SEISMIC ATTRIBUTE ANALYSIS AND RESERVOIR CHARACTERIZATION OF ‘’GEORGE’’ FIELD, OFFSHORE NIGER DELTA, NIGERIA

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ABSTRACT

Seismic Attribute Analysis and Reservoir Characterization of ‘George Field’ offshore Niger Delta was carried out with a view to determining the hydrocarbon potential of the area. The data set used for the study includes three dimensional seismic data and a suite of geophysical well logs from four wells A, B, C and D. In order to further confirm the presence of hydrocarbon in the identified structures, attribute analysis was carried out. The energy and the amplitude attribute extraction maps and the instantaneous frequency volume attributes maps for the reservoirs were generated. The trapping mechanism is a fault assisted closure. The amplitude, average energy and instantaneous frequency extraction maps revealed higher values around the structural highs which coincide with the locations where producing wells A, B, C and D had already been drilled thereby validating earlier interpretations that led to their drilling.

Keywords: *Attribute Analysis, Reservoir Characterization, Geophysical well logs, Trapping mechanism*

1. INTRODUCTION

Seismic attributes have been increasingly used in both exploration and reservoir characterization studies and routinely been integrated in the seismic interpretation processes [1]. There are different classes of seismic attributes based upon the nature of estimation and property of the reservoir they reveal. For estimation of seismic attributes any of the following can be used as input: a single seismic trace, a set of pre-stack CMP or CRP gathers or the entire seismic volume [2]; [3]. The principle objective of the attributes analysis is to provide accurate and detailed information to the interpreter on structural, stratigraphic and lithological parameters of the reservoir. In our current study, the attribute analysis is estimated to characterize the reservoir in terms of the hydrocarbon bearing zone. The instantaneous amplitude attribute, energy and the instantaneous frequency volume attributes maps for the reservoirs were generated to confirm the presence of bright spots which are suggestive of the presence of hydrocarbon in the reservoir zone.

2. LOCATION OF THE STUDY AREA

The study area is situated on latitude 3º and 6ºN and longitudes 5º and 8ºE, Niger Delta Nigeria (Fig. 1). The George field falls within the parasequence of set of Agbada Formation and the structure consists of a simple rollover anticline that is bounded to the north by a major growth fault. The crest is flat/elongated and runs parallel to the bounding fault. The stratigraphic sequence (Fig. 2) in the field consists of marine shales of Akata Formation which is about 6100 m thick, the Agbada Formation which is 4500 m thick and it is overlain by the Benin Formation which is about 1820 m thick [4]. Deep offshore of Niger Delta of Nigeria is situated over oceanic crust emplaced during Cretaceous Paleogene first related spreading of the South Atlantics. Initial sedimentation began within Upper Cretaceous – Lower Oligocene hemipelagic mudstones of the Akata Formation, late Oligocene through recent progradation for the Niger Delta into the slope rise environment allowed for turbidite deposition of the more coarse grained siliclastics of the Agbada Formation [4,5]. The latter contain the lower and middle Miocene reservoir- seal couplets responsible for the major deepwater hydrocarbon accumulations discovered to date. The underlying Akata Formation is believed to contain the main source intervals. Tertiary extension on the Niger Delta shelf was the driving process for gravity driven structures of the deepwater [4,5]. According to [6, 7, 8], the Tertiary sequence consists of alternations of clastic lithologies that occur in stacked sections of (regressive) offlap cycles. These lithologies comprise sandstones, silts and shales of much similarity, whatever their age or situation in the sequence. Thus, in a vertical sense, the sequence can be subdivided into three lithofacies in ascending order of Akata, Agbada and Benin Formations (Fig. 3). The overall regressive clastic sequence reaches a maximum thickness of 30,000-40,000 ft (9,000-12,000 m) at the approximate depocenter in the central part of the delta [5].

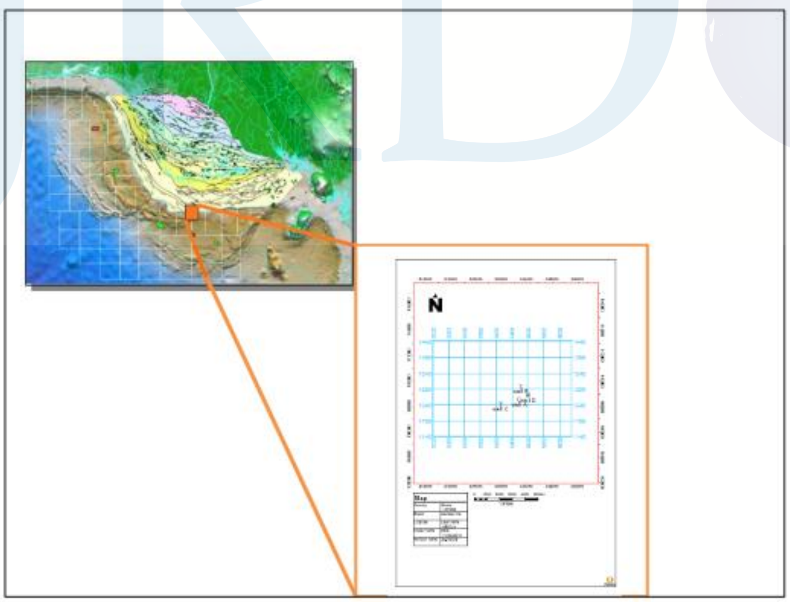

Fig.1: Map of the Niger Delta showing the base map of the study area and the well locations

