Original Article

Investigating the possibility of hydrocarbon reservoirs in Karanj oil field

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ABSTRACT

The increasing development of industry and the expansion of vital arteries in different parts of Iran requires that the situation of subsurface lineaments be seriously considered to identify hidden faults and analyze the risks arising from it. In the interpretation of aerial geophysical data in this study, mainly the evaluation of geological formations and their changes to explore minerals and oil has been considered. Therefore, in interpreting magnetic data, attention was paid to phenomena and complications, as well as methods that can help identify the desired anomalies. In this regard, preparing a magnetic field strength map was very useful and necessary. This map was taken based on raw geophysical data related to 2015 with the guidance of the tutor and was prepared using software analysis. Because rocks have different magnetizations, a magnetic difference map can provide excellent lithological distribution images. The total magnetic field strength data of each lithology unit have a specific magnetic response. Fault zones or zones that are fragmented generally show a low-intensity magnetic response due to the passage of water or fluids and weathering of magnetic minerals, the shape of these anomalies are usually visible as linear structures. The results of this study showed that the reservoir rock of this oil field has northwest to southeast extension and there is a possibility of faulting along the northeast to southwest in this reservoir. This faulting probably caused a discontinuity in the tank and this caused the gas injection not to increase the pressure and thus increase the harvest.

Keywords: Oil field, Magnetic field, Hydrocarbon reservoirs.

Introduction

Today, the use of geophysical methods in mineral exploration and selection of suitable places for exploration is common. Geophysical methods are expensive methods [1] and can be used in two stages of mineral exploration. The first is the search phase, or the initial steps of exploration, in which aerial geophysical data taken on a small, regional-scale over a large area can be used to find anomalies. Another step is to use ground-based geophysical methods in the preliminary, semi-detailed, and detailed exploration phases. At this stage, geophysical information can be used to determine the exact location of the hidden storage, its shape, extent, and depth. Also, based on geophysical information along with geological information, suitable locations for drilling can be determined and finally, the number of deposit reserves can be estimated [2]. It is also worth noting that the interpretation and modeling of aerial magnets can help identify subsurface faults or buried faults. Interpretation and modeling of geophysical data are to determine the existing anomalies and their characteristics from the changes observed in the data [3]. In general, the interpretation and modeling of geophysical data are done both qualitatively and quantitatively. In qualitative interpretation, most of the types of structures that cause anomalies are considered, their direction and extension, and the extent of their spread. In this case, the shape, depth, extent and extension, and the physical properties of the anomalies are determined relatively. Today, such information has been developed to evaluate subsurface geology, especially linear structures in tectonic studies and its application in seismic hazard analysis [4].

The increasing development of industry and the expansion of vital arteries in different parts of Iran requires that the situation of subsurface lineaments be seriously considered to identify hidden faults and analyze the risks arising from it. In interpreting

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aerial geophysical data in this study, mainly, the evaluation of geological formations and their changes to explore minerals and oil was intended. Therefore, in interpreting magnetic data, attention was paid to phenomena and complications, as well as methods that can help identify the desired anomalies. In this regard, preparing a magnetic field strength map was very useful and necessary. This map was taken based on raw terrestrial geophysical data for 2015 with the guidance of the tutor and was prepared using software analysis. Because rocks have different magnetizations, a magnetic difference map can provide excellent lithological distribution images. The total magnetic field strength data of each lithology unit have a specific magnetic response. Fault zones or zones that are fragmented generally show a low-intensity magnetic response due to the passage of water or fluids and weathering of magnetic minerals. The shape of these anomalies is generally visible as linear structures.

