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# Spectral Depth Estimate of subsurface Structures over Parts of Offshore Niger Delta, Nigeria.

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**ABSTRACT**
*Two dimensional spectral depth analysis of the aeromagnetic data covering longtitude $3^0 30^I$ to $4^0 30^I$E and latitude $4^0 30^I$ to $5^0$ 00 N; corresponding to parts of offshore Niger Delta was carried out to investigate the thickness to the sedimentary cover. The total magnetic intensity (TMI) data on a scale of 1:384463 were digitized in grid of 1km x 1km spacing and values of the TMI, X, Y were picked at the intersection of the grid nodes. This was implemented in ArcGIS 9.3 software and the xyz data was saved as MS Excel file format. The magnetic data was separated into 39 windows of 15km x 10km using MS Excel sheet for spectral depth analysis, the data was then imported into the Microcal OriginPro8 software for Fast Fourier Transform (FFT) to be performed on each window. The result reveals two major magnetic anomaly source depths: $D_1$ and $D_2$; with $D_1$ and $D_2$ representing the deep-seated and shallow sources respectively. Areas with deep lying magnetic bodies have sedimentary thickness ranging from 5600 m to 13636 m and with an average depth of 9466 m whereas shallow anomalous bodies have the thickness of the sediment to ranges from 1250 m to 3684 m but with an average depth of 2467 m. The 9466 m representing the depth to basement suggest enough sedimentary thickness within the area of study. Hydrocarbon accumulation, and perhaps exploration, will probably be high provided other conditions are favorable.*

***Keywords***: *Aeromagnetic data, offshore Niger Delta, sedimentary thickness, Spectral depth analysis, basement relief*

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## I. INTRODUCTION

Depth to basement is a germane exploration parameter particularly for areas where there may be mature hydrocarbons. Geologists and Geophysicists have done extensive work in terms of geological mapping of Nigeria, with Niger Delta inclusive. They have worked on the interpretation of aeromagnetic data obtained mainly from restricted areas of their studies. In spite of this enormous work in the area of magnetic interpretation, not much has been done in the Niger Delta region, specifically offshore Niger Delta.

In the work carried out by [1] within the Niger Delta region, the basement structural framework was delineated thereby assisting to define areas of sedimentary section of promising prospects for hydrocarbon exploration. These authors subjected the acquired data to various geophysical techniques like tilt depth, Euler Deconvolution, Analytic signal, derivatives and 2D modeling, their result indicated NE-SW, NW-SE and E-W tectonic trends that affected the area. [2] in their work, using part of Imo River, identified features associated with the basin and infer the influence of such features on the basin and its hydrocarbon bearing potential. This was achieved by subjecting the data to various enhancement techniques using sulphur 8 which revealed structural features trending in the NE-SW direction. [3] by using regional magnetic data tried to reveal the relationship between deep basement architecture and hydrocarbon target. Their study showed that regional magnetic anomalies are sensitive to the variations of the structure and composition of the crystalline basement hence the control on oil and gas located in the tertiary strata of Niger Delta by the underlying Precambrian crystalline basement using potential field (magnetic) data.

In addition to the pre-existing knowledge, [4] highlighted the tectonic features obtained from the interpretation of the aeromagnetic maps of okigwe-oguta axis which lies within the Niger Delta and Anambra basin of Nigeria. During the course of the work, data processing techniques like spectral analysis and modeling were applied. From the result of their research work, it was observed that the region is characterized by positive and negative magnetic anomaly amplitudes, smooth contours, magnetic lineaments as well as the magnetic signatures trending in the NE-SW which shows the existence of the Charcot fault zone within the region.

Quantitatively, the basement depth underlying sedimentary cover can be mapped automatically with techniques like Werner deconvolution, Euler deconvolution, the source parameter imaging (SPI), the analytical signal, tilt angle and spectral analysis. However, for the reappraisal of the hydrocarbon potential within the study area, the spectral depth analytical technique was applied. By determining the hydrocarbon prospect of the area, the variability of the basement depth as well as its morphology will be ascertained. Spectral analysis provide rapid depth estimates from regularly spaced digital field data, no geomagnetic or diurnal corrections are necessary as these remove only low wavenumber components and do not affect the depth estimates which are controlled by the high wave number components of the observed field [5]. The spectral method averages over an area so that, if noise is a factor, the results will give a more accurate result than other methods that are commonly used [6]. This technique is based on the shape of the power spectrum for buried bodies with a susceptibility contrast [6]. For magnetic bodies the results are more complex in the sense that, although the same equations apply, in practice, the spectrum gives information primarily about the location of the top and bottom of a magnetic layer [7].

This research work will thus give more insight about the sedimentary thickness within offshore Niger Delta using spectral depth analysis.

### *1.1 Location and geologic settings of study area*

The study area lies between longitude $4^{0}30^{i}$ E and $5^{0}$ E and latitude $3^{o}30^{i}$N and $4^{0}30$N with an approximate area of 6050 km$^{2}$ within the offshore Niger Delta sedimentary basin of Nigeria, (Fig 1.1).The Niger Delta is situated in the apex of the Gulf of Guinea on the West Coast Africa. The stratigraphic and structural disposition of the Niger Delta has been documented by several workers [8].The Niger Delta was formed by the buildup of sediments over a crustal tract developed by rift faulting during the Precambrian with outlines controlled by deep seated faults associated with rifting [9]. Rifting diminished in the late Cretaceous and gravity tectonism became the primary deformational process after the rifting phase in the Niger Delta. The Niger Delta started as two different depocenters in the Bende- Ameki area, east of the Delta and in the Anambra Shelve, West of the delta in the mid to late Eocene. These two depocenters later formed a single deltaic sedimentary basin in the late Miocene to date [7].