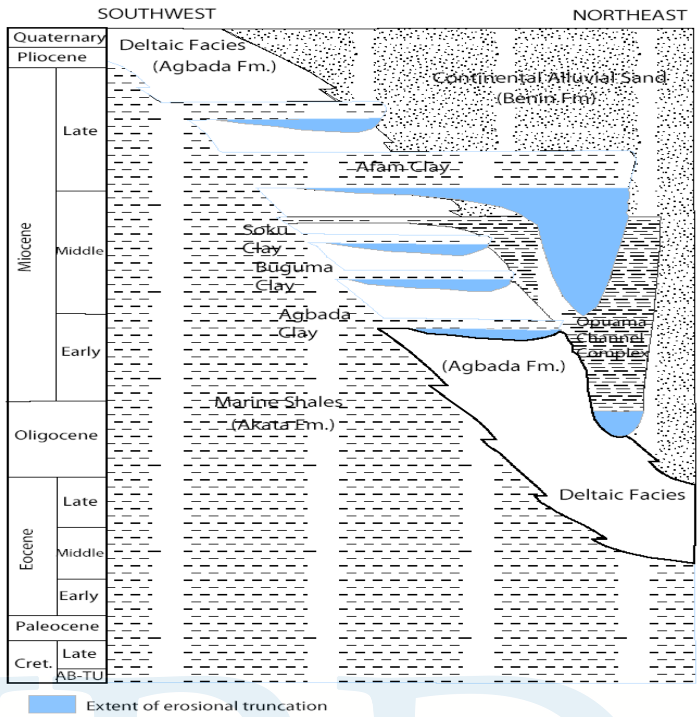

Fig. 2: Stratigraphic Column Showing the Three Formations of the Niger Delta. [After 7, 8]

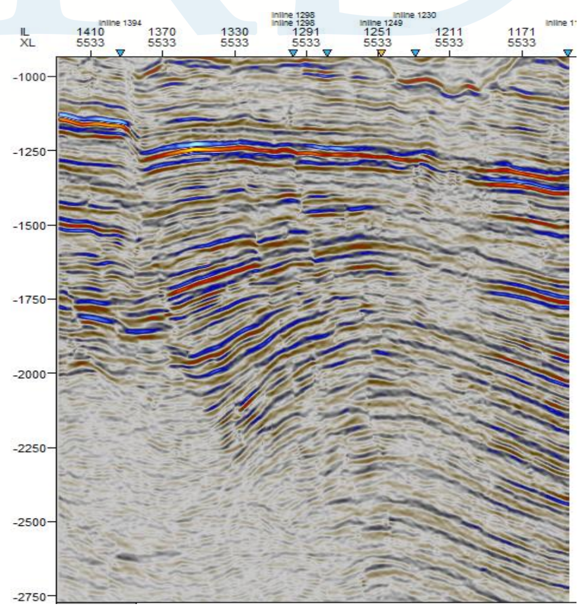

Fig. 3: Typical uniterpreted seismic

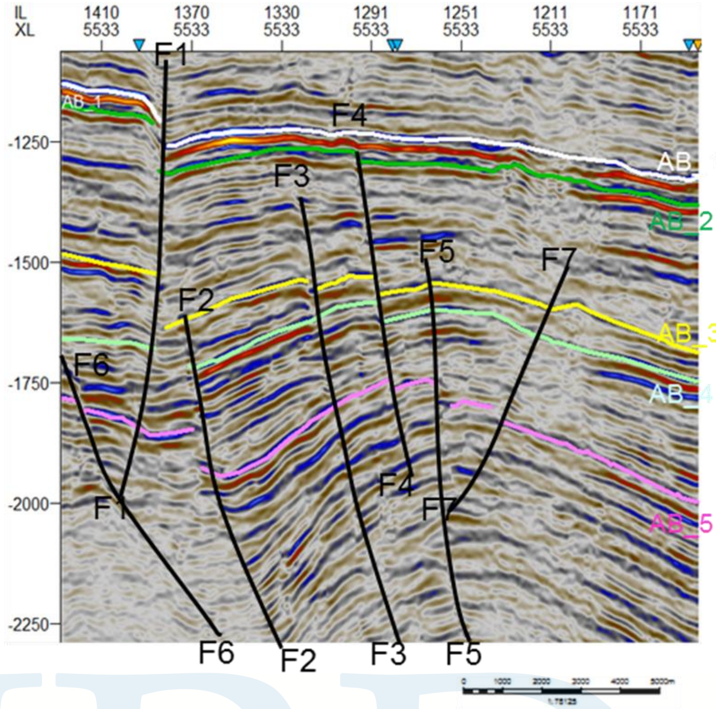

Fig. 4: Interpreted seismic section showing the mapped horizons and faults

3. MATERIALS AND METHODS

The data sets used for this study comprises; geophysical well logs (GR, Resistivity, Sonic) from four wells; A, B, C and D, checkshot data and 3-D Seismic data (496 Inlines and 780 Crosslines) covering a total area of about 85.8 km^2. The instantaneous amplitude attribute to locate the reservoir (gas bearing zone) is calculated. This is achieved through complex trace attribute analysis as explained by [9]. In this method, a seismic trace is considered as a complex trace having real and quadrature component. Real part is the actual seismic trace recorded.

