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Utilizing the Gravity Method to Detect the Potential Effect of the Salt Dome in the Nahr Omar Oilfield, Southern Iraq

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Abstract

Geophysics is one of the branches of Earth sciences and deals with studying the Earth's interior by studying the variation of physical properties within rock layers. Applied geophysics depends on procedures that involve the measurements of potential fields, such as the gravitational method. One of the significant oil fields in southern Iraq is represented by the Nahr Omar structure. A power spectrum analysis (SPA) technique was used to collect gravity data within the chosen oil field area in order to confirm the salt dome in the subsurface layers. The analysis of SPA resulted from six surfaces representing the gravity variation values of the depths (m)14300, 3780, 3290, 2170, 810, and 93.5. Gravity surfaces have been converted to density surfaces to determine density and velocity models from these six depth slices. The inverted data were consistent with the Nafe and Drake standard curves of converting densities to average velocities. The current study illustrated the benefit/assist of the inversion technique of gravity data to average velocity, to a large extent, in detecting the salt dome effects on the subsurface strata for the Nahr Omar oilfield. In comparison, the decrease in the average velocity of the salt dome area is related to this effect. The acquired inversion results were supported by available seismic data within the Nahr Omar area and utilized the seismic attributes processing technique.

Keywords: Gravity data Inversion; Power Spectrum analysis (P.S.A); Density/Velocity Models; RMS amplitude attributes

استخدام طريقة الجاذبية للكشف عن التأثير المحتمل لقبة الملحية في حقل نهر عمر النفطي، جنوبي العراق

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جامعة بغداد, كلية العلوم, قسم علم الأرض, العراق

الخلاصة

الجيوفيزياء هي أحد فروع علوم الأرض وتتعامل مع دراسة باطن الأرض من خلال دراسة التباين في الخصائص الفيزيائية ما بين طبقات الصخور. تستخدم الجيوفيزياء التطبيقية إجراءات تتضمن قياس المجالات الجهدية مثل طريقة الجاذبية. يمثل تركيب نهر عمر أحد الحقول النفطية المهمة جنوبي العراق. لذا للتحري وأثبات تأثير وجود القبة الملحية تحت سطح حقل نهر عمر النفطي، تم استخدام تقنية تحليل طيف الطاقة لبيانات الجاذبية ضمن منطقة حقل نهر عمر النفطي، والتي نتج عنها ستة أسطح تمثل قيم

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الجاذبية للأعماق (14300م، 3780م، 3290م، 2170م، 810م، 93.5م). تم تحويل أسطح الجاذبية إلى أسطح كثافة وقيم الكثافة الى موديلات سرع متوسطة لنفس هذه الأعماق الستة. بيانات الدراسة كانت متوافقة مع منحنى (Nafe–Drake) القياسي لتحويل الكثافات إلى معدل السرعات. حيث تم تحديد تأثير القبة الملحية من خلال انخفاض السرعة المتوسطة، دعمت هذه النتائج باستخدام البيانات الزلزالية المتوفرة ضمن منطقة نهر عمر، فضلا عن استخدام معالجة تقنية الخصائص الزلزالية (Seismic attributes).

1. Introduction

The gravity technique is a crucial tool for solving different subsurface mapping challenges. It is the main approach in some specialized geological research, such as mapping near-surface voids, analyzing metallic ore deposits quantitatively, and describing salt geological structures [1]. Utilizing technical geophysical surveys and readily available well data/information, which is employed as a control point, can highly assist in dealing with different geologic difficulties when the background of structural and stratigraphic subsurface models is less detailed [2]. The gravity method found lateral density changes, significant in the seismic method and vertical density changes. The gravity and magnetic methods' primary benefits are that they are faster and less costly than the seismic method; however, they offer the same level of knowledge about the subsurface as the seismic method. There could also be ambiguities in terms of interpretation [3]. Instead, the Power Spectrum (PSA) techniques for analyzing the gravity data would place greater importance on the low and high amplitudes in relation to the depth of the earth's strata utilizing energy-decay behaviour curves [4]. This research is an attempt to invert Bouguer gravity data to the density and velocity models for a selected area of the Nahr-Omar Oil Field in the southern part of Iraq (Figure 1), i.e., to exploit the relationship between the density and velocity models with salt dome existence in the subsurface of the study area and the effect of it on the development of the field structure history. Gravity methods have been employed for a long time to analyze geological features that range in size and depth from very deep crustal blocks to near-surface ore deposits [5]. Seismic and well-data information is combined with gravity data to reduce ambiguity in gravity method results. Many geophysical studies have used gravitational data to prove many geological facts. Several researches in the field of geophysics have used gravitational data to identify many geological structures. The study of [6] used gravity and vertical magnetic maps to analyze basement rock structure lineament in the Al-Jezira area in N-S Iraq. The author indicated the axis characterization of lineament and faults present in maximum gradient by applying the Total Horizontal Divertive filter. The other study used gravity and magnetic data to delineate the general lithological basement rocks based on the qualitative interpretation of aeromagnetic, gravity, isostatic anomalies and basement depth maps [7]. Furthermore, processing and interpretation of Bouguer gravity field data using dimensional filtering techniques to separate residual gravity field from the Bouguer gravity map for a part of the Najaf province in the S-W of Iraq has been conducted to detect the subsurface faults [5].

The scientific objective of the current research is to probe the effect of the salt dome within the Nahr Omar oil field depending on the conversion of the earth's potential gravity into average velocity values, representing one of the modern scientific techniques. The obtained results will be compared with existing seismic data/studies to highlight the effects of salt domes, which are regarded as an essential geological phenomenon in oil exploration.

2. Study area

Iraq's southern region is where the study area is situated, which is within the border of the Basrah province. Surface topography graduated from 6 m in the NW to 2 m in the SE part (Above Sea Level), Shat-Al-Arab River passing at the area study by general direction (NW to

SE) (Figure 1). Dimensions of the Nahr Omar oil field are 25 x 13 Km, and an elongated dome anticline with NNW-SSE direction represents the structure. Table 1 displays the coordinates of the study area boundaries in the UTM system.

Table 1 Coordinates of study area boundaries (WGS1984 UTM Zone- 38)

point	East	North
A	734185.65	3426225.05
B	778280.15	3426622.96
C	778659.09	3378360.62
D	734607.21	3377949.62