Conversely, some of these areas may be affected by mineralization processes by mineralizing solutions, and magnetic minerals are formed secondary to them. In this case, these structures show high-intensity linear magnetic anomalies. Anomalous maps can be drawn according to the position of magnetic masses in the form of residual maps, upward expansion, downward expansion, first and second derivatives, reduction maps to the pole, etc., and are used for better interpretation and more detailed studies. Magnetic maps are often very complex and difficult to interpret, requiring a great deal of skill and experience, and sufficient knowledge of physics and mathematics with geological information. The reason for this is the vector property of the total magnetic field of the earth, which from one point to another, not only changes its size but also has a variable direction. Magnetic measurements at each station include the sum of subsurface effects. A magnetic map seldom gives a picture of single turbulence, but rather contains relatively sharp anomalies of shallow sources (medium-sized anomalies), which are usually representative of our favorite geological sources, and besides It also includes extensive anomalies of a regional nature. Separating anomalies helps us to better understand shallow sources [5].

One of the most important issues in oil geology is the ways of exploring and locating oil and gas reservoirs. In this regard, several methods can be used to determine the probability of such reservoirs.

In the most optimistic case, the existence of oil and gas reservoirs can never be realized with only one method, but the overlap of different methods, especially geophysical methods, increases the probability of detecting the reservoir.

In fact, hydrocarbon reservoirs are geologically important because of their economic importance, and the determination of physical patterns in a field can be useful in determining undiscovered fields. Therefore, the use of geophysical methods and determining the physical properties of an oil field is important in this regard. Since many studies, especially in the south of Iran, on oil fields have not been conducted in terms of magnetic anomalies, this research has an innovative aspect and is important in this regard.

Hydrocarbon reservoirs are important from the point of view of geophysical exploration due to their economic importance, and the determination of physical patterns in a field can be useful for determining undiscovered fields. Therefore, the use of geophysical methods and determining the physical properties of an oil field is important in this regard. Since many studies, especially in the south of Iran, on oil fields have not been done from the point of view of the magnetic anomaly, in this study, the possibility of hydrocarbon reservoirs in the Karanj region was discussed.

Materials and Methods

Magnetic field

The strength of a magnetic field at a point is the amount of magnetic force exerted on a unit of polar power, namely:

$$H = \frac{F}{P_0} = \frac{P}{\mu r^2} \qquad (1)$$

Magnetometry

The basis of this method is the measurement of anomalies created in the earth's magnetic field, which is usually caused by the presence of metal deposits (ferromagnets). In general, this method is effective in identifying the position of objects that cause magnetic anomalies. The nature of the magnetic field is such that the presence of magnetic objects with different dimensions in it can cause significant changes. The magnetic field is always the result of magnetic dipoles, so the force lines of the field do not have a fixed direction in each position [6].

Earth magnetic elements and its characteristic properties

If a magnetic needle can move around an axis of its center of gravity in all directions, it can position itself anywhere on the earth's surface along the earth's magnetic field (B). Vector B can be decomposed into two components, horizontal H and vertical Z. The angle between vectors B and H is called the angle of inclination and is denoted by I. Component H can be decomposed into two components East (Y) and North (X). The angle between the components H and X is called the declination angle and is denoted by D.

The values of D, I, Y, X, Z, H, B are called the Earth's magnetic elements, and the relationships between them are as follows:

$$Z = B \sin \hat{I} \qquad (2)$$

$$X = H \cos \hat{D} \qquad (3)$$

$$H = B \cos \hat{I} \qquad (4)$$

$$B^2 = \mathrm{X}^2 + \mathrm{Y}^2 + \mathrm{Z}^2 \qquad (5)$$

$$B^2 = \mathrm{H}^2 + \mathrm{Z}^2 \qquad (6)$$

$$H^2 = \mathrm{X}^2 + \mathrm{Y}^2 \qquad (7)$$

The vertical plane that contains the vectors Z, B and H is called the local magnetic meridian on Earth.

Assuming the Earth is homogeneous in the Northern Hemisphere, the end of the north pole of the magnetic needle (the momentum direction) tilts inward and is perpendicular to the magnetic pole in the Northern Hemisphere. In the southern hemisphere, it is opposite and the end of the south pole of the magnetic needle (opposite to the momentum direction) is tilted towards the ground and is upright right on the magnetic pole in the southern hemisphere. Therefore, the main magnetic moment of the earth is in the direction of the geographical Antarctic [7].