Next, the thickness is estimated following the spectral decomposition analysis in the reservoir zone to get the dominant frequency in that zone. The studies performed by [1]; [2]; [3] demonstrate the effectiveness of spectral decomposition using the discrete Fourier transform (DFT) as a thickness estimation tool. In thickness mapping there is an inverse relation between the dominant frequency and the thickness of the target zone. Dominant frequency characterizes the thickness of the bed and the amplitude is known to be maximum at the tuning thickness estimated from the dominant frequency [1]. Thus, spectral decomposition can reveal and map seismic features as a function of spatial position, travel time, frequency, amplitude and phase and help us to visualize, interpret and quantify the seismic response to an extent that was previously unattainable [1].

4. RESULTS AND DISCUSSION

The seismic sections extend to 3.0 seconds two way travel time (Figure 3). The reflection continuity below 2.25 seconds is generally poor, chaotic and of low amplitude especially across the crosslines, which could be interpreted as the Akata Formation. The character of the seismic record changes with depth. The study therefore, focuses on reflections between 1.0 second and 2.3 seconds. Reflections within this interval have good continuity and high to moderate amplitude variation. The rock units present within the study area are the intercalation of sand and shale units. The major Formation encountered within the area is the Agbada Formation, within which the five identified reservoirs (Figure 4); AB_1, AB_2, AB_3, AB_4 and AB_5 were mapped. The character of the seismic record changes with depth and seven faults (Figure 4) labeled as F1, F2, F3, F4, F5, F6 and F7 were delineated and mapped. A rollover anticline formed as a result of deformation of the sediments deposited on the downthrown block of fault F1. The fault F1 which is a major fault can be interpreted as the active fault, while the other faults (F2, F3, F4, F5, F6 and F7) which are both synthetic and antithetic faults are minor faults. The major structure responsible for the hydrocarbon entrapment in the field is an anticlinal structure which is located at the center of the surfaces In order to evaluate the presence of hydrocarbon in the identified structures, attribute analysis was carried out. The energy and the amplitude attribute extraction maps and the instantaneous frequency volume attributes maps for the reservoirs were generated.

4.1 Attributes Analysis for Reservoir AB_1

(a) Energy Attribute Map

Figure 5 is the energy attribute extraction map close to reservoir AB_1, which shows that the areas around the anticlinal structure at the northeastern/central part of the study area as bright spots. The bright spots are suggestive of the presence of hydrocarbon accumulation. Wells C and D were located around these areas.

(b) Amplitude Attribute Map

Figure 6 is the amplitude attribute extraction map close to reservoir AB_1 also showed the presence of high amplitude areas (yellow patches) around the anticlinal structure and the two wells C and D drilled around it. There are also yellow patches at the western part of the area where the contour values seem to be closing but the survey did not cover this part. The high amplitude areas are suggestive of the presence of hydrocarbon accumulations.

(c) Instantaneous Frequency Attribute Map

The instantaneous frequency volume attribute map for AB_1 reservoir is as shown in figure 7. The two wells C and D were located around the low frequency anomaly zones. The low frequency anomalous zone is suggestive of the presence of hydrocarbon accumulations which corresponds to the areas around the anticlinal structure.