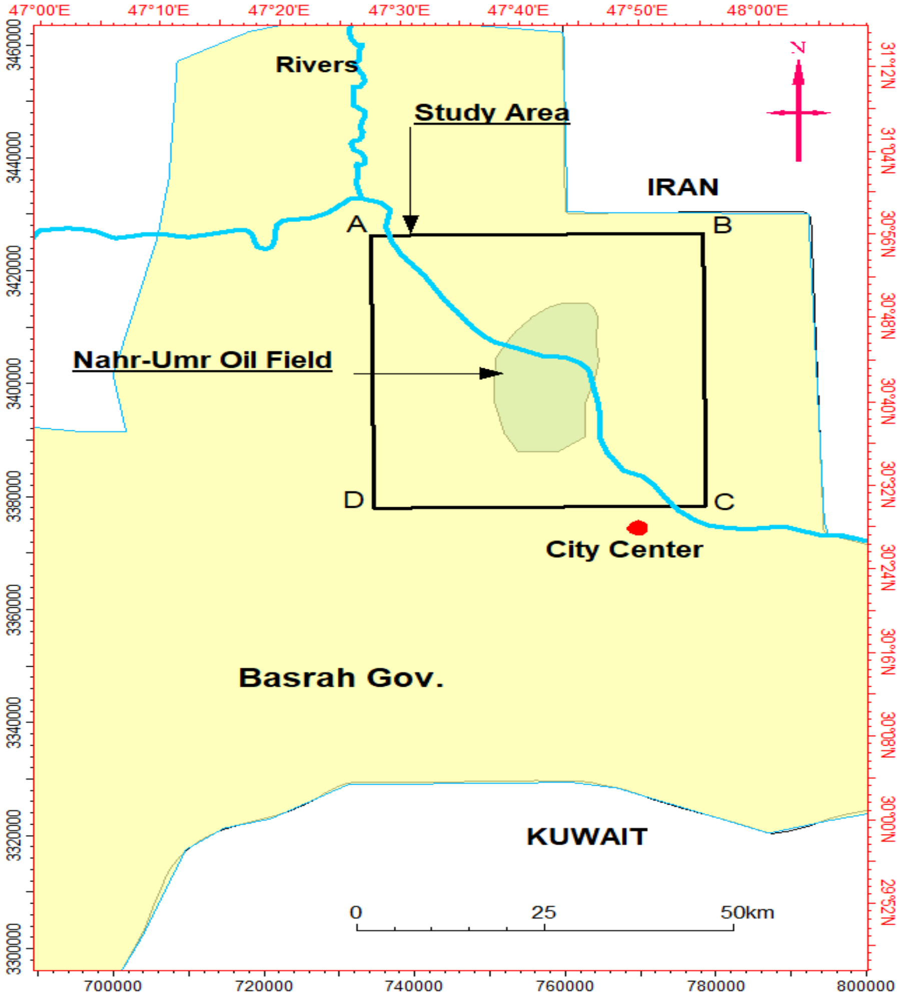

Figure 1: Map of Basrah province, the study area indicated by the black square, which is the Nahr Omar oil field is located within the study area

3. Geologic Setting of the Study Area

The exposed stratigraphic units of the study area's surface are represented by the Quaternary deposits (Depression Fill) [8]. The Quaternary sediments cover one-third of Iraq's surface area, mostly within the Mesopotamian Plain, and the Quaternary sediments in the

Mesopotamian are around 250m (Figure 2). Geological research illustrated that the structure of the Majnoon oilfield is separated by a saddle, even though it is believed that the structure is part of the Majnoon oilfield [9]. A network of normal faults ranging from radial to parallel occupy the structure's crest [10]. However, based on the gravimetric and magnetic surveys conducted in the region, the geophysical investigations validated the function of salt tectonics in the evolution of the subsurface structures [11].

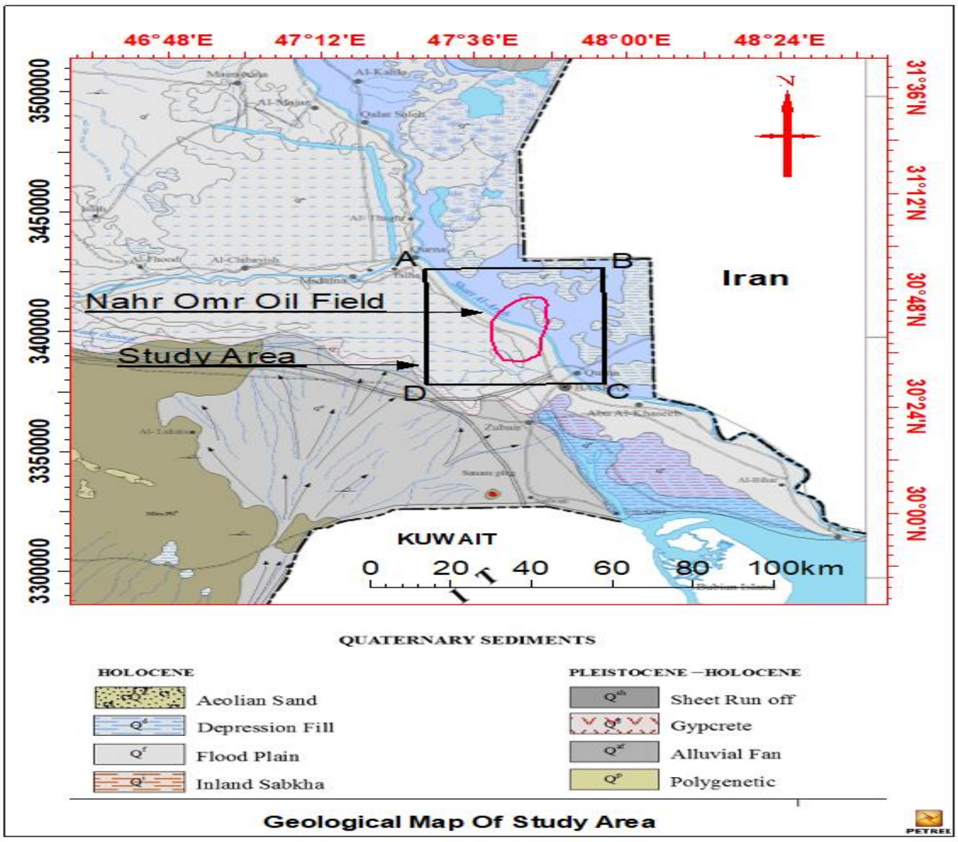

Figure 2: Geological map showing the stratigraphic units on the surface of the study area [8]

4. Materials and Methods

4.1 Gravity stations distribution in the study area

The Bouguer gravity survey was conducted during the 1940s and 1950s by the French Geophysical Institution (CGG), according to a base map of measurement stations with different interval spaces between measurement points (Figure 3). The area surveyed the study area conditions a 1 km space interval between every two measurement points [12].

