ADVANCES IN PETROLEUM GEOSCIENCE RESEARCH IN NIGERIA

Basin Analysis and Reservoir Characterisation Studies

K. Mosto Onuoha, *FAS* (Editor)

6. GENERATING NEW PROSPECTS AND PLAYS FROM FACIES ANALYSIS OF 3D SEISMIC DATA: AN EXAMPLE FROM THE EASTERN NIGER DELTA BASIN

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ABSTRACT

Mature petroleum fieldsare fields within which petroleum production has declined after an earlier phase of peak production. Many of such fields exist in the onshore Niger Delta and production from these fields could be increased by applying newer exploration techniques to re-evaluate old prospects and discover new ones. One of such numerous techniques is facies analysis and Afenmai Field was chosen for illustrative study to demonstrate the applicability or otherwise of this technique to generate new prospects and plays in a mature petroleum producing field. Structurally mapped seismic horizonswere generated from sequence stratigraphic interpretation of lithologic data, foraminifera information, open- hole geophysical well logs, fluid information and 3D seismic data. Results show that hydrocarbon charged sands within the field are characterized by medium values of root mean square(RMS) and instantaneous frequency. Agbada Formation top was found to constitute a regional unconformity surface related to lowstand relative sea level, and therefore a new play. An unconformity play was identified on the seismic section at deeper sections not penetrated by wells. New subtle unconformity prospects on depth structure maps generated from these plays are structural highs with medium RMS and instantaneous frequency values. A new structural prospect was generated within the footwall of the NW-SE trending structure building fault on the eastern part of E8000 sand's depth structure map. The E1000 sand contains hydrocarbons within the rollover anticline on its hanging wall block. A new prospect is constituted by a 3-way closure on the NW of this anticline. New 3-way closure prospects were also revealed on the SE and NW of the footwall block.

INTRODUCTION

A delta is a sedimentary succession that is built up at the mouth of a river, within the setting where the river flows into a large body of water such as a lake, sea or an ocean. A typical example is the Niger Delta. It is constituted by the succession of sediments built up at the mouth of the Benue-Niger river system, onto the Atlantic Ocean during the Tertiary.Deltas are commonly major petroleum provinces. The delta formation process transports sands (which are potential petroleum reservoirs) into deeper realm of the ocean where abounds organic-rich mud with high petroleum generation potential. The organic -rich mud is a potential petroleum source rock.The accumulation of the sedimentary succession is preceded by crustal down warping that creates accommodation space for the succession. Crustal instability, differential delta subsidence, and the transportation of sand over under compacted clays and shale create delta associated structural traps such as growth faults; roll over anticlines and shale diapirs. Changes in relative sea level coupled with variations in sediment supply create a variety of subtle traps in a delta. A petroleum play is the composite of reservoir rocks, seals or cap rocks and traps that are connected to a source rock via migration pathways.Traps that have been identified and delineated within a play by seismic horizon mapping upgrade to prospects. Exploration wells are the wells drilled to test whether a delineated trap contains petroleum accumulation. Areas within a delta where exploration wells discover petroleum accumulation in a delineated prospect become a petroleum field. The field from which petroleum is produced becomes a production field. A production field becomes mature as production attains its peak and begins to decline. Such mature fields constitute old petroleum fields (Halliburton, 2017). In the Niger Delta, old fields also include unevaluated fields discovered using 2D seismic data. Examples of such old fields in the Niger Delta are ForcadosYokri Field in shallow eastern offshore (Wood *et al.*, 1991), Oguali Field in the eastern part of the Northern Depobelt (Edeki, 1991), Elepo Field of the Central Swamp Depobelt(Overell and Nwachukwu, 1995).

Three dimensional (3D) seismic data provides a high resolution 3D image of the subsurface that is adequate for capturing reservoir structure, geometry, orientation and depositional environment. Thus the analysis and interpretation of 3D seismic reflection data constitute a dominant method used for petroleum exploration. Gressly(1838) originally defined a sedimentary facies to capture a sedimentary rock body with a distinctive combination of geometry, petrographic constitution and paleontological character imposed on it by its depositional environment, and distinguishes it from its surrounding rocks (Unuevho,2014). Sedimentary environments serve as the mills in which facies and petroleum are produced.The areal and temporal relationships of sedimentary facies predetermine the stratigraphic positions of petroleum accumulations.Thus,the structural mapping of chronostratigraphicfacies surfaces as seismic horizons on 3D seismic data sets will reveal new plays and generate new prospects in old petroleum fields.

OLD EXPLORATION MODELS AND NEW PROSPECT OPPORTUNITIES IN THE NIGER DELTA

The 10 January 1901's discovery of oil field at Spindletop, near Beaumont, Texas, skewed the petroleum industry's exploration efforts towards the search for structural traps (Halbouty, 1991). Large geological structures were considered to be prospective traps for petroleum in the petroleum exploration models. This is perhaps because structural traps are more conspicuous on seismic sections than other traps. Consequently, the principal old fields in the Niger Delta are constituted by structural traps (Figure1) comprising simple rollover anticlines, multiple growth faults, synthetic and antithetic growth fault system, and collapsed crest structure (Weber and Daukoru, 1975; Romieu, 1991). Most of these structures had been found by the early 1990s.