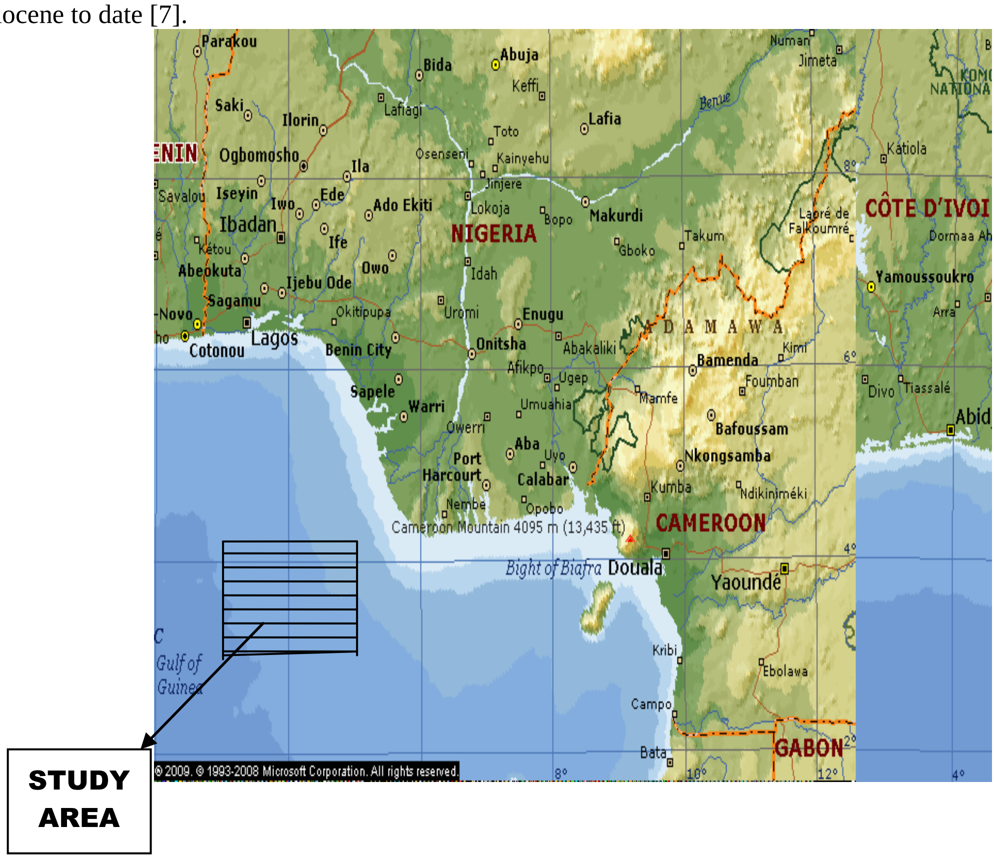


**FIG 1 Index map of nigeria and environs showing the study area [10]**

## II. MATERIALS AND METHODS

The digitized total magnetic intensity map with sheet number 333b and 340 (Fig 3.1) was sourced from the Nigerian geological survey agency, NGSA. The data, acquired on a series of NW-SE flight lines in 2009 by Fugro Airborn service, is part of offshore Niger Delta covering an area of about 6052 $km^2$. It is of high resolution than those of 1970s in that it has a terrain clearance of 100 m and line spacing of 500 m while tie lines occur at about 20 km. The Ms Excel, Sulfer 10, Arc GIS and the Origin Pro 8 Geophysical software were used for the data analysis, processing and interpretation.

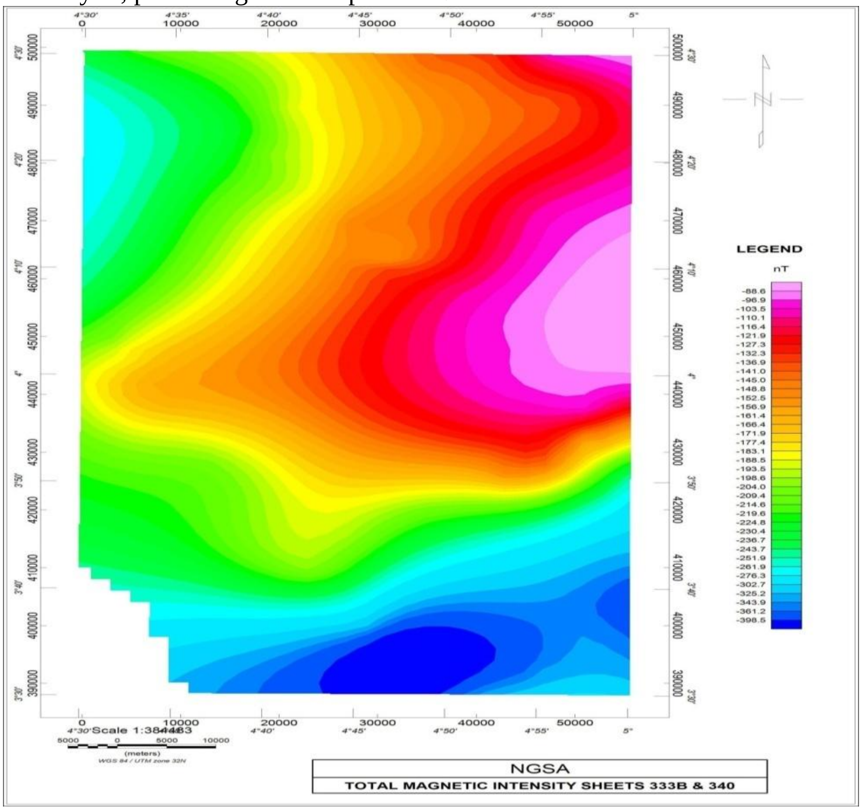


**Fig 2 Raster map of the study area**

In this work, the process of mapping the depth to basement using a grid of magnetic data involves calculating the average radial power spectrum over a rectangular window on a magnetic grid. Depending on the resolution of the data any window size can be appropriate. This paper found that a 15x10 kilometer window is useful for basement depths encountered. Thirty nine (39) rectangular windows were generated using the filtering tool of the MS Excel sheet. This thereby makes easy the depth parameter to be determined as spectral analysis was performed on each window. By calculating the depth value for each window or cell in a stepwise fashion, as shown in the graphs below, the average value of the whole cells thus gives the thickness to sediment. The depth values obtained using the graphs below were summarized with TABLE 4.1. Hence, the average radial (Energy) power spectrum is calculated using Fast Fourier Transform (FFT), it is plotted in MS Excel using Excel chart wizard as Log of Energy (FFT magnitude) versus radial frequency in Rad/km. A straight line is then visually fit to the energy spectrum, both in the higher and lower frequency of the figure. The negative of slope of this line is equal to twice the depth to the center of mass of the bodies producing the magnetic anomaly. After the depth has been calculated over one window a new calculation is made over a new window. This continues over the grid until all windows have had their radial spectra calculated and the depths picked. The Depth values due to low frequency magnetic sources are then imported into surfer 8 for depth to magnetic basement (Fig 4.1AP) to be generated.