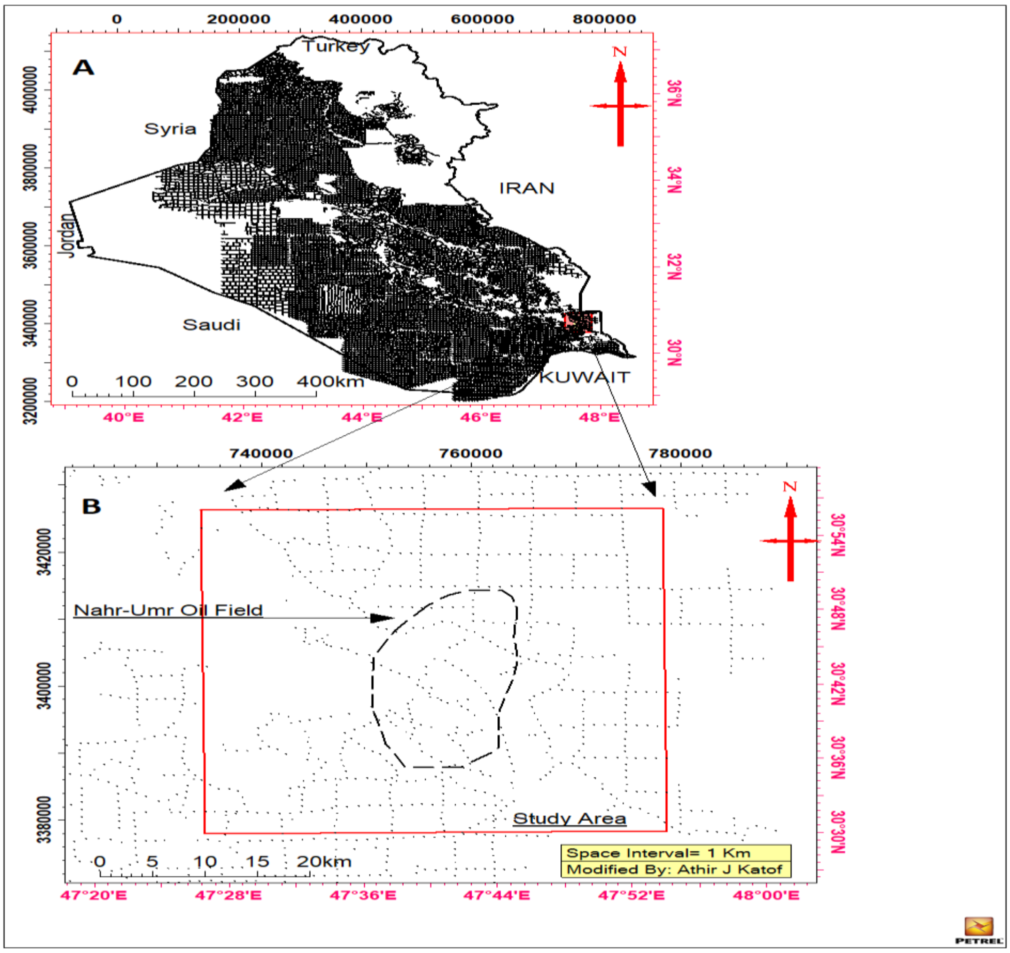

Figure 3: (A) The distribution Map of gravity measurement points for Iraq and (B) The distribution Map of gravity measurement points for the study area [12]

4.2 Software overview

In the current research, three software were used to process and interpret all used data:

1. GETgrid software (GETgrid version 1.2, gravity and magnetic software from GETECH, 2003) is used to analyze the Power Spectrum for Bouguer gravity data.
2. Geosoft software is used to make the inversion of gravity data to estimate and model the density and velocity data.
3. Petrel software (2018) makes the 2D surfaces of density and velocity models, which is used afterwards to construct the 3D velocity data cube.

4.3 Well data analysis and Density-Velocity relation estimation

Depending on the linear relationship between velocity (inverted sonic log) and density (RHOB-log) in well (NR) and comparison as shown in Figure 4. The total relation curve between density and velocity in the well (blue line) is highly consistent with Nafe and Drake standard curves more than other curves in Figure 5 [13]. However, this equation can be used to estimate the density and average velocity within the selected study area.

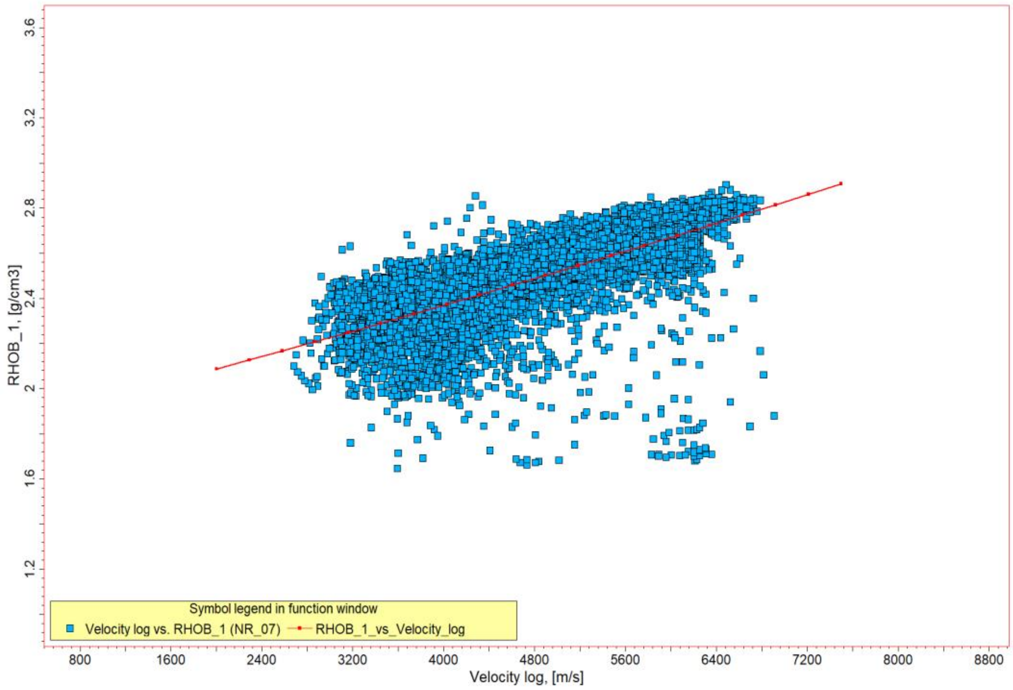

Figure 4: The Velocity log-density relationship of the (Nr) well

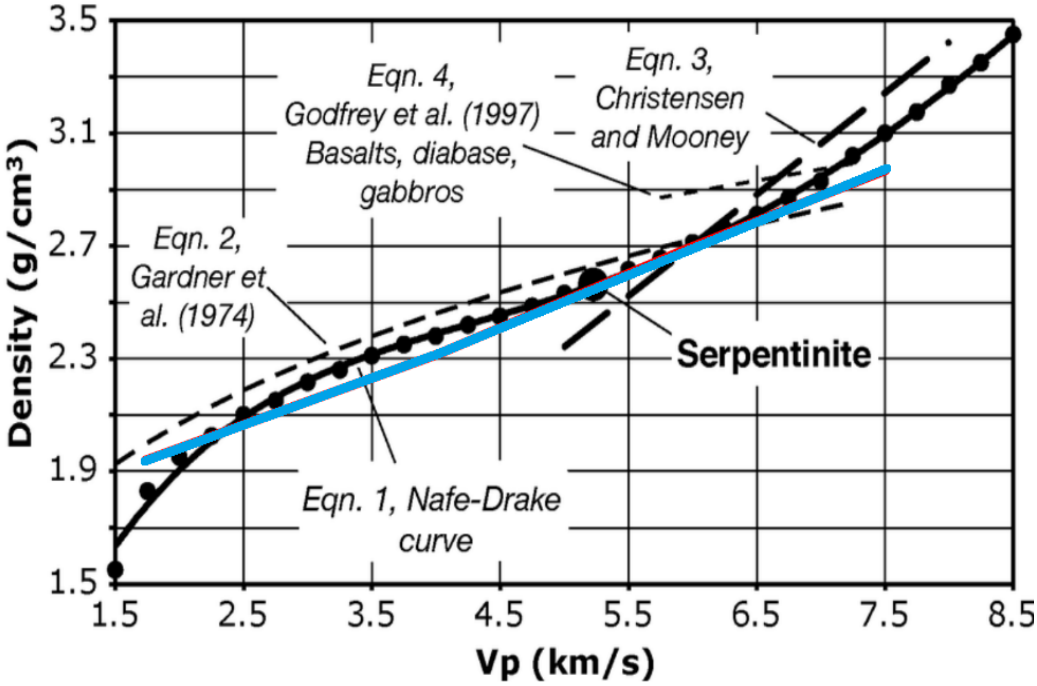

Figure 5: The general behaviour matching of Density and Velocity curves in (NR) well (in blue) along the standard corresponding curve of Nafe – Drake modified from [14]
The Sea, A. E. Maxwell (Editor), Vol. 4, Wiley-Interscience, New