By definition, the magnetic pole in the northern hemisphere is called the negative pole, and the magnetic pole in the southern hemisphere is called the positive pole. Connecting points on the earth's surface where the magnetic needle is completely horizontal (i.e., all of component B is horizontal) produces a line called the magnetic equator, which lies approximately along the geographical equator [7].

The closer we get from the magnetic equator to the magnetic pole, the greater the angle I will be, reaching 90 degrees at the magnetic poles. In fact, magnetic poles are places where the angle of inclination (I) is equal to 90 degrees. The value of vector B will be about 25,000 gammas (nT) in the magnetic equator and about 70,000 gammas in the magnetic poles [7].

Magnetization of rocks

The degree of magnetization of rocks in the induced magnetic vicinity of the Earth's magnetic field is defined by the following equation.

$$I = KH \tag{8}$$

where H is the Earth's magnetic field and K is the magnetic susceptibility of matter. Magnetic susceptibility is a non-unit coefficient that depends on the physical properties of the material and its values can be positive or negative. In the magnetometric method, K is a physical parameter that plays an important role in understanding the nature of materials [7].

Magnetization and magnetic susceptibility

A magnetic dipole is defined as a magnetic dipole as a positive and negative magnetic dipole with equal intensities located at very small distances (r). The magnetic dipole moment M is defined as Equation (9) and its unit is amperes per meter [7].

$$\vec{\mathrm{M}} = m\vec{L}\vec{L} \tag{9}$$

The distance of the poles from each other and m is the magnetic intensity.

The magnetization of an object is obtained by summing all the magnetic dipole moments divided by the total volume of the object. The unit of magnetization in SI amps per meter and in the emu system is Gauss. The ratio of the magnetism to the intensity of the external field is called magnetic susceptibility:

$$J = X^{\vec{F}} \tag{10}$$

where $\vec{F}$ is the magnitude of the external magnetic field (inductive magnetic field), $\vec{J}$ is the magnetization, and X is the dimensionless magnetic susceptibility.

In the SI system, the relationship between the quantities of magnetism, the intensity of the external field, and the magnetic induction vector is expressed as Equation (11).

$$\vec{B} = \mu_0\vec{F} + \vec{J} = \mu_0(\vec{F} + \vec{J}) = \mu_0(\vec{F} + X\vec{F}) = \mu_0(1 + X)\vec{F} = \mu\vec{F} \tag{11}$$

$$\mu_0 = 4\pi * 10^{-7}$$

where $\vec{B}$ is the magnetic induction vector, μ is the magnetic permeability of the environment and μ_0 is the magnetic permeability in a vacuum. The quantities $\vec{J}$ and $\vec{B}$ and $\vec{F}$ have the same dimension.

Total magnetic field anomalies

The total field anomaly at any point is obtained by measuring the total field using a magnetometer and subtracting the regional field from the measured field. The total field anomaly is obtained from Equation (12) where $\vec{T}$ is the intensity of the total field measured and $\vec{F}$ is the regional field.

$$\overrightarrow{\Delta F} = |\vec{T}| - |\vec{F}|$$
(12)

Assume that the field $\vec{F}$ is due to a magnetic source that has disturbed the magnetic field of the field, so the total field is:

$$\vec{T} = \vec{\mathrm{F}} + \Delta\vec{\mathrm{F}}$$
(13)

Using Equation (12), the anomaly of the whole field can be expressed as follows:

$$\Delta\vec{\mathrm{F}} = |\vec{F} + \Delta\vec{\mathrm{F}}| - |\mathrm{F}|$$

Assuming $|\Delta\vec{\mathrm{F}}| \gg |\vec{\mathrm{F}}|$, which is usually the case, the total field anomaly can be defined as follows:

$$\overrightarrow{\Delta \mathrm{T}} \approx \hat{\mathrm{F}}.\overrightarrow{\Delta \mathrm{F}}$$

where F is a unit vector in the direction of the Earth's magnetic field. Therefore, if the regional field is much larger than the field due to the magnetic source, the total anomaly can represent one of the components (ΔF). If | | (ΔT) is harmonic and holds in the Laplace equation. Therefore, the anomaly of the total field at any point is almost equal to the image of the field due to the source in the direction of the regional field, provided that the regional field is much larger than the field due to the source [7].