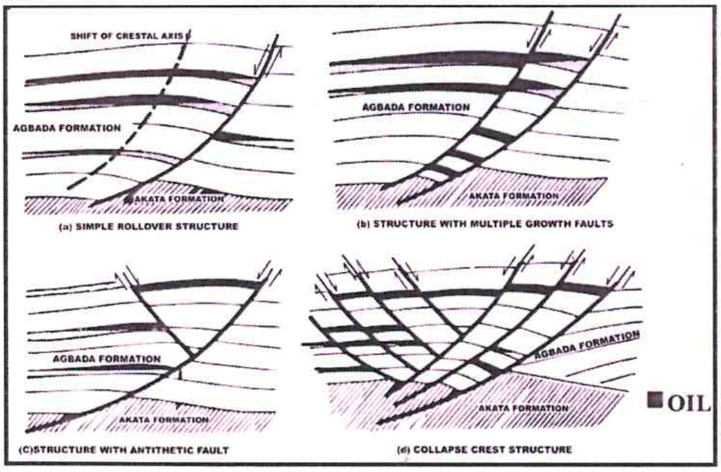

FIG. 1: Principal oil field structures in the Niger Delta (Weber and Daukoru, 1975)

Edeki(1991) revealed that there is virtually absence of undrilled prospective structures that are shallower than 12000ft in the eastern Niger Delta. Thus new play and prospect opportunities are partly structural traps within subsurface realms deeper than 12000ft (Romieu, 1991; Edeki, 1991). Despite the fact that deep structural prospects exist within intervals of liquid hydrocarbon or even within the wet gas zone, most of the wells drilled before the 2000s in the Niger Delta did not reach the top of the oil window. Other opportunities for new plays and prospects are the subtle traps.

These traps are constituted by numerous facies changes that are consequence of crustal instability, relative sea level fluctuations, variation in sediment supply, major river diversion and rapid sedimentation.

Martin (1966) and Halbouty (1991)distinguished subtle trapping mechanisms as follows: (1) stratigraphic traps that are formed by lateral changes in reservoir rock properties; (2) paleogeomorphic traps that result from deposition on the slope of buried hills or upon the face of buried valleys; (3) unconformity related traps which are essentially truncation against clay filled incised valleys, incised fluvial channel sandstones that are trapped laterally against impermeable older shales and lithologic pinch-outs against an unconformity surface. These traps are illustrated in Figure 2.

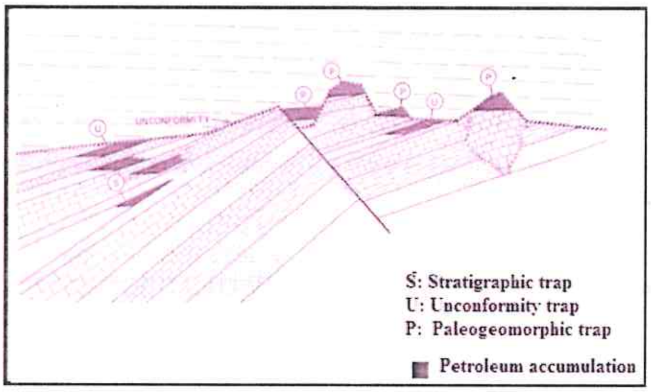

Fig.2: Types of subtle traps (Halbouty, 1991)

Examples of unconformity related traps within which petroleum accumulation has been discovered in the Niger Delta are Opuama Field, Pologbene Field, Gwato Field and Opuekebe Field in OML 49/40(Adejobi and Olayinka, 1997).Lowstand slope fans andbasin floor fans are also included among unconformity traps. They have been found to be petroleum bearing in the offshore depobelt of the Niger Delta (Ozumba, 1995). Nigerian Agip Oil Corporation's Obrikom and Obiafu Fields are examples of paleogeomorphic traps because they include sand pinch-out towards the Abakaliki High (Krushi and Idiagbor, 1994).

SHORTCOMINGS ASSOCIATED WITH CONVENTIONAL PROSPECT GENERATION TECHNIQUES

New prospects are conventionally generated in old petroleum fields by seismic structural mapping of reservoir topsdelineated on wireline logs from lithostratigraphic correlation. Figure 3 illustrates that such lithostratigraphic correlations link chronostratigraphically different sandstones together, exaggerate reservoir continuity, and falsely constrains marine sandstone reservoirs to change faciesupdip into shales and mudstones.