## III. RESULTS AND DISCUSSION

Spectral analysis of the aeromagnetic data of the study area reveals two major magnetic anomaly source depths, $D_1$ and $D_2$. The slope is a negative slope; hence the corresponding depth values are all negative values. The depth, $D_1$ and $D_2$ represent the deep seated and shallow sources respectively. Areas with deep lying magnetic bodies have sedimentary thickness ranging from 5600 m to 13636 m but with a true depth of about 9466 m whereas shallow anomalous bodies have the thickness of the sediment to ranges from 1250 m to 3684 m but with a true depth of about 2467 m. The thickest sedimentary cover occurred at the South Eastern portion of the

study area located in block 10. This was estimated to be 13636 m which is at variance with the result obtained by [11]. They obtained the maximum thickness to be 10 km. which perfectly agree with the thickness of block 21 and 33. The depth to shallow sources for cell two, twelve and fifteen were not computed due to the absolute noise effect within the region. The result of the spectral analysis, however, shows alternating sedimentary thickness values as against the claim by [12] who suggested that the sedimentary thickness increases southward.
This study, hence, identified that basement structures play major role in sediment and hydrocarbon distribution in the Niger Delta through basement relief (basement highs and lows). This factor, structural highs and lows, are conspicuous and appear to have controlled the trapping of hydrocarbon in the Niger Delta. [13] identified two basic types of basement control on the overlying sedimentary section in Kasas: basement topographic control and reactivated basement faults or shear zones. The depth to basement map show structural characteristics and they are used in this study as assessment tool for hydrocarbon exploration. The development of the delta has been dependent on the balance between the rate of sedimentation and the resulting sedimentation patterns appears to have been influenced by the structural configuration and tectonics of the basement [14]. The depth to basement map reveals a minibasin flanked by faults that serve as a migratory path or conduit for hydrocarbon. This minibasin found northwest ward is the focal point for oil and gas and therefore is the preferred target for hydrocarbon exploration in the study area. Moving southeast ward is found maximum depth and a structural low represented by a synclinal structure. The syncline formed by the frequent subjection of strata to compression is regarded as the generating depocenters as the oil and gas generated in such regional lows will migrate up dip. So this research opines that the depth to basement within the study area is characterized by basement highs and basement lows and the structural lows are attractive site for oil and gas exploration.