Case Study

Karanj oil field

Karanj oil field is one of the Iranian oil fields, which is located in Khuzestan province, 40 km southeast of Ramhormoz city and 115 km east of Ahvaz, and is adjacent to the Parsi oil field in the north and Aghajari oil field in the south. Karanj field was discovered in 1963 by drilling well No. 1 Karanj, and oil production began a year later. The development of the Karanj oil field also began in 1982 with the injection of gas into its Asmari reservoir. At present, the average crude oil production capacity of this field is equal to 237 thousand barrels per day. The Karanj oil field, with 9.6 billion barrels of crude oil reserves, is one of the fields managed by the National Company for the South Oilfields, where oil production and gas injection operations are carried out by Aghajari Oil and Gas Exploitation Company. Figure (1) shows the location of the Karanj oil field [8].

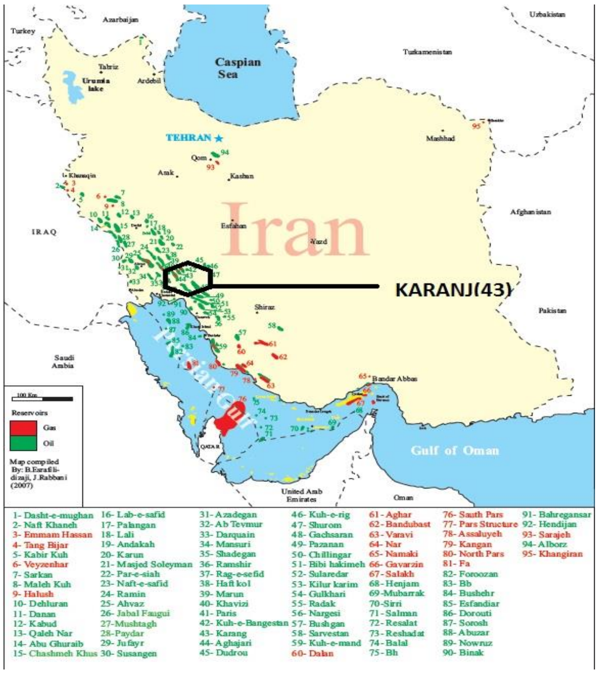

Figure 1- Location of the Karanj oil field

Geological location of Karanj oil field

The Karanj anticline with the northwest-southeast trend is part of the Zagros orogenic belt which is located in the southwest of Iran and 130 km southeast of Ahvaz. Fars Group formations are the main stratigraphic units of this surface anticline.

This field is located in the simple folded belt of Falcon's (1961) division, and Dezful embayment of Faver's (1975) division, and in the folded belt of Motiee's division (1995), between latitude 49°38′N to 31°16′N and longitude 49°39′E to 49°45′E.

The oil field was discovered in 1963. The field's recyclable reserves are estimated at 1.65 billion barrels of oil and about 3.5 trillion cubic feet of gas. Currently, the water and oil level (o.w.c) in this field is -2648 and the oil and gas level (G.O.C) is -2180.

The source rock in this field is Gurpi Formation and the reservoir rock is the Asmari Formation with Oligo-Miocene age.

Figure (2) shows a three-dimensional image of a part of southwestern Iran that shows the location of the Karanj oil field relative to other fields.