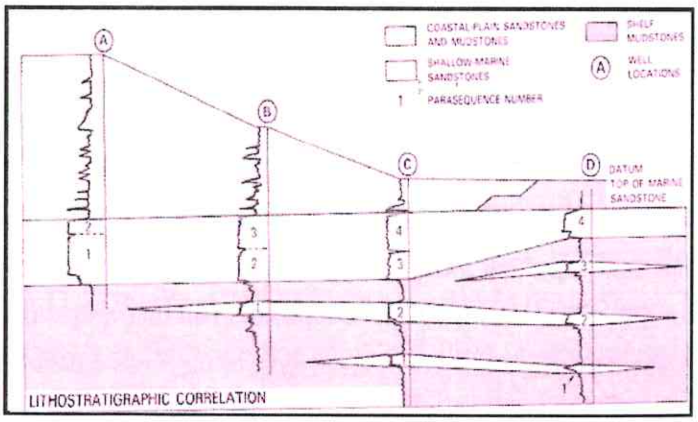

FIG. 3: Lithostratigraphic correlations (Van Wagoneret al., 1990)

The correlative seismic reflectors (or horizons) corresponding to such reservoir tops do not often enable correct chronostratigraphic or lithologic predictions in areas that are distant from well control.Figure 4illustrates that the red horizon (which is a typical seismic horizon that is correlative with a reservoir lithologic top picked on wireline logs)) has a different age and represent a different in each of the wells.

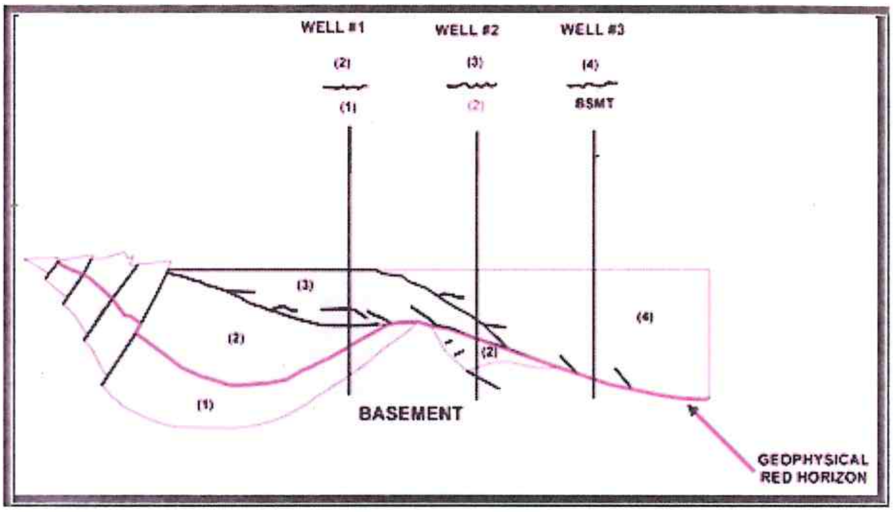

FIG.4: Timetransgressive red horizon mapped on seismic sections (Hubbard et al., 1985)

The generated depth structure map displays erroneous prospect architecture, which results in drilling dry wells when the prospects are tested.

FIELD LOCATION, MATERIALS AND METHOD OF STUDY

Afenmai Field (a fictitious name adopted to preserve data confidentiality) is located within the Central Swamp Depobeltof the Niger Delta Basin. The Coastal Swamp Depobelthosts over 150 developed petroleum fields and contributes over 40% of the delta's onshore petroleum production. Afenmai Field was discovered long ago in the Central Swamp Depobeltof the Niger Delta from interpretation of 2D seismic data, and was classified as an Unapprised Discovery (UAD). The field covers a surface area of approximately 242km^2(93.4 square miles). Eight wells have been drilled in this field, and this gives an average well density of 1 per 30km^2. This well density presents an opportunity for new petroleum plays and prospects in the field.This work illustrates the deployment of sequence stratigraphic principles in an integrated approach to infer depositional environments, paleobathymetric changes, sequence boundariesand system tracts. Sequence stratigraphic model of Vail (1987)as well as VanWagoner*et al.* (1990) was adopted in this work. This model has been adopted by many geoscientists, among whom are Ozumba(1995), Adegoke (2002), Larue and Legarre (2004),Magbagbeola and Willis (2007) , Shell(2011), Adegoke (2012), Ajaegwu*et al.*(2014), Dim *et al.*(2014) and Unuevho (2014).The materials employed in the study comprise lithologic data, foraminifera information, wireline logs, fluid information, 3D seismic data sets, and a workstation that utilises*Geographix*5000 and *Petrel* 2008 1.1. The well base information for the well logs, lithologic data and the 3D seismic data sets were fed into the workstation. The well log section was constructed with the*Geographix*5000 and *Petrel* 2008 1.1. Sequence stratigraphic model of Vail (1987) and VanWagoner *et al.* (1990) was employed to conduct holistic interpretation of lithologic data, biostratigraphic data and well log motif, and to subsequently establish a chronostratigraphic correlation on the well section.

The available foraminiferal data were interpreted in terms of paleoenvironment and relative paleobathymetry using graphical illustration of the association between typical foraminifera genera and specific depositional environments (Fig.5) given by Boersma (1980) and paleobathymetric interpretations of benthic foraminifera given by Petters (1982).