4.4 Power Spectrum Analysis of Gravity Data

Using the PSA technique, the distribution of gravitational anomalies will be clarified depending on the high and low amplitude and frequency for the specific depths [15]. Figures 6 and 7 show how the Bouguer gravity grid is imported into the GETgrid program and the spectral gradient is examined in terms of amplitude and frequency values. The deeper depth level will produce energy with a high frequency and low amplitude, in contrast to the shallow depth level's low frequency and high amplitude [16]. Each depth slice will image the anomalies with a certain depth level. This procedure predicts that the studied Bouguer gravity data will result in six depth levels highlighting the dominant anomalous effects: 14.3 Km, 3.78 km, 3.29 km, 2.17 km, 0.81 km, and 0.95 km, as shown in Figure 8.

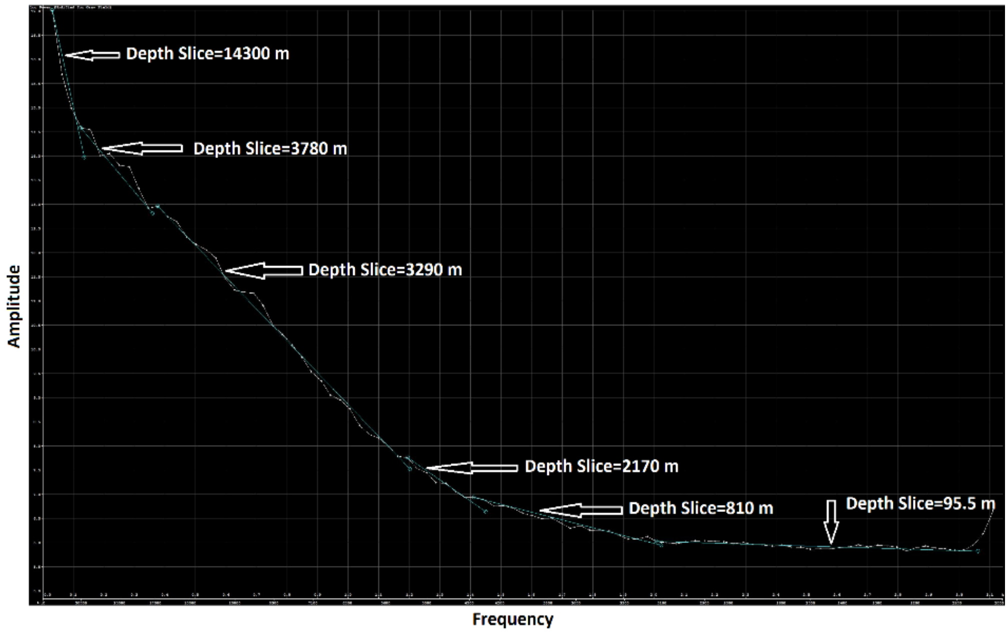

Figure 6: The Analysis of the Power-Spectrum of Bouguer data with different depth-levels in meter

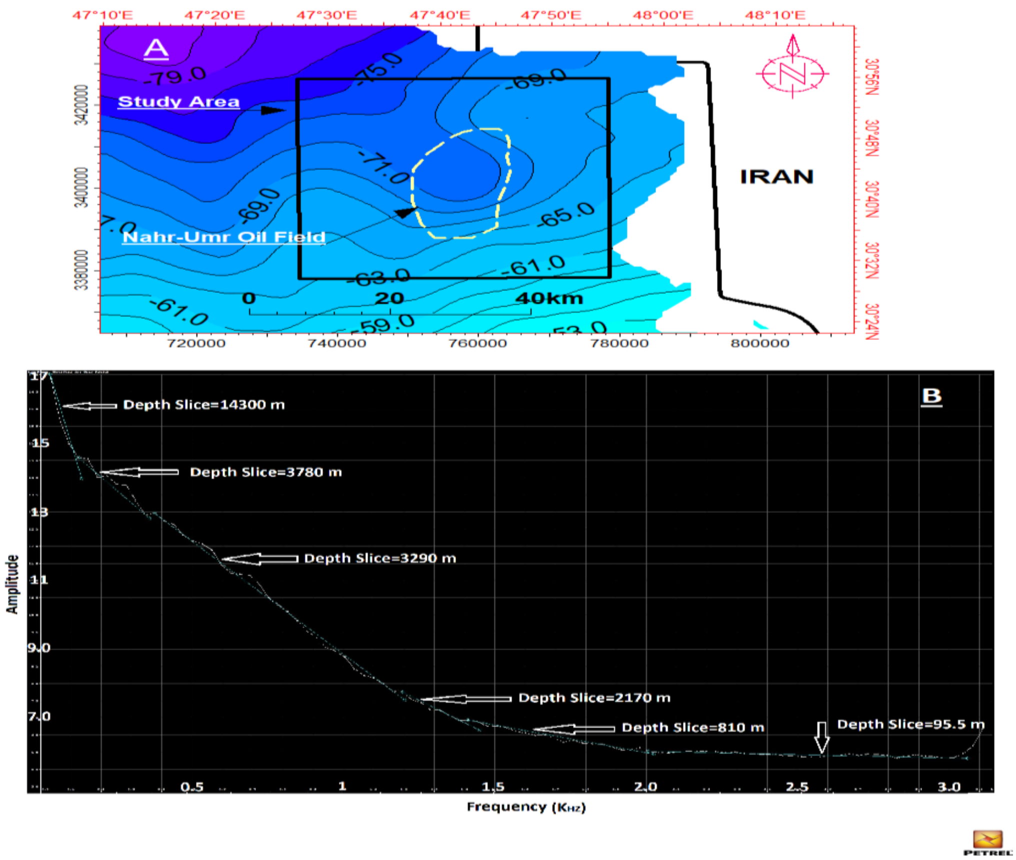

Figure 7: A) The Bouguer gravity data of the study area **and** B) The Power Spectrum analysis of Bouguer data, the map shows the spectrum curve of the high-low frequencies/amplitude variants.