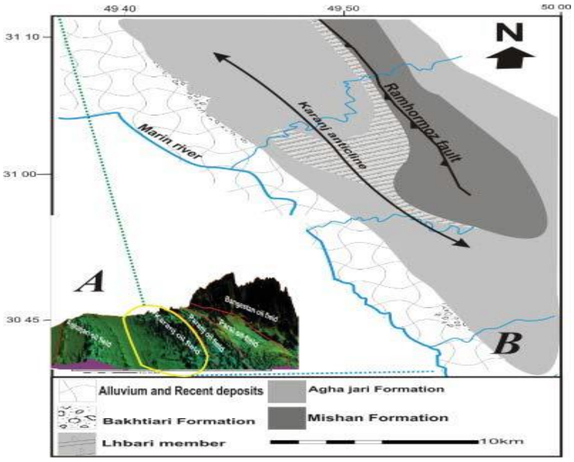

Figure 2- A three-dimensional image of a part of southwestern Iran where the location of the Karanj oil field relative to other fields is indicated (A). Geological map of the Karanj oil field(B).

The device used in this study

The magnetometer used in this study was a proton transgenic model Tgsm-19, which is a complete system for measuring the total intensity of the Earth's magnetic field. The system is a proton motion magnetometer along with a rotating magnetometer, gradiometer, and VLF. The most important features of the proton magnetometers used in this study are the following:

Accuracy of 0.01 gamma measurement, having a very accurate GPS below 1 meter to record the exact location of the coordinates of each station. It has a state solid-state memory with a capacity of 32 MB to record the measured field in each station along with much additional information required such as Z, Y, X coordinates of the station, hour, minute, and second of measurement, date, and so on. LCD screen to see the measured numbers and the position of each station. Has a port for draining information stored in memory to a computer. Displays the signal-to-noise ratio for each measurement. When measuring each station by the user using a magnetometer, several important points are observed. The direction of the sensor in all measurements should be to the north. The distance from the sensor to the measuring point must be observed equally for all devices. For this purpose, the sensor is placed on three pieces of a half-meter aluminum rod. Pause for at least 10 seconds to relax the sensor and also measure several times at each station to ensure accurate measurement. Non-accompanying or identical magnetic devices with the operator during the measurement period to prevent noise and false magnetism. Keep all devices that make noise, such as cell phones, knives, etc., away from the operator. Figure (4-4) shows a view of a proton magnetometer. The position of each station is determined by the GPS connected to the device. Therefore, when the direction of the profiles is completely north-south, the operator at the time of harvesting is enough to hold the X position on the GPS and move only in the direction of the Y-axis to the next station and measure.

Interpretation of Magnetometric Operations

Network design and magnetometric operations

After collecting the initial information, the Karanj oil field was selected for magnetometric operation. This operation was performed on profiles with a north-south trend with distances of 20 meters. The reading distances on each profile were also determined to be 20 meters. 7 profiles were surveyed at a distance of 20 meters, each with a length of 1100 meters, to extend the study area to the east and cover the reservoir number 21. The harvesting network was formed as a square with reading distances of 20X20 meters. A total of 7 north-south profiles were designed, the distance of each magnetometer station on these profiles is 50 meters. Finally, 154 stations were read on the ground. The exact location of each station was determined by color and locator on the ground. The locator was a Garmin type and had a location error of fewer than three meters. The coordinates of the WGS-84 elliptical UTM system were determined. The measurement of the magnetic field strength was repeated three times at each point and then its mean was recorded along with the UTM coordinates of the location. Simultaneously with field readings, in a fixed station (base station), the intensity of the magnetic field was measured and recorded at fixed intervals of 10 minutes. This repetition of the reading started before the beginning of the harvest and continued until the end of the harvest every day (two working days in total). Figure (3) shows a schematic map of the study site.