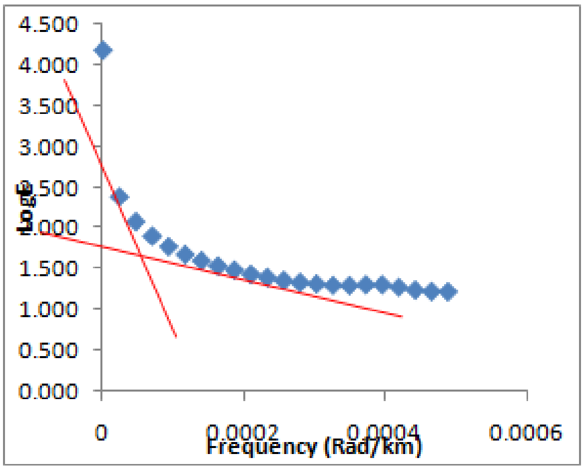


FIG 4.1A: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL ONE

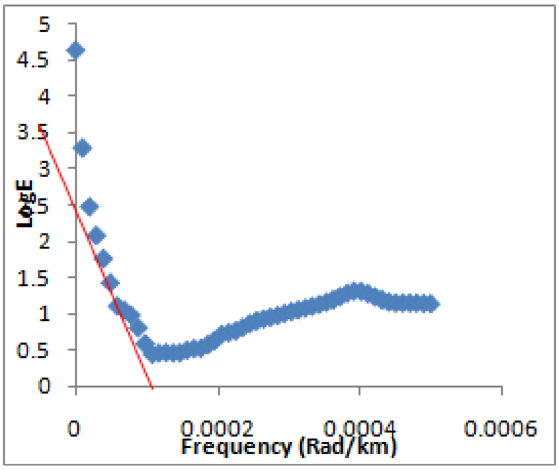


FIG 4.1B: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL TWO

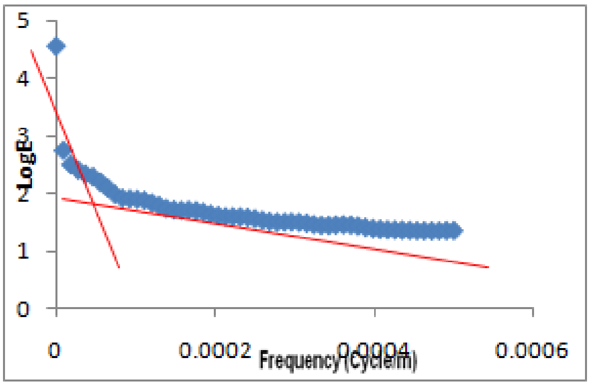


FIG 4.1C: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL THREE

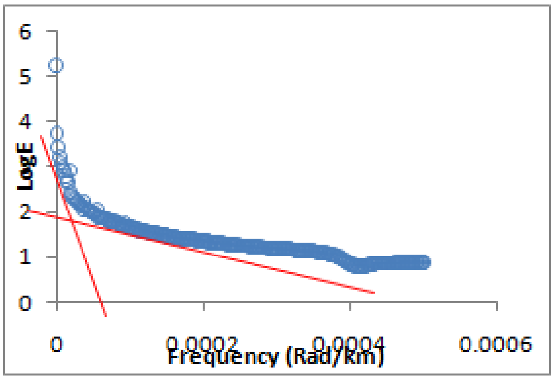


FIG 4.1D : A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL FOUR

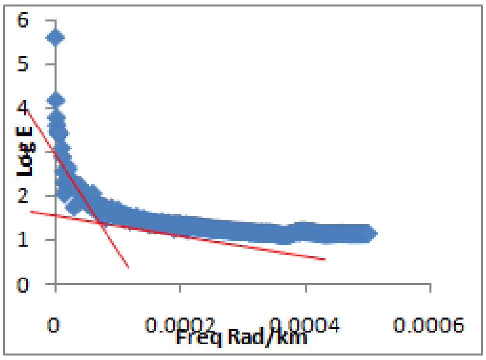


FIG 4.1E: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL FIVE

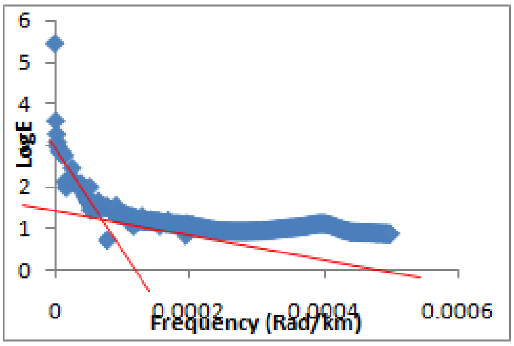


FIG 4.1F: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL SIX

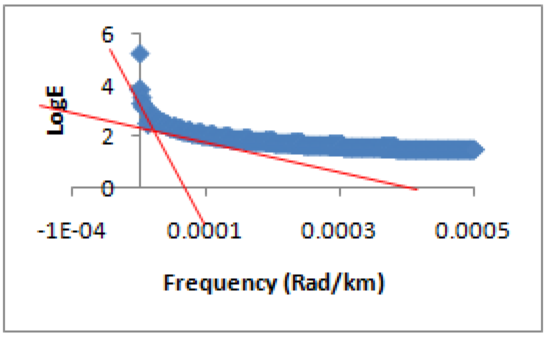


FIG 4.1G: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL SEVEN

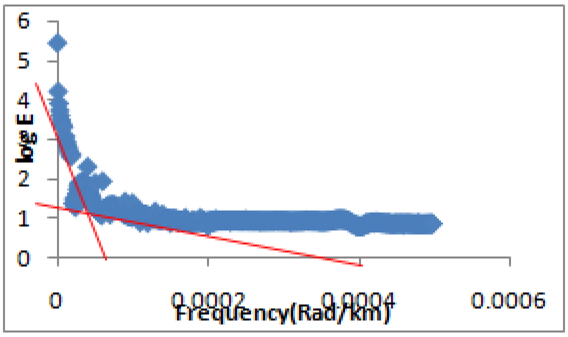


FIG 4.1H: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL EIGHT

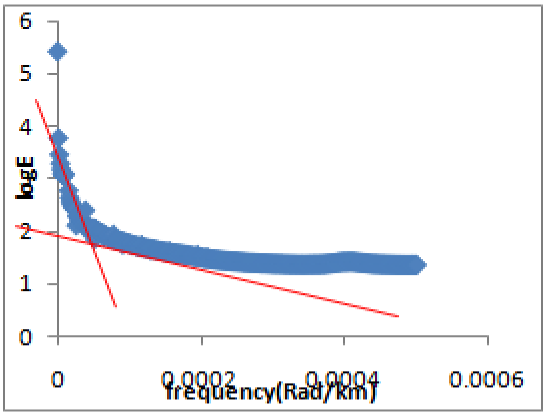


FIG 4.1I: A GRAPH SHOWING DEPTH DEEP FOR AND SHALLOW SEATED FEATURES FOR CELL NINE

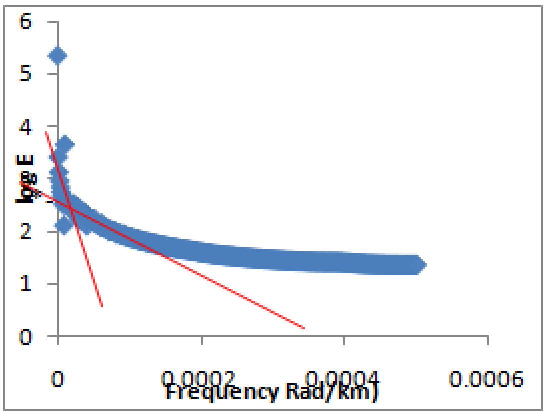


FIG 4.1J: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL TEN

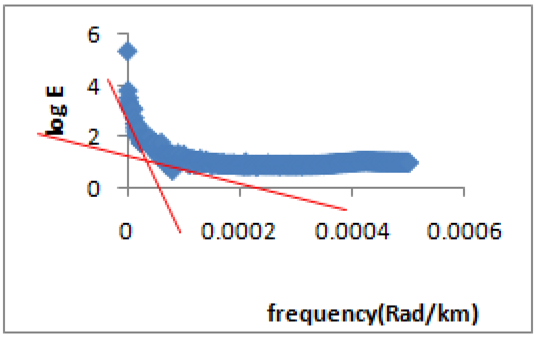


FIG 4.1K: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL ELEVEN

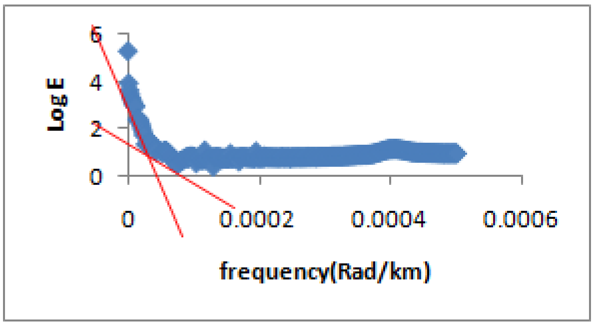


FIG 4.1L: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL TWELVE

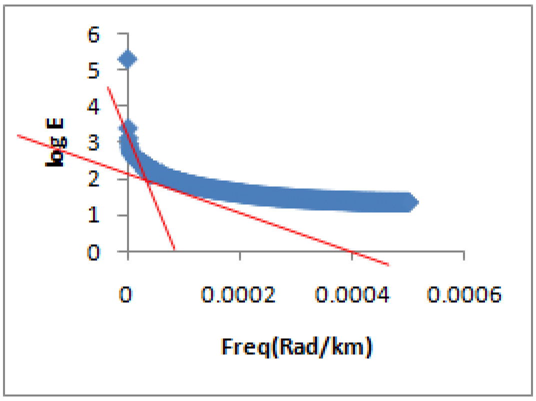


FIG 4.1M: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTEEN

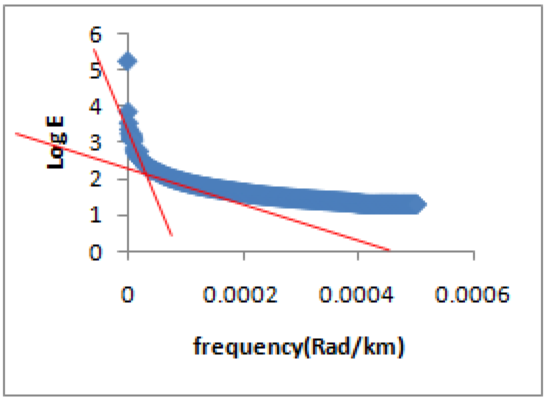


FIG 4.1N: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL FOUTEEN