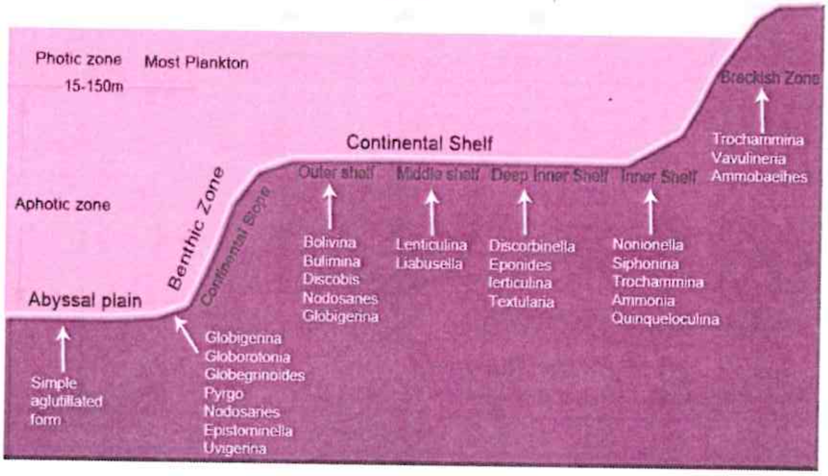

Fig.5: Benthic foraminifera genera association with bathymetric trend (Boersma, 1980)

Additional templates employed for foraminifera interpretation are the association of benthic foraminifera with specific depositional environmentsgiven by Ozumba (1995), and the paleoenvironment interpretation of the association of *CassigerinellaChipolensis* with *Uvigerina*and *Bolivina* given by Okosun and Liebau (1999). Inferred relative bathymetry was used as a guide for relating top and base of sands to chronostratigraphically significant stratal surfaces such as sequence boundaries, transgressive surfaces, maximum flooding surfaces and regressive surfaces at well locations. These surfaces were correlated from well to well throughout the well cross-section. The chronostratigraphicstratal surfaces were used as a guide in relating reservoirs to systems tracts.

RESULTS AND DISCUSSION

The eight wells were named 001, 002, 003, 004, 005, 006, 007, and 008.The sand units penetrated in all the eight wells were considered to be field wide, and were grouped intoD-sand units, E-sand units and F-sand units. The sub – units within each sand unit were distinguished using Arabic numerals. Some of the sub-unit sands are D1000, D2000, E4000 and F1000. Tables 1-3 show the biostratigraphic information for wells 001, 002, and 003. Similar information was available for the other wells (005-008), but are not detailed here..

Table 1: Biostratigraphic data for well 001

SUB-SEA DEPTH TO TOP(inft)	SUB-SEA DEPTH TO BASE (in ft)	ZONE CODE	FORAMINIFERA	GEOLOGICALAGE
30	3980		Barren	
2520	5400	P840		Late Miocene
3996	5260	F9600/F9700		Middle Miocene

5280	6170		Undiagnostic	
6180	7870	F9500		Middle Miocene
7880	8640	F9300/F9500		Early-Middle Miocene
8660	10190	F9300	Rich *Bolivina 25*	Early Miocene

Table 2:Biostratigraphic data for well 002

SUB-SEA DEPTH TO TOP (IN ft)	SUB-SEA DEPTH TO BASE (IN ft)	ZONE CODE	FORAMINIFERA	GEOLOGICAL AGE
40	4040		Barren	
4060	5360	F9600/F9700		Middle Miocene
5380	6160		Barren	
6170	6200		Undiagnostic	
6220	7980	F9500	Top *Uvigerina 5*	Middle Miocene
6270	6270	F9540	*Bolivina 25/ Uvigerina* 5	Middle Miocene
8000	10066	F9300		Early Miocene

Table 3: Biostratigraphic data for Well 003

SUB-SEA DEPTH TO TOP (inft)	SUB-SEA DEPTH TO BASE (inft)	ZONE CODE	FORAMINIFERA	GEOLOGICAL AGE
0	1490		No data	
121	3659		Barren	
1500	2812	P850/P880		Late Miocene
2960	4489	P830/P840		Late Miocene
3689	4940	F9600/F9700		Middle Miocene
4490	4800	P770		Middle Miocene
4970	6240	P740		Middle Miocene
4970	6390		Barren	
6300	7460	P720		Middle Miocene
6400	8020	F9500	Top *Uvigerina5*	Middle Miocene
7540	9850	P680		Early Miocene
8040	8980	F9300/F9500		Early Miocene
9000	10010	F9300	Rich *Bolivina*	Early Miocene

The depositional environments inferred from the foraminiferal fauna are presented asFigure 6. The intervals that are barren of foraminifera are interpreted to constitute continental to marginal marine lithofacies. Selley (1978), Boggs (2006) and Nichols (2009) interpreted such clastics to be fluvial lithofacies. The presence of *Nonion-6* reflects inner-shelf depositional environments (Petters,1982). The presence of*Uvigerina,Chiloguembelina* and *Cassigerinella* genera indicateouter shelf to upper bathyal depositional environments (Boersma,1980;Braiser 1980; Petters 1982; Ozumba 1995; and Okosun and Liebau (1999).

