. Dimitrials et. al (1987) computer program has been utilized in the calculation of the radial spectrum. The program transformed the data from the space domain to frequency domain by means of FFT and then calculates the radial spectrum. The logarithm is taken and the resulting values are radial spectrum of the anomalous field under consideration. By this technique the two dimensional data are transformed into one dimensional dimension.

The window size used in the calculation process was 40x40 Km which is equal to 16x16 grid points with grid interval of 2.5Km. Source depth up to 8Km is valid. The overlap of the windows was 4 grid intervals. The calculated depths are done for the inner part of the area under consideration and a zone of 9 grid points width are eliminated around the output depth map.

The distribution and style of gravity anomalies are reflected on the estimated basement depths. The estimated depth values for the study area through using two dimensional power spectral technique are ranging between 3.5 – 9.5 Km (Fig. 3). The deduced basement structures indicate the existence of graben and horst features. They are making a deep and large areal extent of graben structures. These features are so clear in the left and right sides of the study area, while the middle part is characterised by an elevated area relative to the other two parts. The orientations of the graben and horst structures are mainly in NNE-SSW. They are making continous zones of low basement surface reliefs, and with lateral displacements. Such picture reflects the various tectonic forces acted on the region.

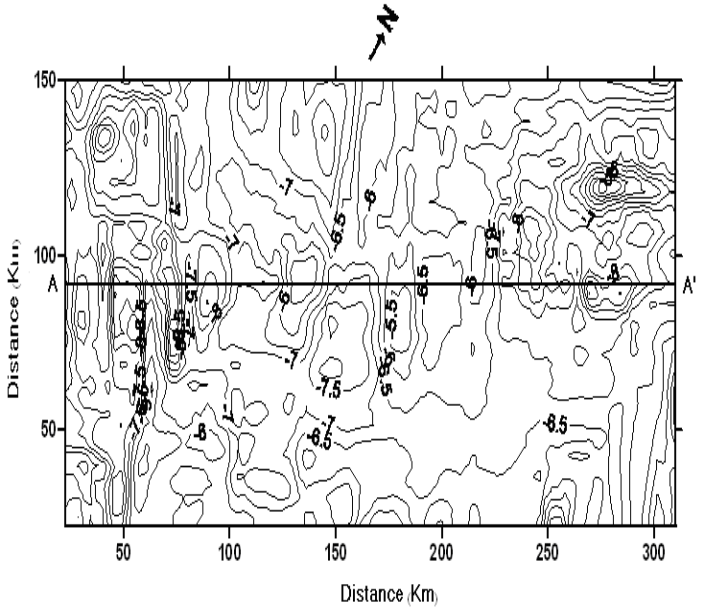


Fig. (3) Countour map of the depth estimation by two dimensional power spectral technique for Rub Al Khali area, NE Yemen. C.I.= 0.5 km

A better picture and more expressive way presentation is shown in a three dimensional representation of the estimated depth values (Fig. 4) and with a cross sectional profile (Fig. 5). The orientation and areal coverage of graben and horst structures can be visualized and follow up. They show the repetition style of these structures and with changing orientations. The

cross section along profile A-A' defined on Figure (3) explains the basement structure styles and then reflects the suprabasement features.

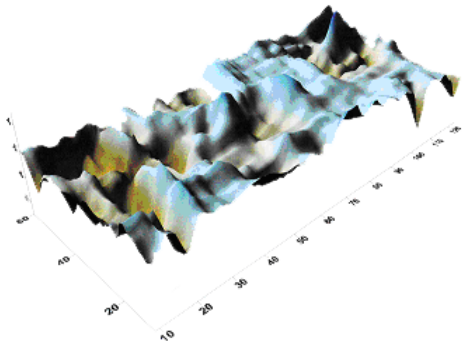


Fig. (4) 3-D representation of the basement depth obtained from two dimensional power spectral depth estimation of gravity data for Rub A; Khali area, NE Yemen.

The locations of graben structures and their areal extent in Rub Al Khali region are so useful in providing the most possible sites for future oil exploration, since most oil fields in Yemen were discovered within basement graben structures. The great thickness of sedimentary sequence within the graben area highlights the possible occurrences of oil formation processes. The great sizes of these structures are also provide an encouragement for further detailed geophysical and drilling works to be done at the most interested and promised sites with in the region.

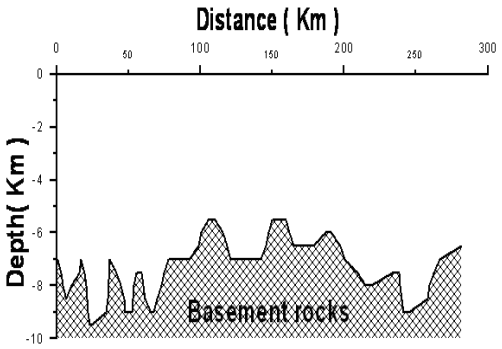


Fig. (5) Basment surface features along profile A-A' on figure (3) exhibited the graben and horst structures.

Conclusions and Discussion:

The analysis of gravity data for Rub Al Khali area using various analysis techniques reflects the possible distribution of structural features as due to graben structures (low gravity anomalies) and horst structures (high gravity anomalies). The depth estimated through using two dimensional power spectral analysis technique reflects these features as an uplifted and subsided areas with in the basement. The obtained depth values are more likely in good agreement of the available from boreholes drilled in the area.

The great differences between the upper surface of horst structures and the bottom of the graben depict the behavior of the basement surface reliefs in an area where little information about deep geology is available. The depicted geologic features of the basement surface and its structural trends and areal coverage highlight the importance of this region for future oil accumulation. The great thickness of sedimentary cover and the competence of the whole sedimentary sequence in the area according to boreholes drilled in the area encourage the oil companies to consider the area as a potential target in future.

Seismic works should be concentrated on locations of the main grabens and particularly those sites that cover large area and extend for a long distance. The same procedure of basement depth estimation can be followed in other part covered by gravity surveys in order to provide a picture about the style of geologic structures at depths with very low cost and short time. A procedure can be used as a guide for future investigation, although there are some constrains on its application which should be applied carefully.

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تمثيل بالابعاد الثلاثة لظواهر سطح صخور القاعدة لمنطقة الربع الخالي , شمال شرق اليمن , باستخدام تقنية التحليل الطيفي للمعلومات الجذبية

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الخلاصة:
تم تطبيق تقنية التحليل الطيفي ببعدين على المعلومات الجذبية لمنطقة الربع الخالي لتقدير عمق تراكيب صخور القاعدة. تقع منطقة الدراسة في شمال شرق اليمن التي تتوافر عنها معلومات قليلة عن الجيولوجيا العميقة. تتراوح قيم الاعماق المحسوبة بين (3,5 – 9,5) كم وتمتاز الاجزاء الغربية والشرقية بالاعماق الكبيرة بينما الجزء الوسط يمتلك صخور قاعدة مرتفعة.
ان نظام توزيع الظواهر التركيبية العميقة والضحلة يعكس اتجاه تراكيب الخسفات والسروج مع ازاحات جانبية. فتراكيب الخسفات التي لها اعماق كبيرة وتمتد لمساحات واسعة تؤشر اهمية هذه المنطقة لأحتمالية تجمع النفط اذ ان معظم حقول النفط في اليمن حددت في تراكيب الخسفات. ان الاشكال المستنبطة للتراكيب واتجاهاتها والاعماق وتمثيلها بالابعاد الثلاثة مفيدة جدا ومشجعة لأستكشاف النفط المستقبلي في هذا الجزء من الاراضي اليمنية.