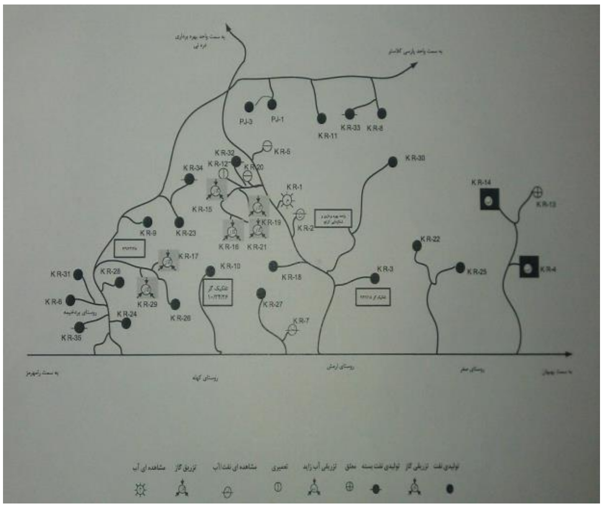

Figure 3- Schematic map of the study area

Results

Review and interpret maps

In this study, ground magnetic data collected by the author with a distance of 100 meters were used, and with the software (4.V6 (OASISMONTAJ) the map of the intensity of the entire magnetic field was obtained. On the harvested data, known as raw data, a map of the total intensity of the magnetic field is prepared in the direction of the vertical axis, and in the map, the intensity of the entire magnetic field is shown as strong and weak poles (Figure 4-7). The color spectrum used to draw magnetometric maps is usually standard, starting with bold blue for the lowest intensity and changing to green, yellow, orange, and red as the field intensity increases. In Montage Oasis software, this color spectrum is drawn as an image shadow. This technique helps to find areas of abnormality. The maps drawn with this technique are very clear. To eliminate the effect of daily changes in the Earth's magnetic field, point a with coordinates 757836 and 3229105 was selected as the origin. After several measurements, by returning to the same point and obtaining the difference in readings at different times of the day, the daily changes of the magnetic field were obtained.

Total magnetic field strength

The study of the general trend of the magnetic map shows the existence of magnetic polarization and general anomaly towards the northwest-southeast axis, which is exactly in line with the Zagros fold.

Figure (4) shows the TREND map of the Karanj region.

In the maps resulting from magnetic anomalies appear in the form of strong and weak poles (magnetic dipole). For a very good grade and thickness deposit, the oscillation between the positive and negative poles of the dipole field is about 5000 to 15000 nanotesla and for a low-grade deposit, it is about 500 to 1000 nanotesla. The intensity of the total field, as shown in the map, has two basic anomalies that can be seen along the northwest-southeast direction.

The stretch in this map corresponds to the general trend of the Zagros. Figure (5) shows the total magnetic field strength for the Karanj region.