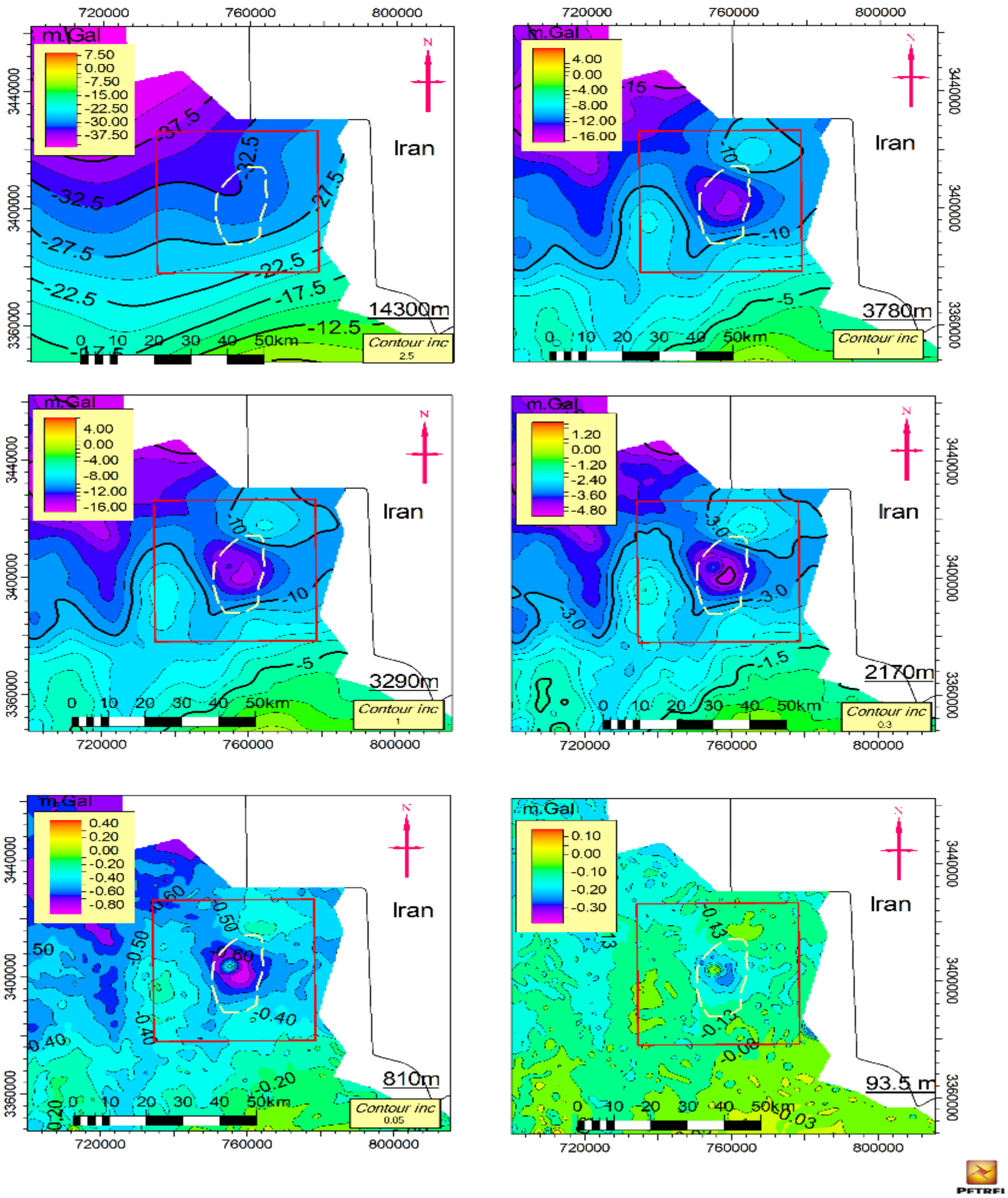

Figure 8: The spectral grids of domination gravity anomalies effects at depth levels of 14.3 km, 3.78 km, 3.29 km, 2.17 km, 0.81 km, and 0.95 km, by applying the analysis of Power Spectrum to gravity Bouguer data, gravity values increase with shallow depths

5. Results

5.1 Density–Average Velocity Data Modelling

As was mentioned earlier, the Power Spectrum technique was used on Bouguer gravity data to produce gravity surfaces for particular depth levels. The aim of modelling the density and average velocity data construction is to make the slices effective for a range of functions' parameters, such as gravity, slice depth, well-data density in relevant slices and the gross depth of the constructed model. Well-data will be used as a control point to estimate an exact match of true densities at well sites [17]. It is possible to extract any depth surface or level from the density-determined model and display it in the density domain. Gravity inversion depended on the density from well-data as the starting point (i.e., control point) to the density distribution when the density model could be estimated from gravity measurements [18].

The density model can then be changed into a velocity model using the Fast Fourier's Transform (FFT) equation's outputs depending on the Nafe and Drake standard curve (Figures 9 and 10).