The occurrence of *Bolivina* genera reflects outer shelf to middle bathyal depositional environments (Boersma,1980;Ozumba ,1995).

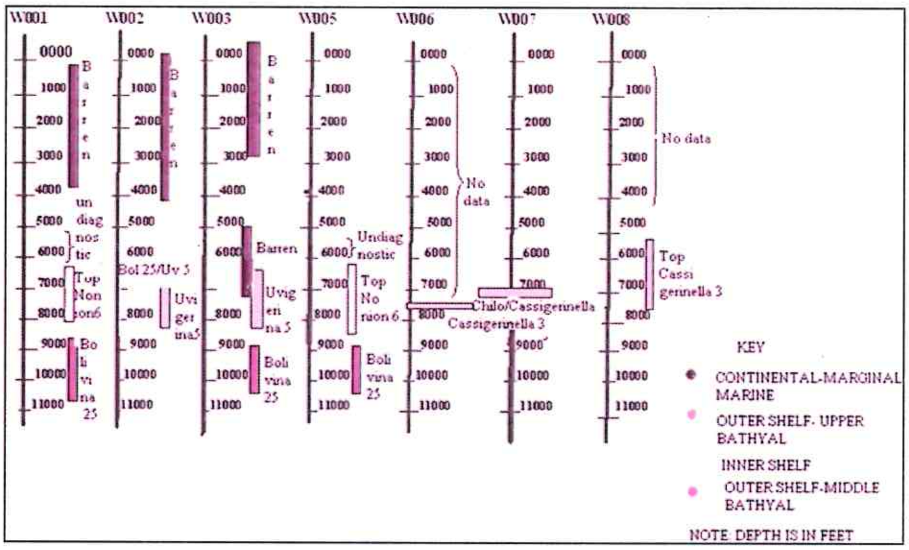

Figure 6: Depositional environments inferred from biostratigraphic data

The time-stratigraphic correlation of the D-sands in wells 001,002, and 003 is presented as Figure 7 while the same correlation for wells 003,004,005 and wells 005,006,007 are shown in Figures 8 and 9. An extension ofthe correlation to well 008 is given in Figure 10.The top of the Agbada Formation is defined along the base of the shallowest, thick regional marginal marine shale in the study area.This conformsto the occurrence of marine shales at the lower portion of Benin Formation in eastern Niger Delta. Marine shales have been reported in literature to be associated with the lower portion of Benin Formation in eastern part of the Niger Delta (Okosun and Liebau, 1999), and to constitute major sediment fill of the shallowest canyons and valleys cut by erosion processes associated with relative sea level fall (Adejobi and Olayinka, 1997). Above the top of the regional marginal marine shales on top of the Agbada Formation, sands associated with continental lithofacies are characterized by GR logs that display a sharp base and finning upwards gradational top of bell log motif. This log shape is typical of delta plain fluvial distributary channel fills and tidal flat sands. The larger bell motifs are possibly the fluvial channels lithofacies while the numerous smaller motifs probably reflect oscillatory tidal variations in tidal flats.*Chiloguembelina, Cassigerinella*and *Uvigerina*foraminifera genera together with cylindrical and crescent log motifs just beneath the marginal marine shale at wells 8,3 and 2 implies that shelf to upper bathyallithofacies underlie the Agbada Formation's top. This vertical juxtaposition of delta plain fluvial distributary channel and marginal marine lithofacies directly above outer shelf to bathyallithofacies, in all the wells, reflects that the top of Agbada Formation is a widespread unconformity surface and therefore a sequence boundary. Thus the top of the Agbada Formation constitutes a regional unconformity that separates overlying regional marine shale from underlying outer marine to upper bathyallithofacies in Afenmai field. On seismic sections (Figure 11), this unconformity surface displays low amplitude reflections above from continuous medium to high amplitude reflections below. The sequence boundary status of this regional unconformity surface is supported by termination of faults on this surface (Figure 11).