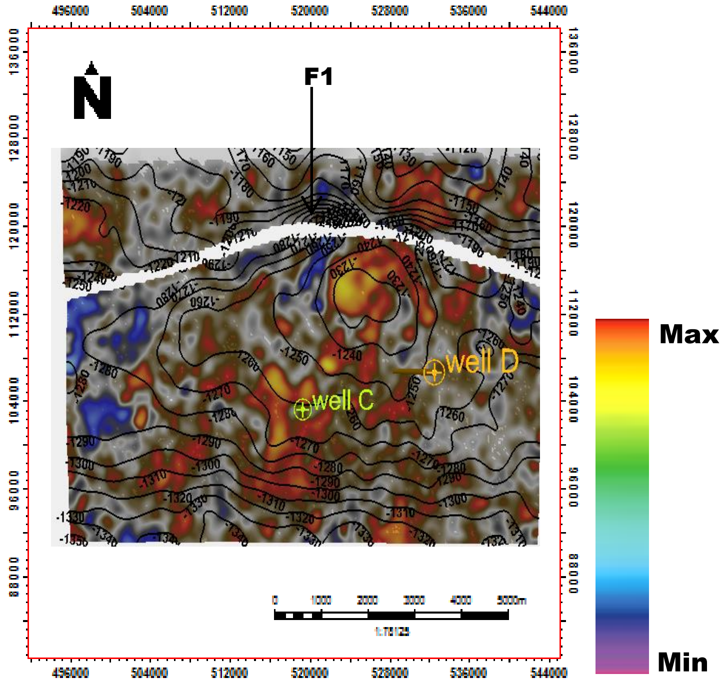

Fig. 5: Energy attribute extraction map on AB_1

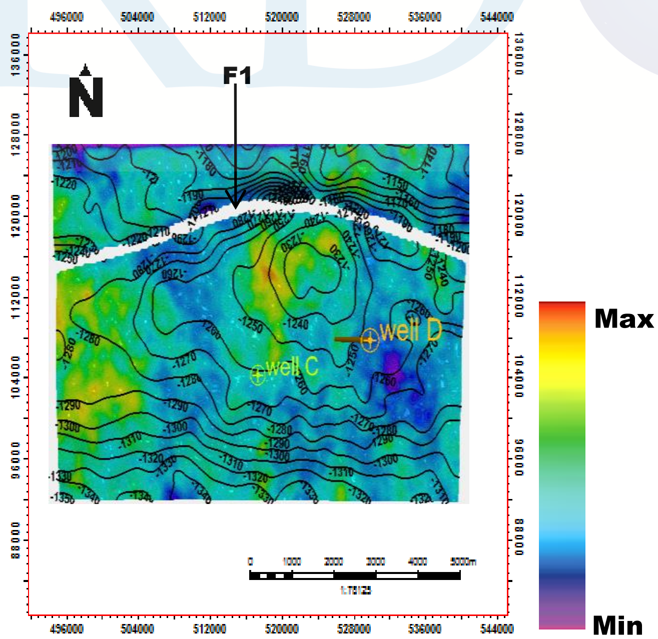

Fig. 6: Amplitude attribute extraction map on AB_1

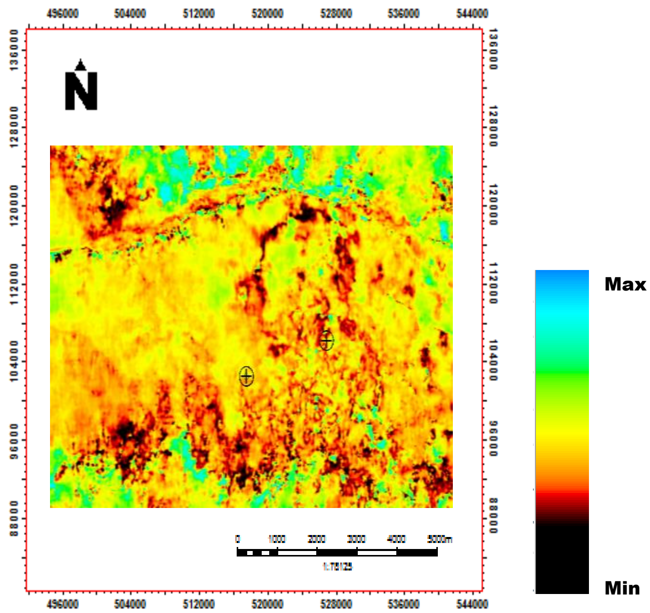

Fig. 7: Instantaneous frequency volume attribute map for AB_1

4.2 Attributes Analysis for Reservoir AB_2

(a) Energy Attribute Map

Figure 8 is the energy attribute extraction map close to reservoir AB_2, which shows the bright spots on the anticlinal structure at the northeastern/central part of the study area. There are also yellow patches at the western part of the area where the contour values seem to be closing but the survey did not cover this part. The bright spots areas are suggestive of the presence of hydrocarbon accumulations

(b) Amplitude Attribute Map

Figure 9 is the amplitude attribute extraction map close to reservoir AB_2 also showed the presence of high amplitude areas (yellow patches) on the anticlinal structure. There are also yellow patches at the western part of the area where the contour values seem to be closing but the survey did not cover this part. The high amplitude areas are suggestive of the presence of hydrocarbon accumulations.

(c) Instantaneous Frequency Attribute Map

The instantaneous frequency volume attribute map for AB_2 reservoir is as shown in figure 10. The two wells C and D were located around the low frequency anomaly zones. The low frequency anomalous zone is suggestive of the presence of hydrocarbon accumulations which corresponds to the areas around the anticlinal structure.