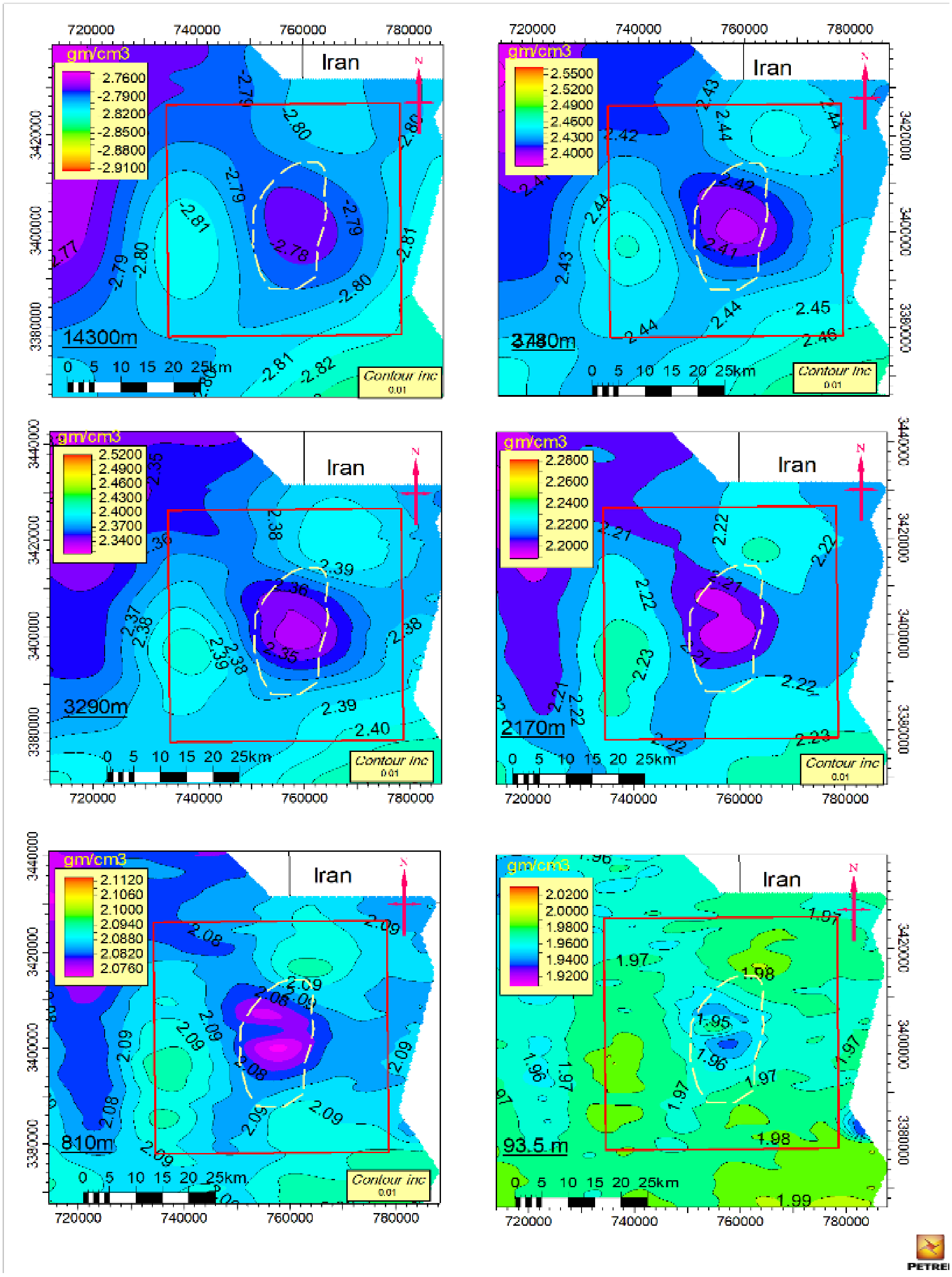

Figure 9: The Spectral Density in a 2D surface grid, built by using (FFT) Transform method, the study area highlighted by the red squares

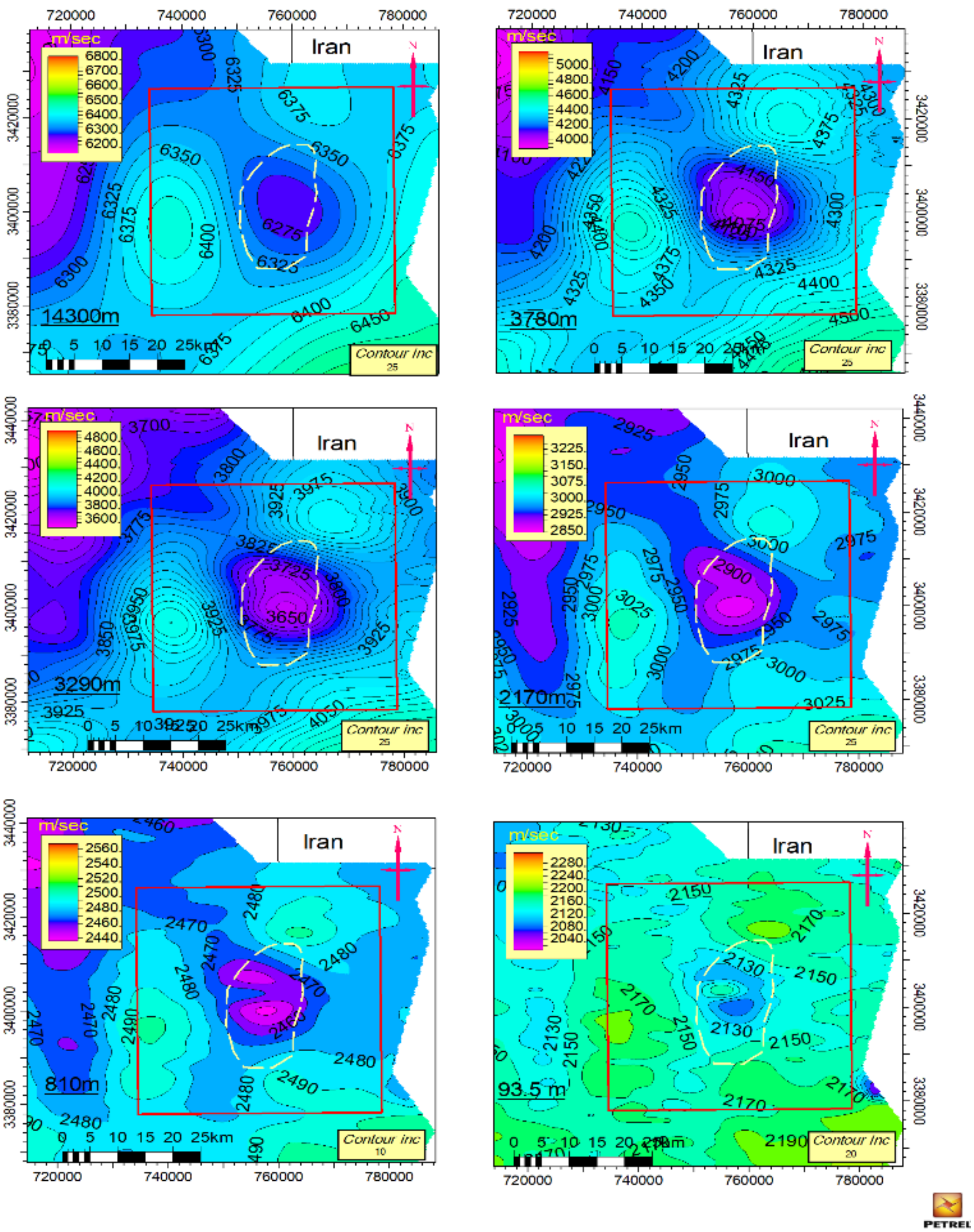

Figure 10: The Spectral velocity in 2D depth levels constructed using the curve of Nafe & Drake for data profile spectral of various depths

5.2 Conversion of 3D Geometrical Model

The available data have been distributed over the 3D model using interpolation of the density and velocity values inside the grid. Estimated density and velocity models may be produced using pre-set system variables since determination and stochastic procedures can use continuous characteristics as part of the geometric modelling processes. A numerical value corresponding to the pertinent system variable is assigned to each cell in the model. A 3D cube of velocity in Seg-y form will be built based on all six subsurface slices reached to the depth of 14300 m., as shown in Figure 11.