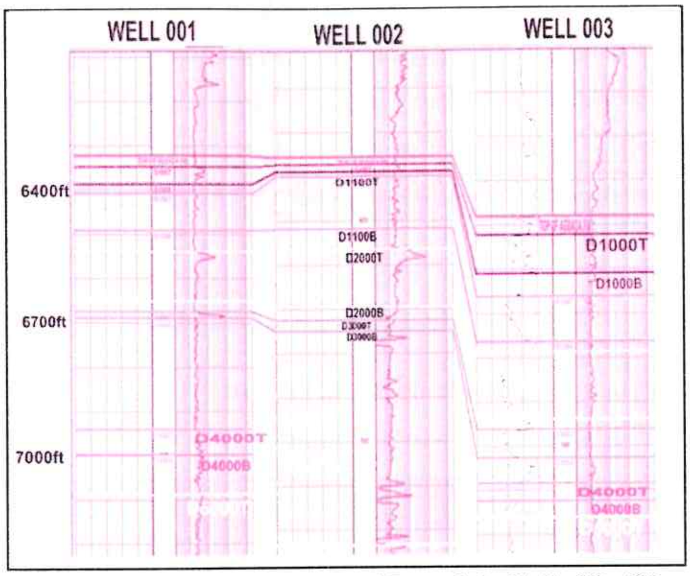

Fig.7: Correlation of top of AgbadaFm and D-sands in Wells 001, 002 and 003

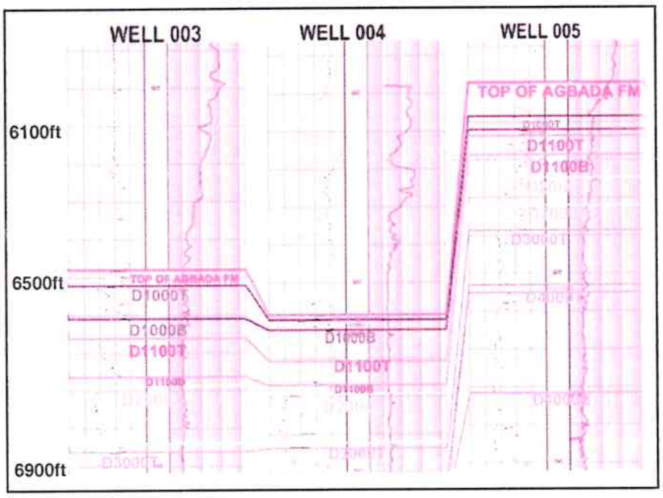

Fig.8: Correlation of top of AgbadaFm and D-sands in Wells 003, 004 and 005

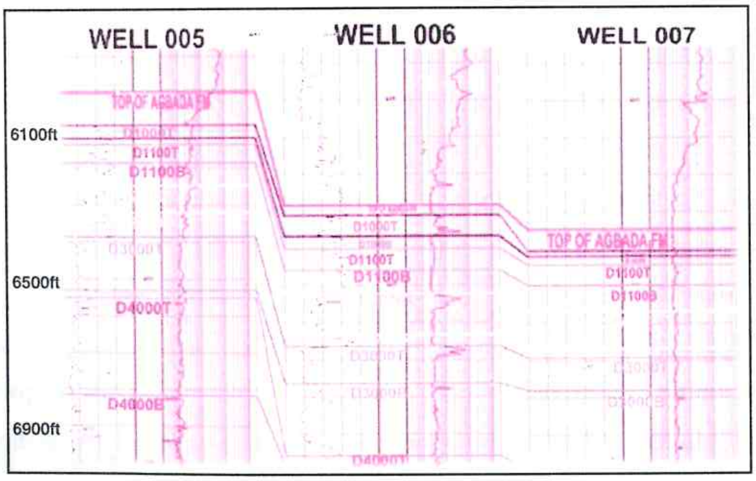

Fig.9: Correlation of top of AgbadaFm and D-sands in Wells 005, 006and 007

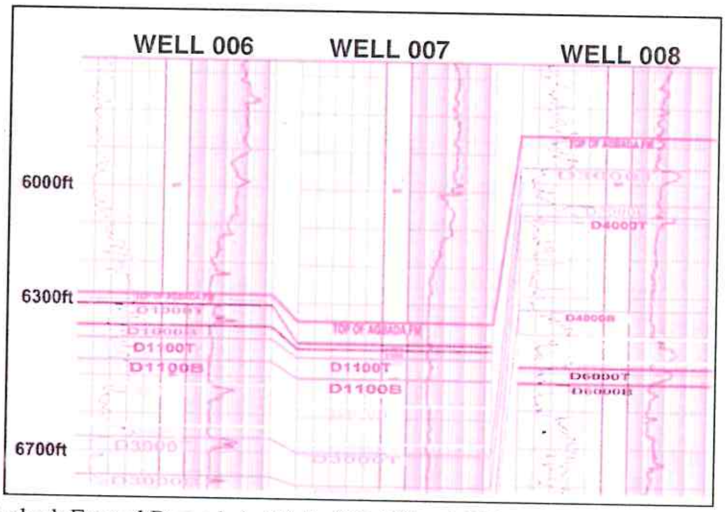

Fig.10: Correlation of top of AgbadaFm and D-sands in Wells 006, 007and 008

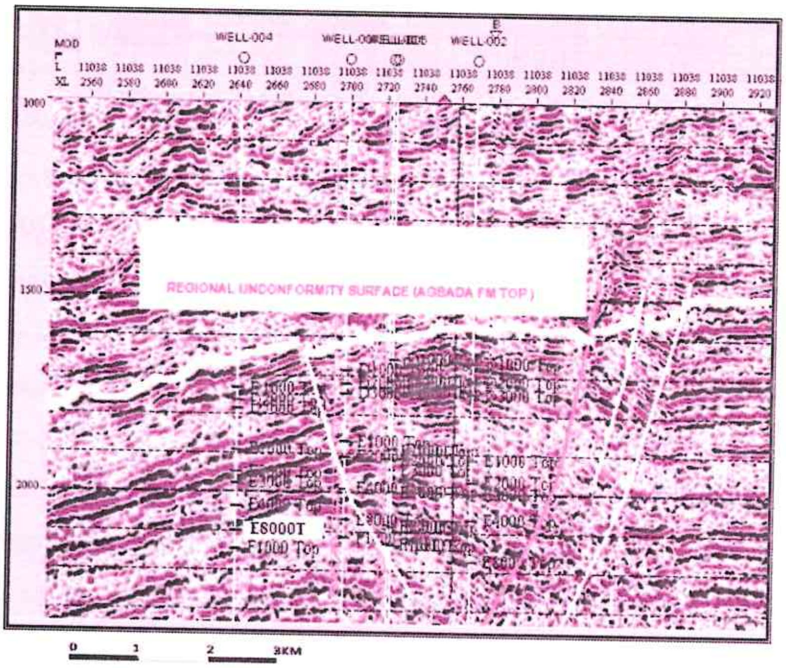

Fig.11: AgbadaFm top and penetrated sands

The Agbada Formation top represents an erosion channel deeply cut into the shelf when the sea level was at lowstand during relative sea level. The marginal marine shales captured as low amplitude reflections are lithofacies that subsequently filled the channel when erosion waned down. This lithofacies do contain lenses of sand body within them, and are commonly underlain with coarse sand. The sand lenses and underlying sand body are prospective reservoir sands. Adejobi and Olayinka(1997) reported that oil bearing intrachannel sands were discovered along a regional unconformity surface that constitutes the top of Agbada Formation in Opuekeba and Gwato fields within Opuama Channel Complex area of western Niger Delta and in Tapa and