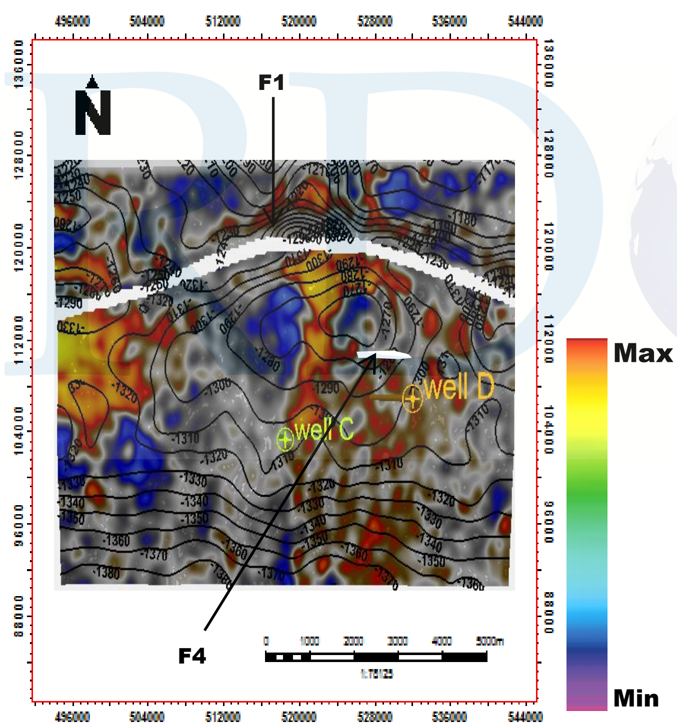

Fig. 8: Energy attribute extraction map on AB_2

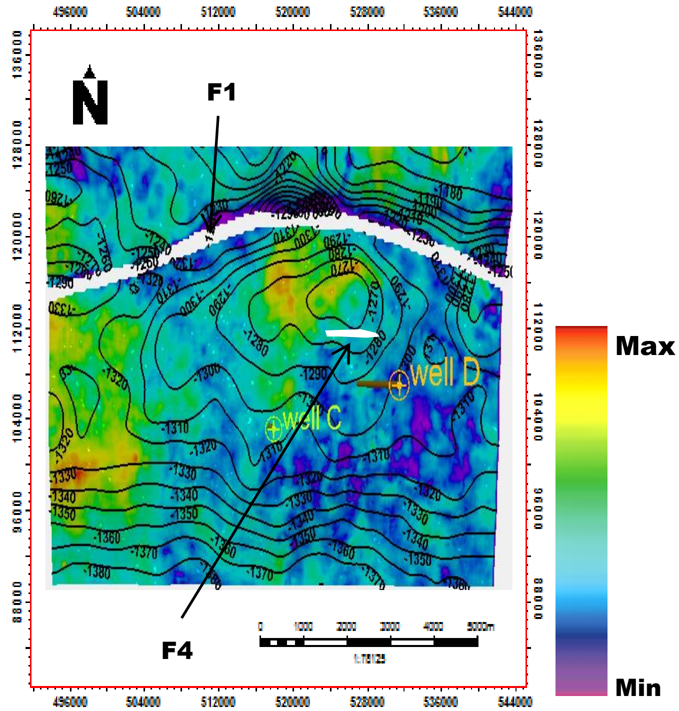

Fig. 9: Amplitude attribute extraction map on AB_2

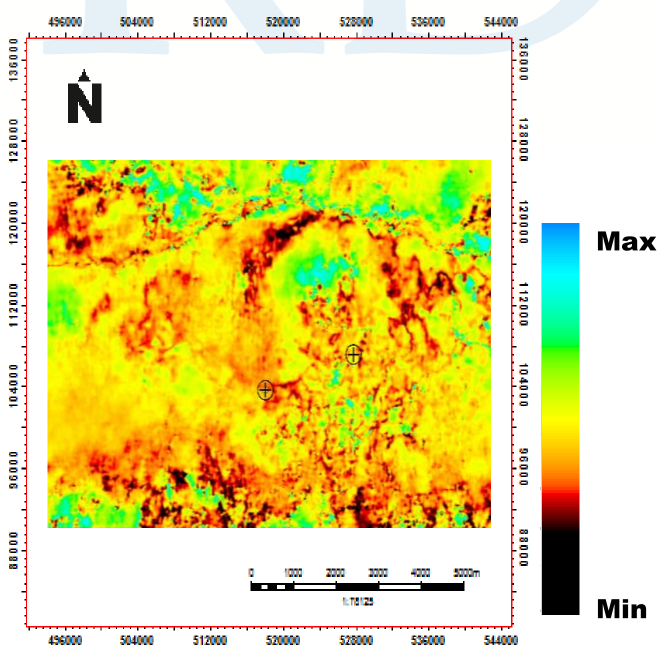

Fig. 10: Instantaneous frequency volume attribute map for AB_2

4.3 Attributes Analysis for Reservoir AB_3

(a) Energy Attribute Map

Figure 11 is the energy attribute extraction map close to reservoir AB_3, which shows the bright spots on the anticlinal structure at the northeastern/central part of the study area. The bright spots areas are suggestive of the presence of hydrocarbon accumulations

(b) Amplitude Attribute Map

Figure 12 is the amplitude attribute extraction map close to reservoir AB_3 also showed the presence of high amplitude areas (yellow patches) around the anticlinal structure. There are also yellow patches at the southwestern part of the area.

(c) Instantaneous Frequency Attribute Map

The instantaneous frequency volume attribute map for AB_3 reservoir is as shown in figure 13. The wells were located around the relatively low frequency anomaly zones. The low frequency anomalous zone is suggestive of the presence of hydrocarbon accumulations which corresponds to the areas around the anticlinal structure.

4. 4 Attributes Analysis for Reservoir AB_4

(a) Energy Attribute Map

Figure 14 is the energy attribute extraction map close to reservoir AB_4, which shows the bright spots on the anticlinal structure at the northeastern/central part of the study area. The bright spots areas are suggestive of the presence of hydrocarbon accumulations.