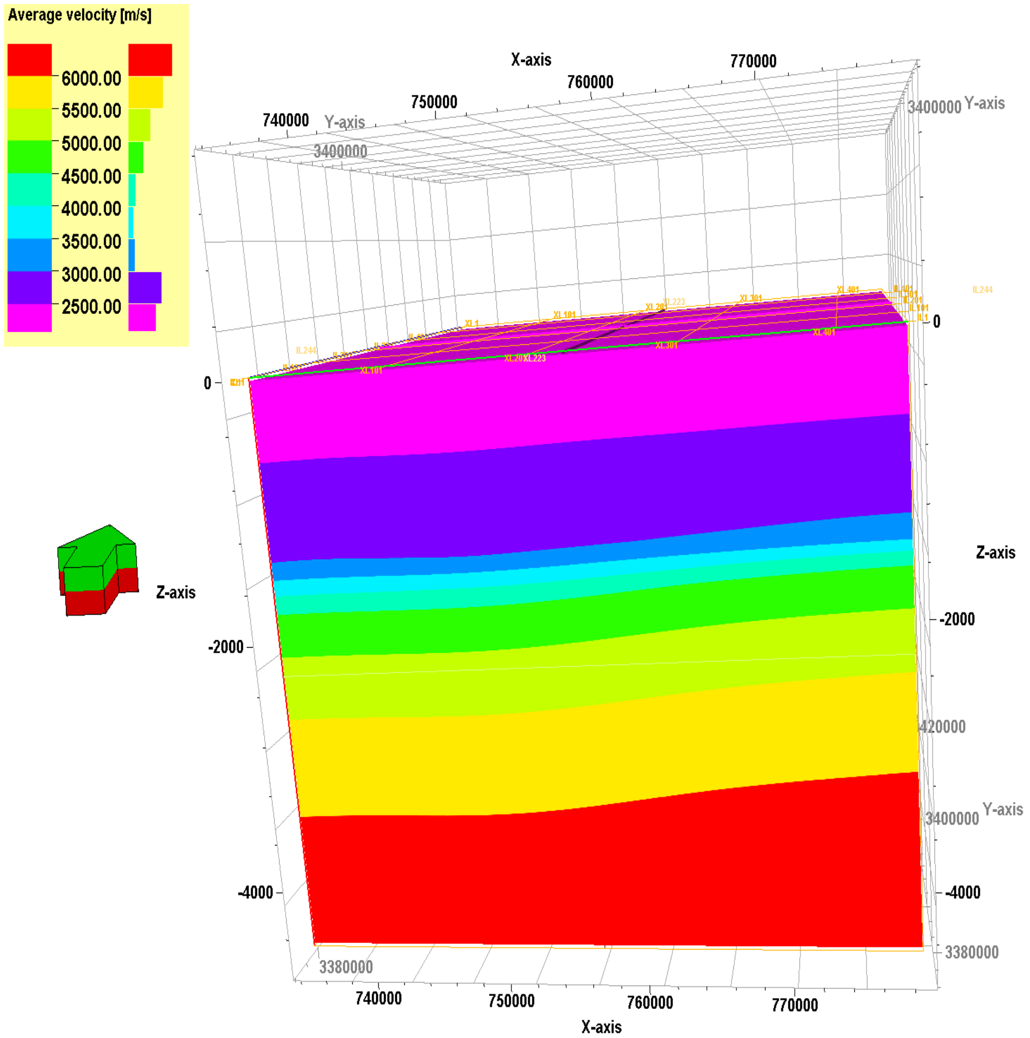

Figure 11: The 3D velocity cube (in Seg-y format) with the depth ranges obtained after converting the model to the inverted average velocity model derived from the gravity subsurface slice

The 3D velocity model will be used to extract the velocity of 2D lines within the study area. The deduced 2D velocity (Seg-y) lines will be helpful in the process of inference of low-velocity at the site of the Nahr-Omar oilfield, which certainly reflects the presence of the salt dome in the subsurface strata. The low speed is an indication of the low relative density in the salt area compared to its surroundings, and is a reflection of the low gravity values.

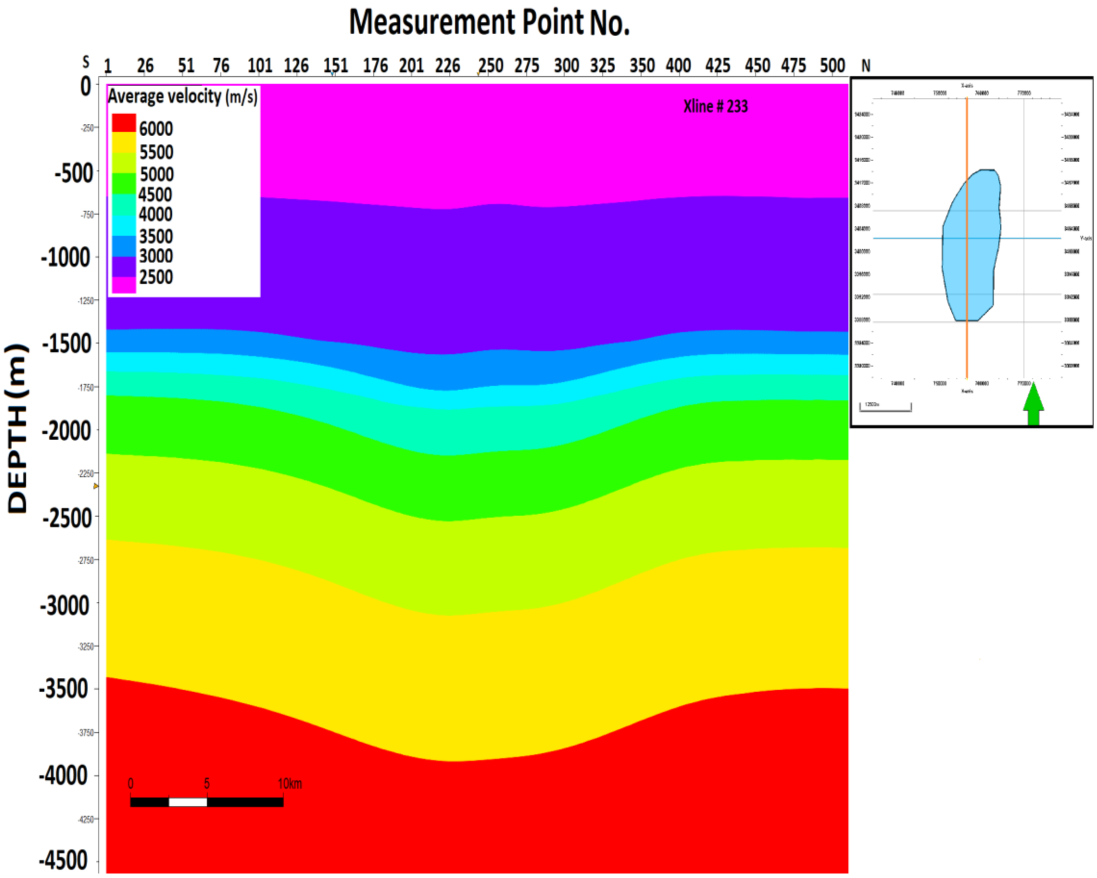

Figure 12: The 2D velocity lines map, which is extracted from the 3D estimated velocity cube according to the salt dome location in the subsurface within the study area. The section shows the drop in the velocity within the salt dome area.

5.3 RMS seismic attribute

A seismic attribute in reflection seismicity is a quantity retrieved or produced from seismic data that may be examined to improve the information that can be more nuanced in a conventional seismic image, leading to a better geological or geophysical knowledge interpretation of the data [19]. In this case, we used a seismic section located in the Nahr-Omar study area, which clearly shows the effect of the presence of salt within the area on the seismic signal obtained from field recordings (Figure 13). Seismic Attribute technique available within the Petrel software was used to show the features of low seismic velocity at the site of the salt dome. The root means square amplitude (RMS amplitude) is a common technique that used to display amplitude values in a specified window of the stack data [20]. RMS amplitude attribute was applied on the seismic section located within the study area, which is modified from the study of [21] to detect the low seismic velocity as shown in Figure 14, the RMS velocity values are decreasing compared with the velocity in the surrounding reflected geological layers in the section.