Ubit fields within south eastern offshore of the Niger Delta.The continuous and parallel medium to high amplitude reflections, represent highstand sea level lithofacies of outer marine to upper bathyal depositional system.The shales within this deepwaterlithofaciesconstitute petroleum source rocks. Anyhydrocarbon generated within them would be released via up dip primary migration into the intra-channel sands. Thus the source rocks and reservoir rocks laterally and vertically juxtaposed along the Agbada Formation top constitute a new petroleum play in Afenmai field.

Figure 12 is the depth structure generated by mapping the top of Agbada Formation while Figures 13 and 14 are respectively RMS amplitude and instantaneous frequency maps extracted along the seismic horizon corresponding to the Agbada Formation top. Hydrocarbon accumulations in the field are characterised by medium values of RMS amplitude and instantaneous frequency (Unuevho, 2014).Hence the association of these values of seismic horizon attributes with high structural position on the depth structure map delineates the Agbada Top petroleum prospect. The delineated prospect is captured on Figure 15.

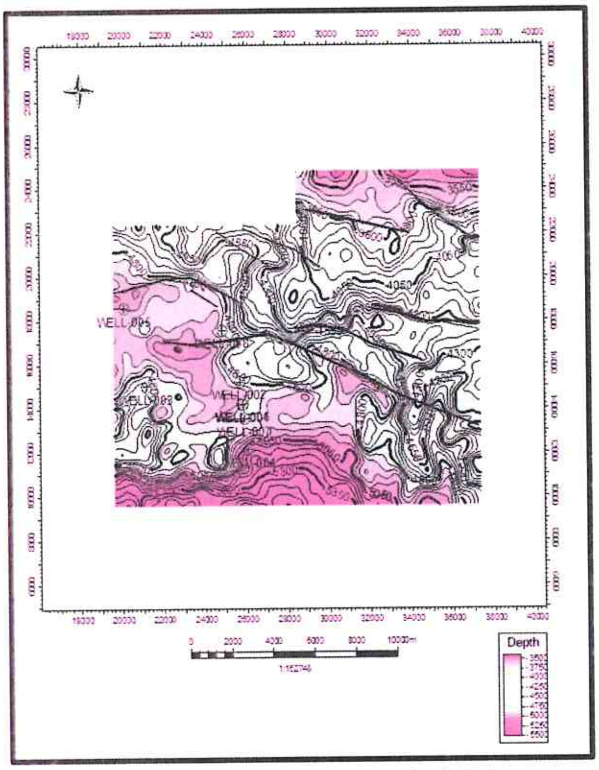

Fig. 12: Depth- structure map for unconformity surface one (Top of AgbadaFm)