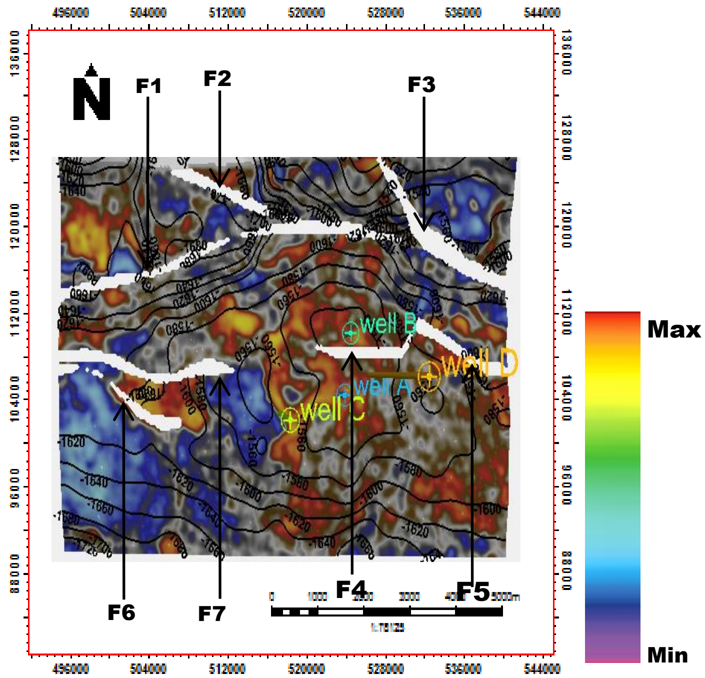

Fig. 11: Energy attribute extraction map on AB_3

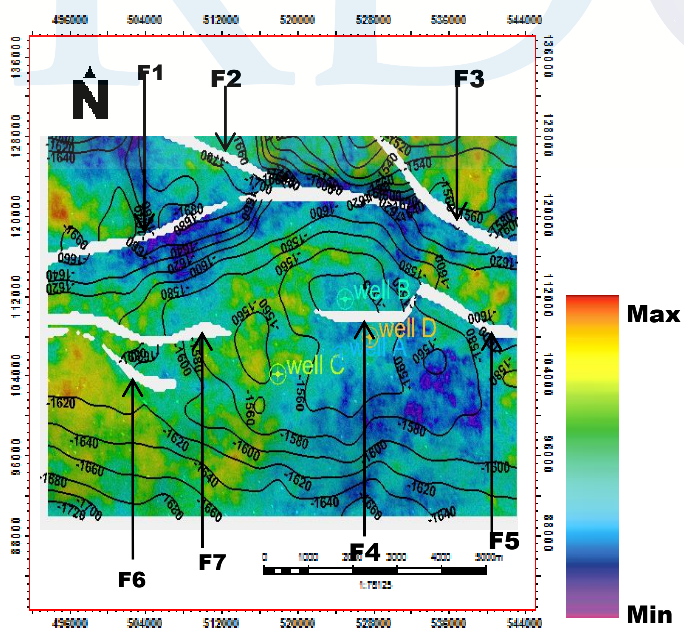

Fig. 12: Amplitude attribute extraction map on AB_3

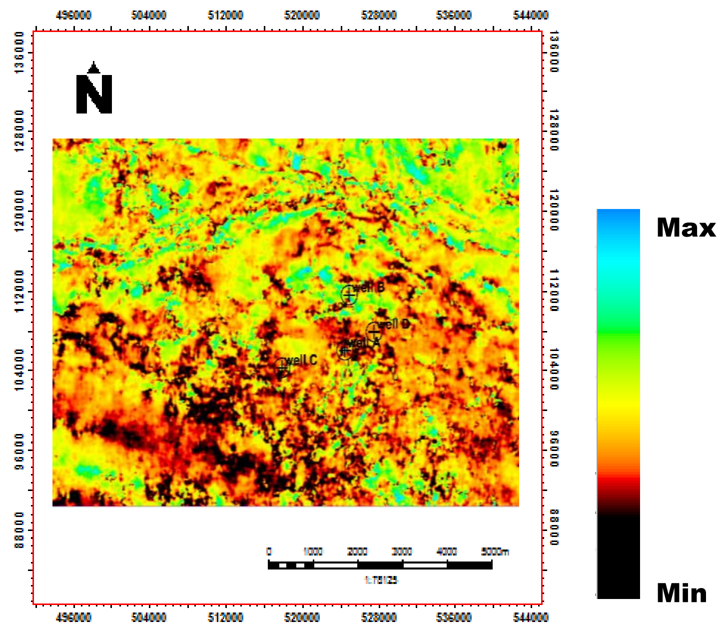

Fig. 13: Instantaneous frequency volume attribute map for AB_3

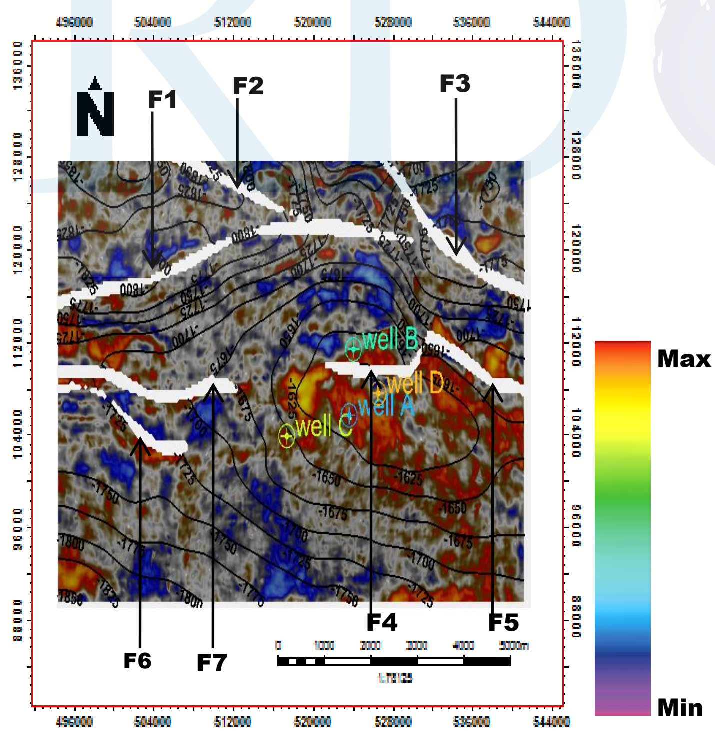

Fig. 14: Energy attribute extraction map on AB_4

(b) Amplitude Attribute Map

Figure 15 is the amplitude attribute extraction map close to reservoir AB_4 also showed the presence of high amplitude areas (yellow patches) around the anticlinal structure. There are also yellow patches at the southwestern part of the area.

(c) Instantaneous Frequency Attribute Map

The instantaneous frequency volume attribute map for AB_4 reservoir is as shown in figure 16. The four wells A, B, C and were drilled around the relatively low frequency