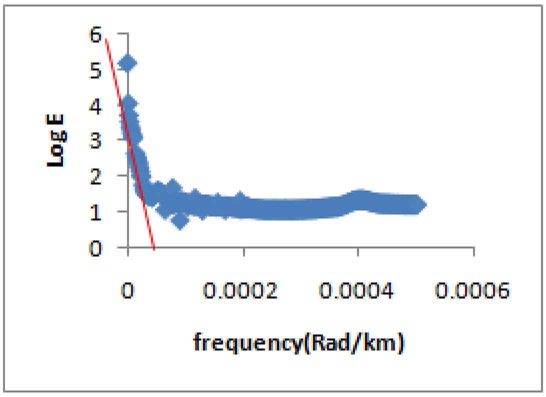


FIG 4.1O: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL FIFTEEN

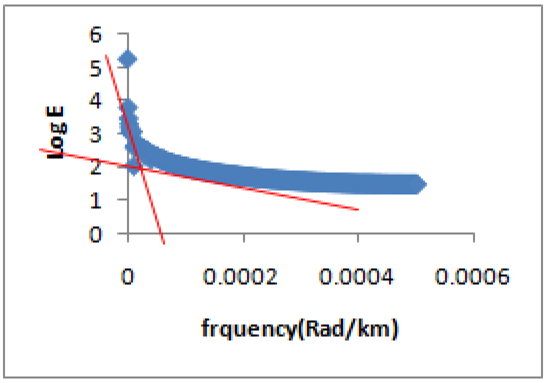


FIG 4.1P: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL SIXTEEN

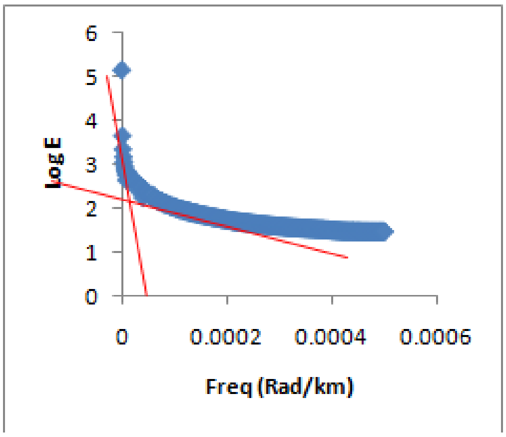


FIG 4.1Q: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL SEVENTEEN

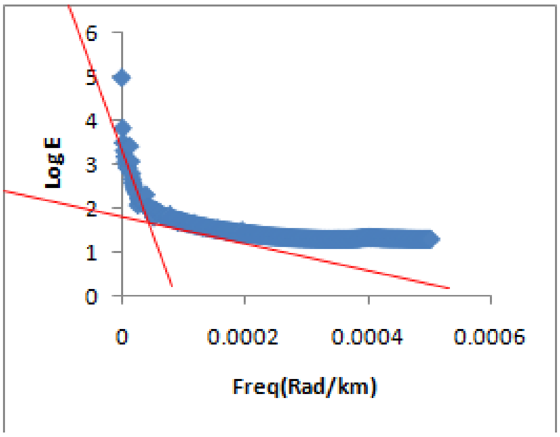


FIG 4.1R: A GRAPH SHOWING DEPTH FOR DEEP AND SHALLOW SEATED FEATURES FOR CELL EIGHTEEN

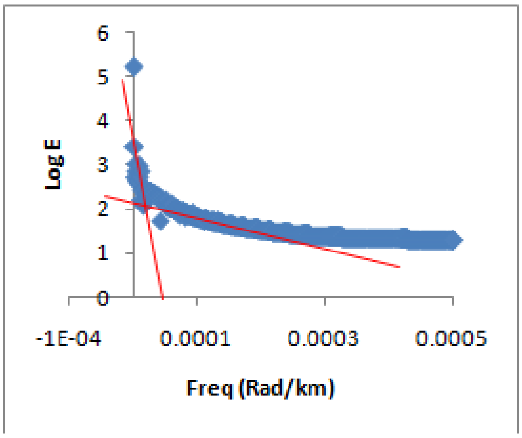


FIG 4.1S: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL NINETEEN

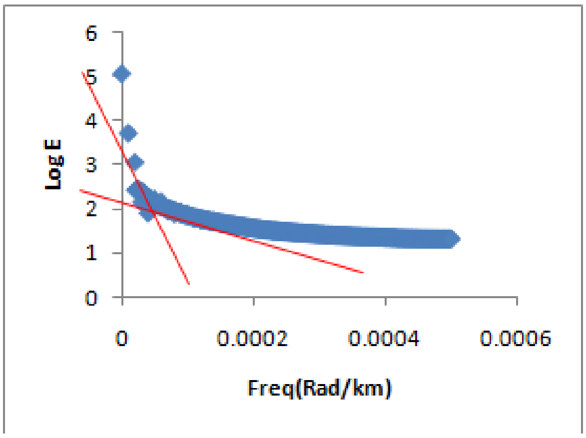


FIG 4.1T: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY

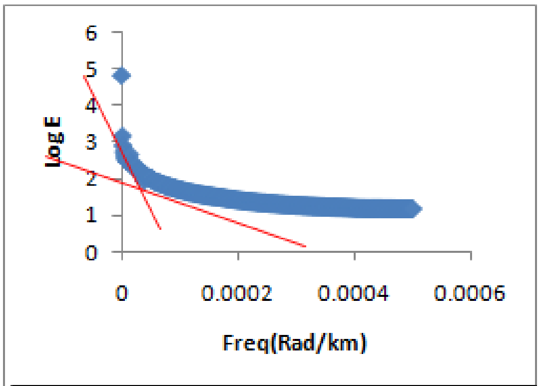


FIG 4.1U: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY ONE

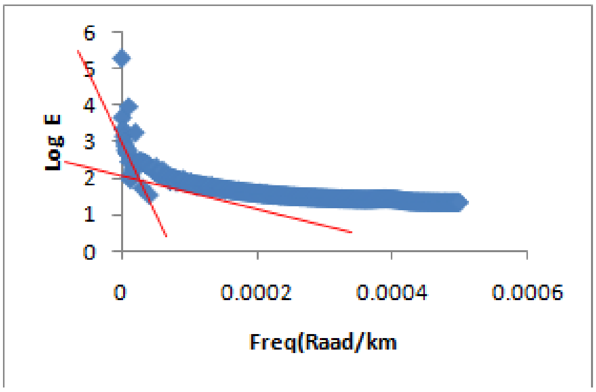


FIG 4.1V: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY TWO

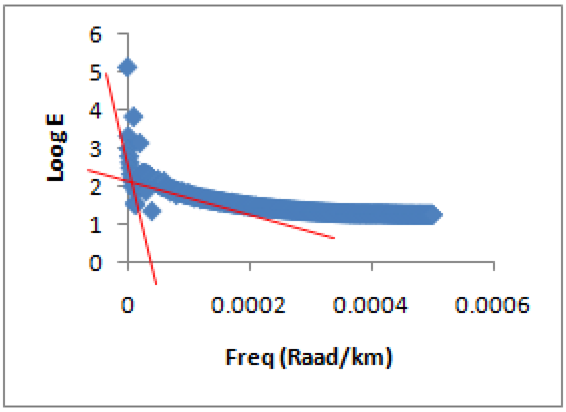


FIG 4.1W: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY THREE

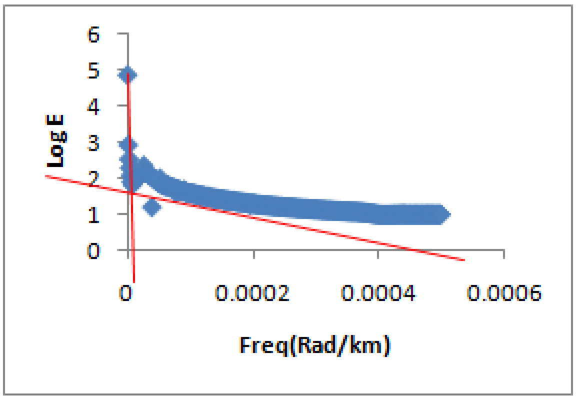


FIG 4.1X: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY FOUR

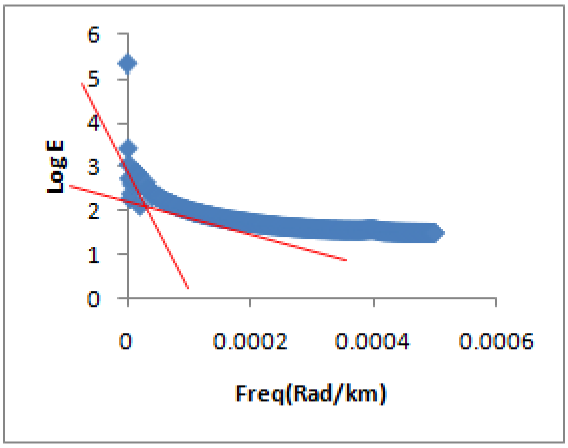


FIG 4.1Y: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY FIVE

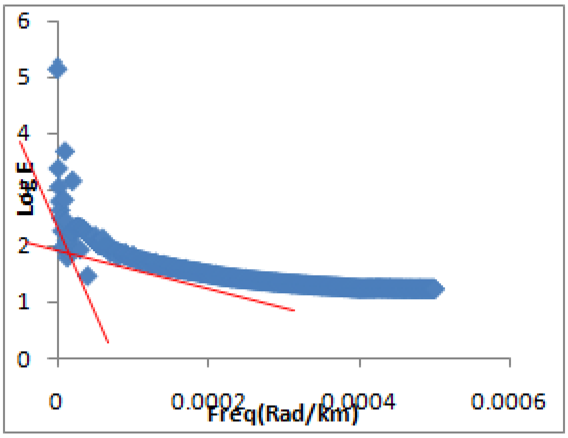


FIG 4.1: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY SIX

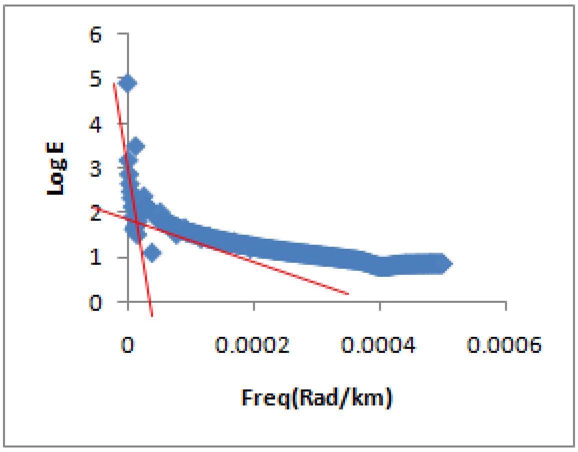


FIG 4.1AB: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY SEVEN

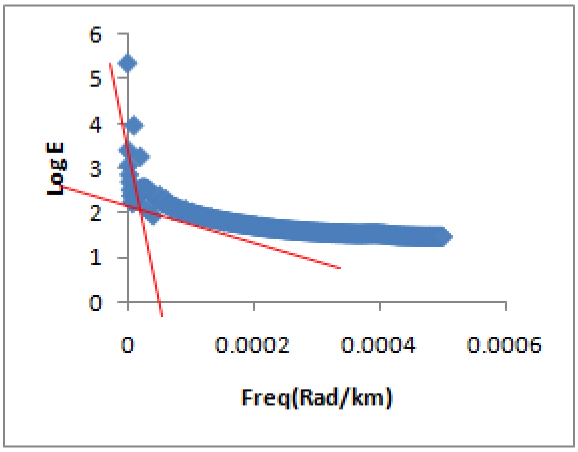


FIG 4.1AC: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY EIGHT

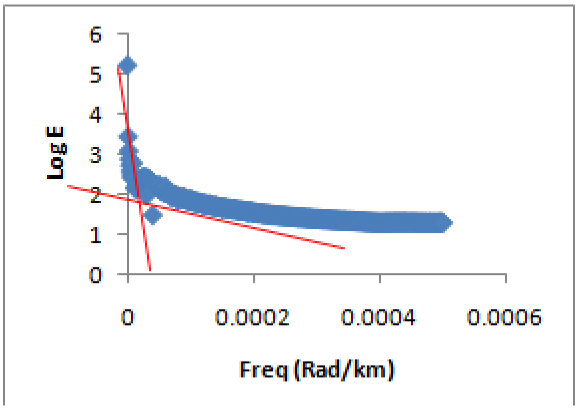