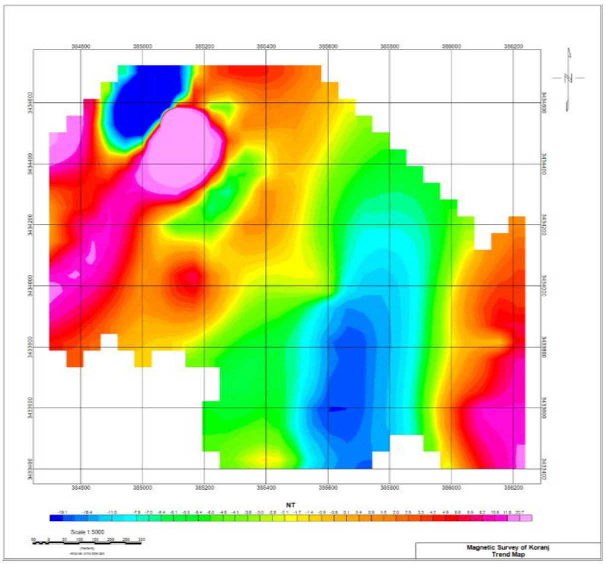

Figure 4- TREND map of Karanj region

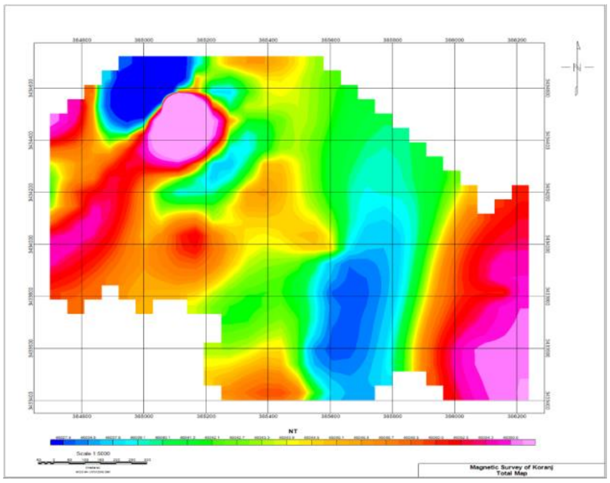

Figure 5- The intensity of the total magnetic field of the study area

Then, to investigate the changes (gradient) of the magnetic field strength in different degrees, a derivation was used. To amplify the surface anomalies relative to the deeper anomalies, a digital filter called the first derivative in the vertical direction was used. Applying this filter on the reversal map to the pole of surface anomalies becomes more visible. In this way, the behavior of these magnetic masses can be studied at a better level. According to the results obtained from the application of the first derivative filter, it was found that the observed magnetic anomalies are mainly due to rocks with outcrops on the surface.

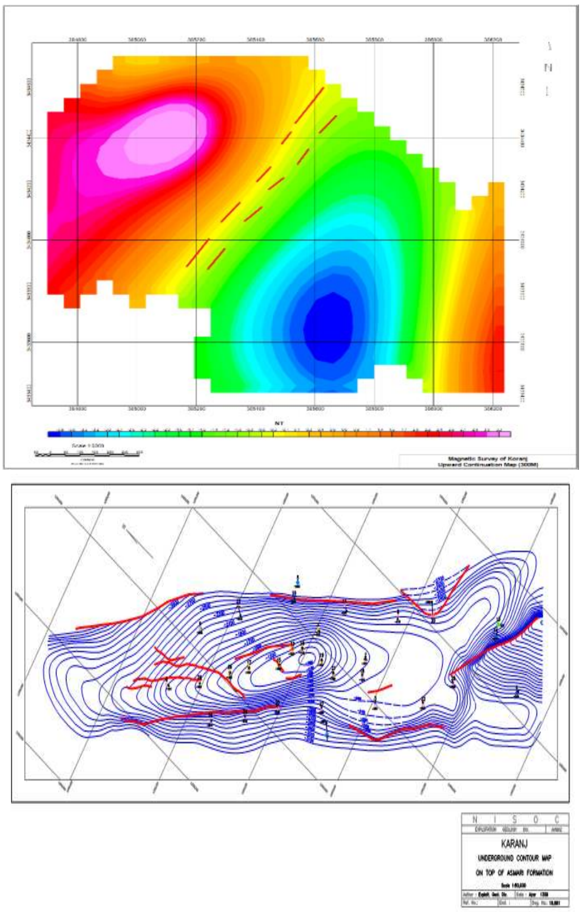

Figure 6- Reservoir rock of Karanj region

Conclusion

The results of this study show that the reservoir rock of this oil field is along the northwest to southeast and there is a possibility of faulting along the northeast to the southwest in this reservoir. This faulting may have caused a discontinuity in the tank and this has caused the gas injection not to increase the pressure and thus increase the harvest.

1. Studies on total magnetic field strength data showed that the field reduction is very small compared to the field.
2. There are many changes in minimum and maximum magnetic differences. Since the study area is often covered with sedimentary rocks and sedimentary rocks generally produce changes less than 10 nano Tesla, these large changes can be due to the presence of fault structures in the area.
3. Examination of the residual field strength map showed that the effects of a magnetic dipole cannot be observed here in the region. Figures and vertical derivative images show that with increasing altitude, the concentration of areas with high magnetic intensity decreases, which indicates their surface origin.

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