anomaly zones. The low frequency anomalous zone is suggestive of the presence of hydrocarbon accumulations which corresponds to the areas around the anticlinal structure.

4.5 Attributes Analysis for Reservoir AB_5

(a) Energy Attribute Map

Figure 17 is the energy attribute extraction map close to reservoir AB_5. The four wells A, B, C and D were located on the anticlinal structure at the northeastern/central part of the study area which are areas of relatively high energy values.

(b) Amplitude Attribute Map

Figure 18 is the amplitude attribute extraction map close to reservoir AB_5. The four wells A, B, C and D were located on the anticlinal structure at the northeastern/central part of the study area which are areas of relatively high amplitude values.

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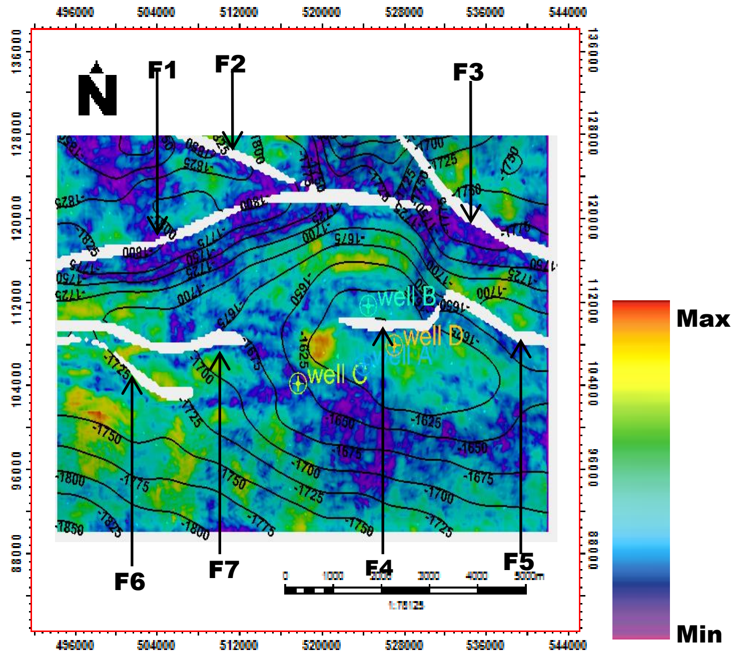