FIG 4.1AD : A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL TWENTY NINE

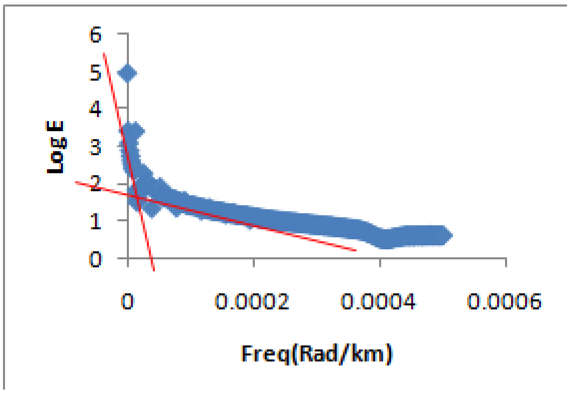


FIG 4.1AE: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY

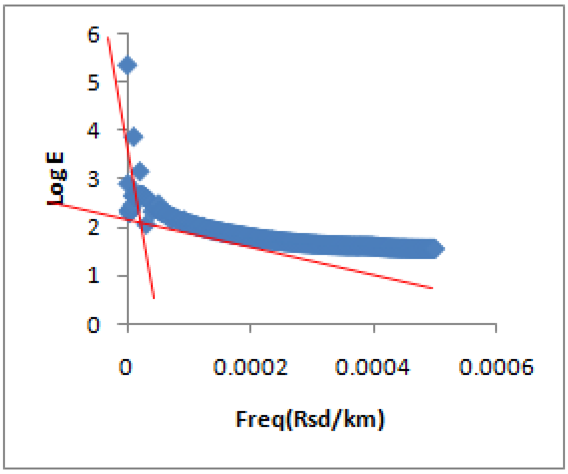


FIG 4.1AF: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY ONE

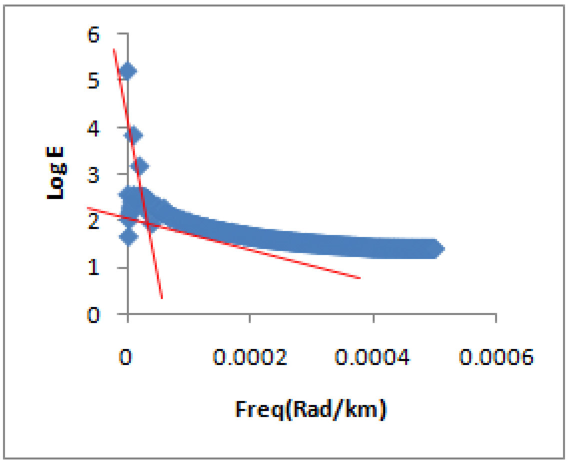


FIG 4.1AG: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY TWO

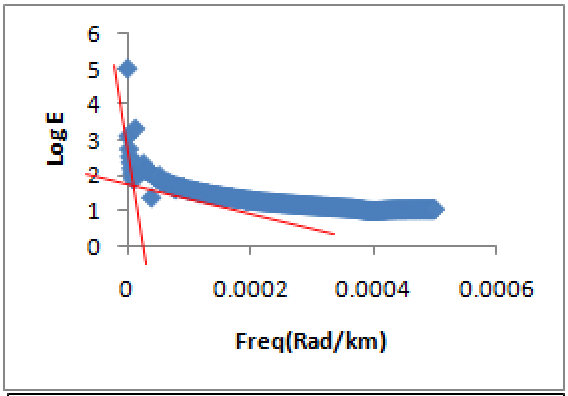


FIG 4.1AH: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY THREE

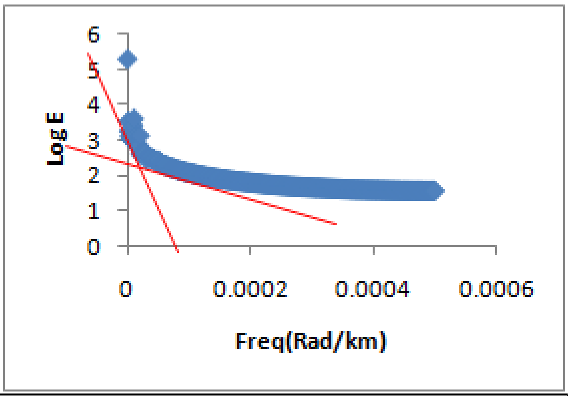


FIG 4.1AI: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY FOUR

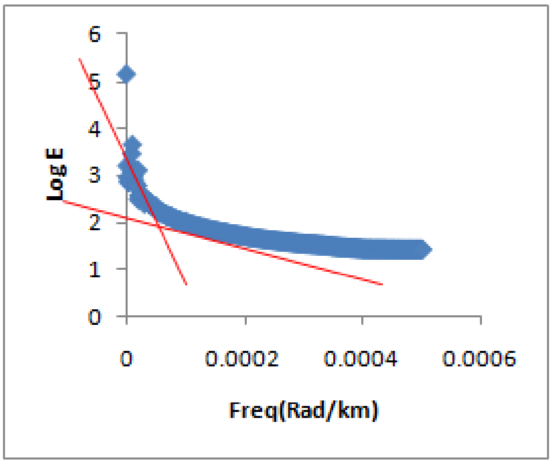


FIG 4.1AJ: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY FIVE

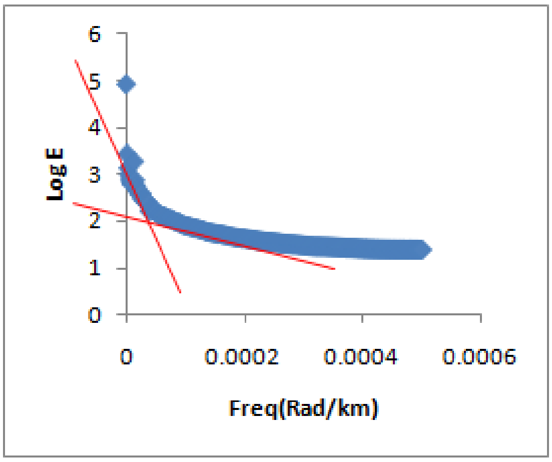


FIG 4.1AK: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY SIX

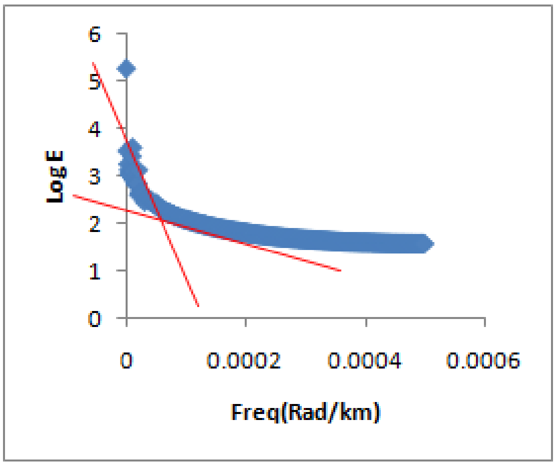


FIG 4.1AL: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY SEVEN

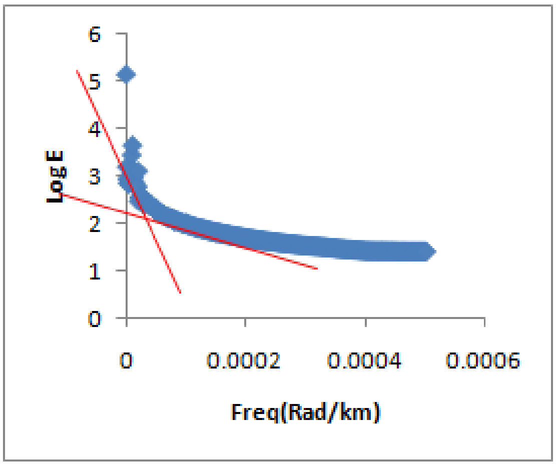


FIG 4.1AM: A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY EIGHT

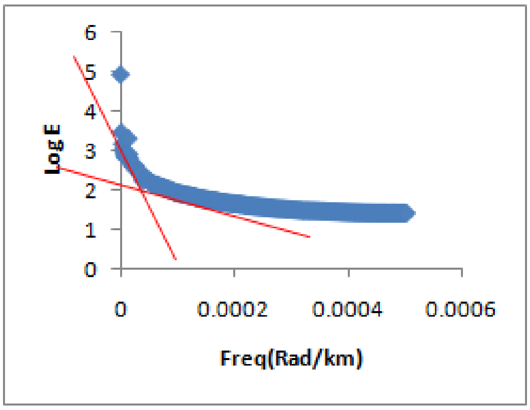


FIG 4.1AN : A GRAPH SHOWING THE DEPTH TO DEEP AND SHALLOW SEATED FEATURES FOR CELL THIRTY NINE

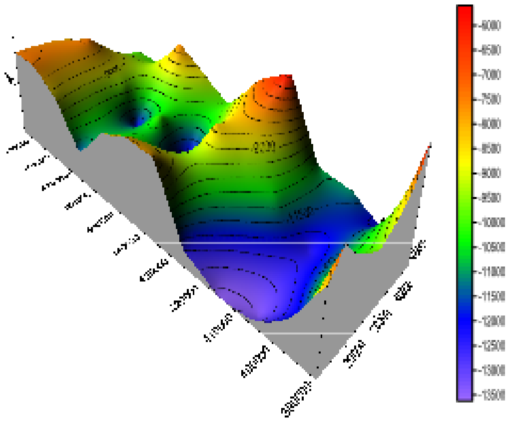

FIG 4.1AP DEPTH TO BASEMENT MAP

**TABLE 4.1 DEPTHS TO MAGNETIC BASEMENT ESTIMATED FROM SPECTRAL ANALYSIS**

| CELL | LONGITUDE | LATITUDE | SLOPE | | DEPTH(m) | |
|---|---|---|---|---|---|---|
| | | | $M_1$ | $M_2$ | $D_1$ | $D_2$ |
| 1 | 15150.00 | 389450.00 | -13138.1 | -4834.6 | -6569.05 | -2417.3 |