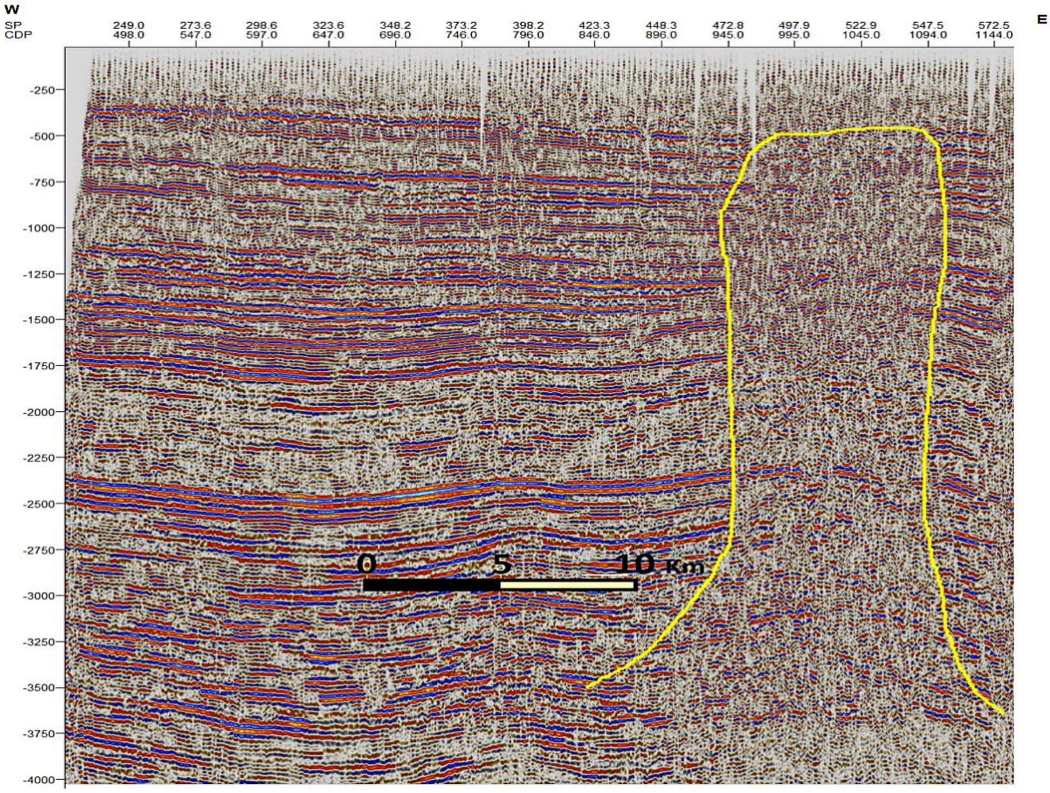

Figure 13: A 2D seismic line within the study area highlight the effect of the salt dome on the seismic data record, Modified from [21]

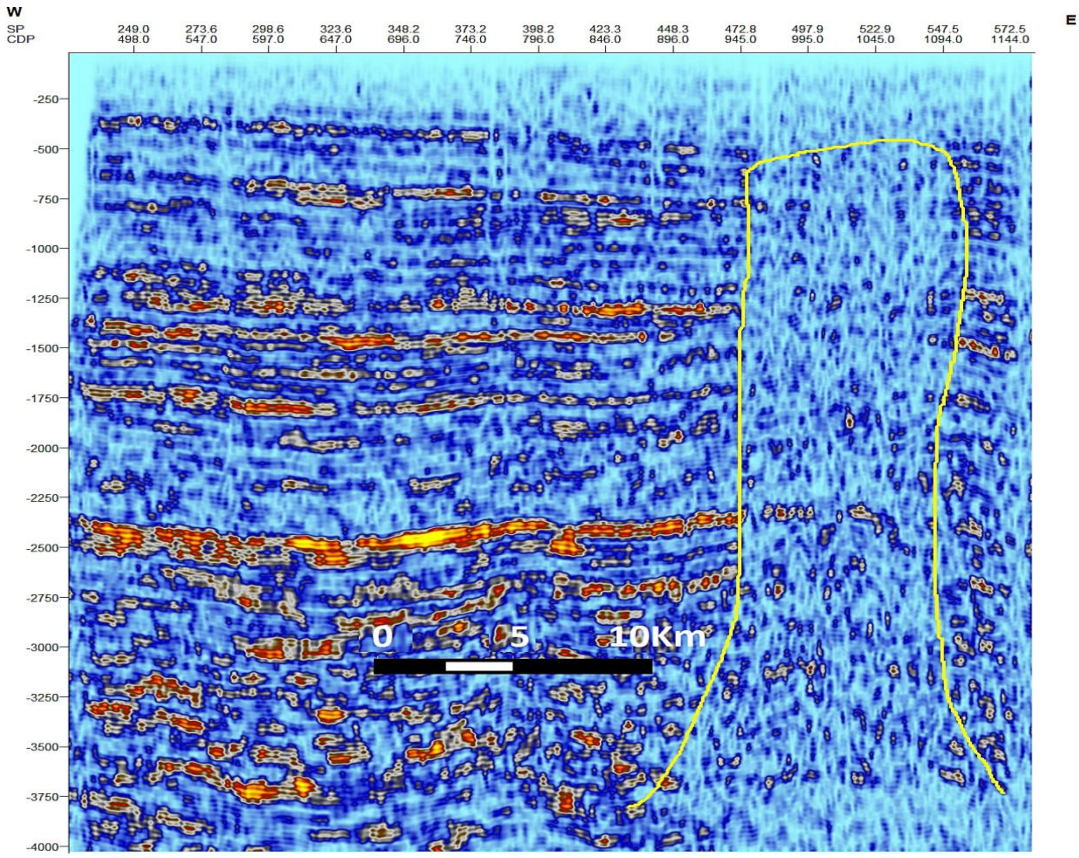

Figure 14: RMS amplitude attributes applied on 2D seismic line within the study area, which presents the effect of the salt dome on the RMS velocity of the seismic recorded data, Modified from [21]

6. Conclusions

The current research is dependent on the potential gravity data integrated with available reflection seismic and well-data, which illustrates the following:

1. The Power Spectrum Analysis quantifies how variance in amplitude is distributed over frequencies and was efficient for identifying periodic behaviour with depth levels.
2. The study illustrated the relationship conversion from the density to average velocity in the Nahr-Omar oilfield area, which was generally consistent with the Nafe and Drake standard curve.
3. The resulting models, i.e., estimated from the gravity data, in two phases of density and velocity models, refer to the places of variation in the values of density and velocity within the study area, which confirmed the effects of the salt dome on subsurface strata of the Nahr-Omar oilfield, i.e., the low seismic velocity in the area of the dome below the field indicated the presence of salt layer, which is represented by its low-density in comparison with the density of the surrounding rocks of all directions.
4. Integration of the gravitational analysis results with the attributes of the seismic data supported the objective of this research. This proved the presence of the salt dome below the field and led to the subsurface development of the structure and formation of the Nahr-Omar oilfield.

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