Fig. 15: Amplitude attribute extraction map on AB_4

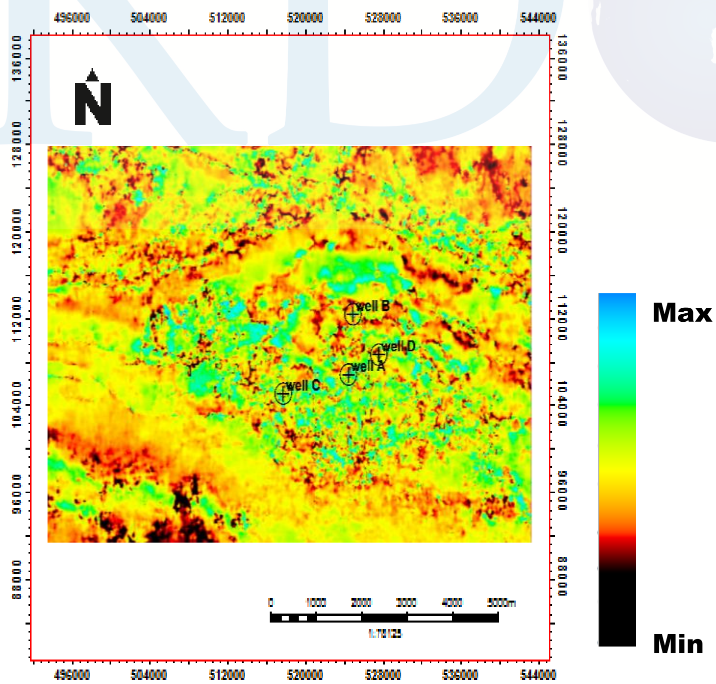

Fig. 16: Instantaneous frequency volume attribute map for AB_4

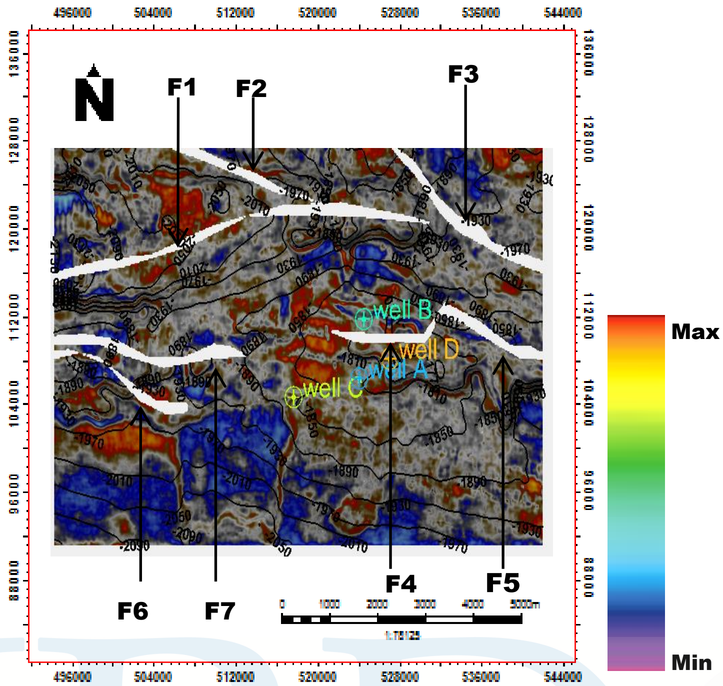

Fig. 17: Energy attribute extraction map on AB_5

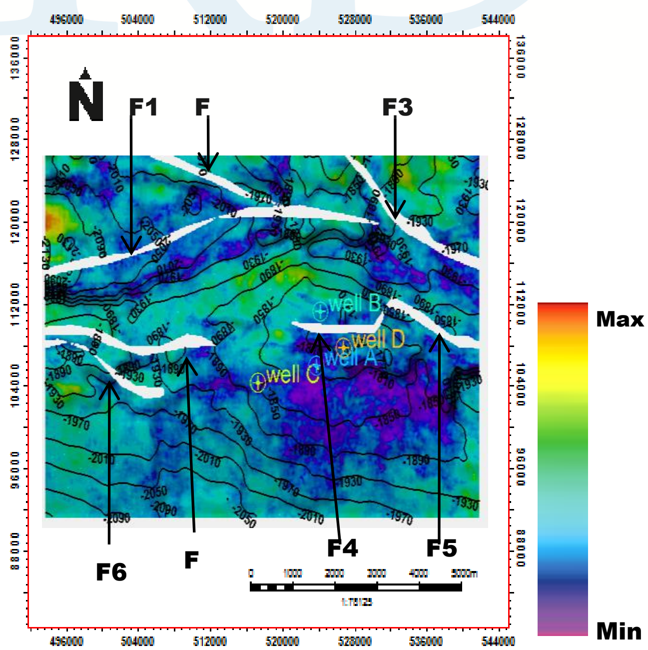

Fig. 18: Amplitude attribute extraction map on AB_5

(c) INSTANTANEOUS FREQUENCY ATTRIBUTE MAP

The instantaneous frequency volume attribute map for AB_5 reservoir is as shown in figure 19. The four wells A, B, C and were also drilled around the relatively low frequency anomaly zones. The low frequency anomalous zone is suggestive of the presence of hydrocarbon accumulations which corresponds to the areas around the anticlinal structure.

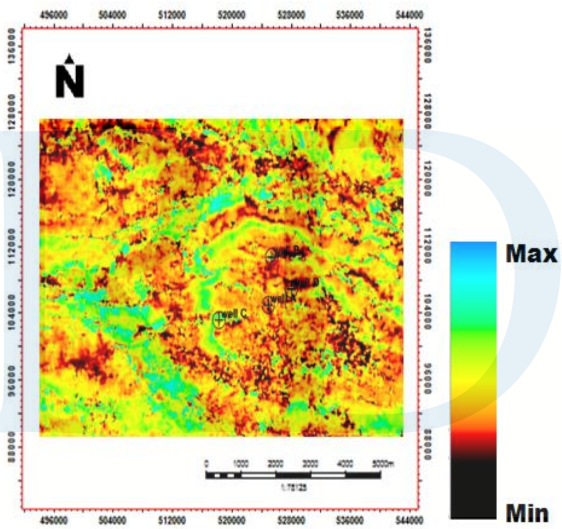

Fig. 19: Instantaneous frequency volume attribute map for AB_5

5. Conclusion

The structural disposition of the five mapped reservoirs greatly favours the accumulation of hydrocarbon. The accumulation and trapping of hydrocarbon in this field is as a result of the rollover structures due to faulting. The trapping mechanism is a fault assisted closure. The amplitude, average energy and instantaneous frequency extraction maps revealed higher values around the structural highs which coincide with the locations where producing wells A, B, C and D had already been drilled thereby validating earlier interpretations that led to their drilling.

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