| 2 | 30150.00 | 389450.00 | -19238.77 | | -9619.39 | |
| 3 | 47150.00 | 389450.00 | -11200 | -2500.00 | -5600.00 | -1250.00 |
| 4 | 14150.00 | 395450.00 | -23076.92 | -4000.00 | -11538.46 | -2000.00 |
| 5 | 30150.00 | 395450.00 | -21428.57 | -4444.44 | -10714.29 | -2222.22 |
| 6 | 47150.00 | 395450.00 | -25000.00 | -2941.10 | -12500.00 | -1470.59 |
| 7 | 12150.00 | 405450.00 | -26923.07 | -6000.00 | -13461.54 | -3000.00 |
| 8 | 30150.00 | 405450.00 | -25000.00 | -3750.00 | -12500.00 | -1875.00 |
| 9 | 47150.00 | 405450.00 | -22140.86 | -3636.36 | -11071.43 | -1818.18 |
| 10 | 10150.00 | 415450.00 | -27272.73 | -7368.42 | -13636.36 | -3684.21 |
| 11 | 30150.00 | 415450.00 | -21538.46 | -4750.00 | -10769.23 | -2375.00 |
| 12 | 47150.00 | 415450.00 | -21538.46 | | -10769.23 | |
| 13 | 10150.00 | 425950.00 | -25000.00 | -5250.00 | -12500.00 | -2625.00 |
| 14 | 29650.00 | 425950.00 | -18750.00 | -5555.56 | -9375.00 | -2777.78 |
| 15 | 47150.00 | 425450.00 | -11500.00 | | -5750.00 | |
| 16 | 10150.00 | 435450.00 | -15789.47 | -4000.00 | -7894.74 | -2000.00 |
| 17 | 30150.00 | 435450.00 | -16483.52 | -4000.00 | -8241.76 | -2000.00 |
| 18 | 47150.00 | 435450.00 | -14450.00 | 5000.00 | -7225.00 | -2500.00 |
| 19 | 10150.00 | 445450.00 | -15789.47 | -6250.00 | -7894.74 | -3150.00 |
| 20 | 30150.00 | 445450.00 | -26666.67 | -4200.00 | -13333.33 | -2100-00 |
| 21 | 47150.00 | 445450.00 | -20000 | -5250.00 | -10000.00 | -2625.00 |
| 22 | 10150.00 | 454950.00 | -17647.06 | -4285.71 | -8823.53 | -2142.85 |
| 23 | 29650.00 | 454950.00 | -19867.00 | -4509.80 | -9933.77 | -2254.90 |
| 24 | 47150.00 | 455450.00 | -17562.50 | -3800.00 | -8781.25 | -1900.00 |
| 25 | 10150.00 | 465450.00 | -23076.92 | -4000.00 | -11538.46 | -2000.00 |
| 26 | 29650.00 | 464950.00 | -24166.07 | -3636.36 | -12083.33 | -1818.18 |
| 27 | 47150.00 | 464950.00 | -14950.00 | -4878.05 | -7475.00 | -2439.02 |
| 28 | 10150.00 | 474950.00 | -17649.05 | -4400.00 | -8823.53 | -2200.00 |
| 29 | 30150.00 | 470450.00 | -19411.76 | -3333.33 | -9705.00 | -1666.67 |
| 30 | 47150.00 | 474950.00 | -20069.00 | -4634.15 | -10034.72 | -2317.07 |
| 31 | 10150.00 | 484950.00 | -15000.00 | -2750.00 | -7500.00 | -1375.00 |
| 32 | 29650.00 | 484950.00 | -14761.00 | -5000.00 | -7380.00 | -2500.00 |
| 33 | 47150.00 | 484950.00 | -20000.00 | -4061.22 | -10000.00 | -2030.61 |
| 34 | 10150.00 | 494450.00 | -25000.00 | -5600.00 | -7500.00 | -2800.00 |
| 35 | 29650.00 | 494450.00 | -16666.66 | -3230.77 | -8333.33 | -1615.39 |
| 36 | 47150.00 | 494450.00 | -24850.00 | -3333.33 | -12425.00 | -1666.67 |
| 37 | 10150.00 | 494450.00 | -14285.71 | -3571.43 | -7142.86 | -1785.71 |
| 38 | 29650.00 | 494450.00 | -18750.00 | -3508.77 | -9375.00 | -1754.39 |
| 39 | 47150.00 | 494450.00 | -25000.00 | -3728.81 | -12500.00 | -1864.41 |

## IV. CONCLUSION

Quantitatively, the results of the spectral analysis show that, if other conditions for hydrocarbon accumulation are favorable, the basin will be thick enough for hydrocarbon maturation and exploration. Thus, the thickness of sediment is a true representation for the offshore Niger Delta areas. Where the data is a super high resolution data, the results will probably be better.

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