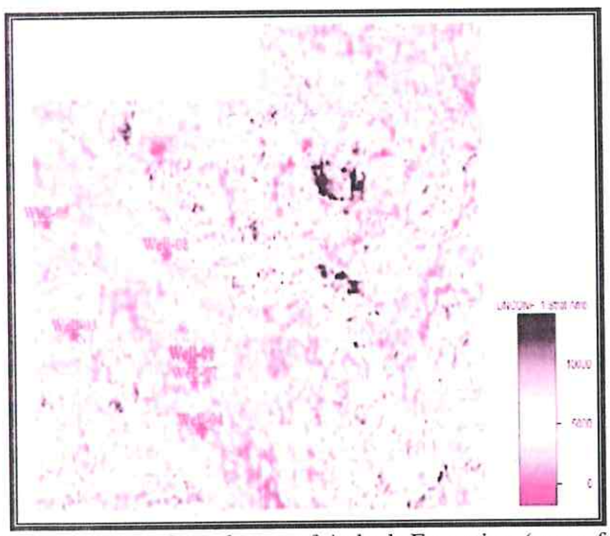

Fig.13: RMS amplitude variation along the top of Agbada Formation (unconformity surface one)

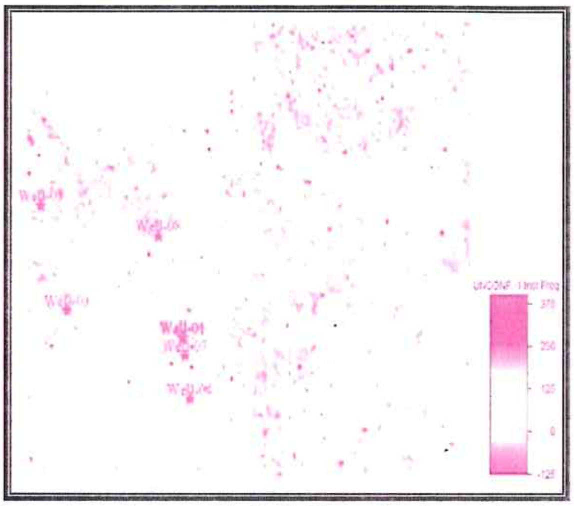

Fig.14: Instantaneous frequency variation along the top of Agbada Formation (unconformity surface one)

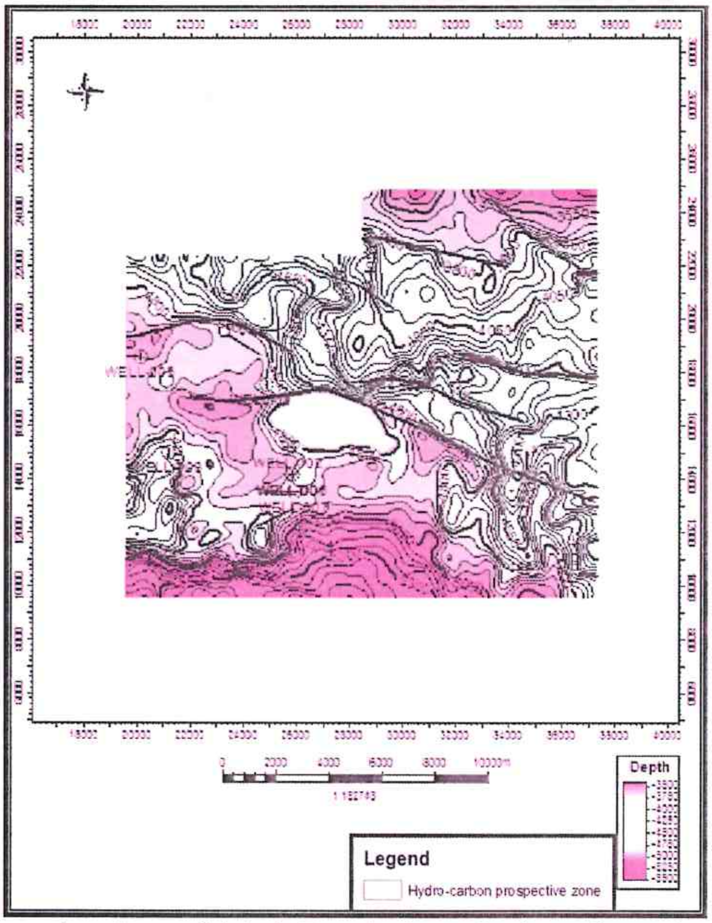

Fig.15: Stratigraphic prospects along the top of Agbada Formation(unconformity surface one)

The time-stratigraphic correlation of the E and F sandsis shown in Figure 16 for wells 001, 002,003 and in figure 17 for wells 003, 004, 005. The correlation of the same sands in wells 005, 006, 007 and wells 006, 007, 008 are shown in Figures 18 and 19 respectively. The *Bolivina 25* horizon (reported in four of the wells) approximately lays within E8000 shale in wells 1 and 3.The E8000 sand, directly overlying this shale, is fossil barren and displays a cylindrical GR log motif. This attribute characterizes distributary mouth bar and channel sands of marginal marine environment. The presence of marginal marine facies directly above outer to bathyalfacies (reflected by the presence of *Bolivina 25*) in the wells indicates a regional unconformity. The E8000 sand is thus a lowstand systems tract (LST) while its base

(E8000B) constitutes a sequence boundary in the wells. The lithofacies units directly vertically below E8000B display an upward-coarsening (funnel pattern) GR motif and belong to highstand systems tract (Fig.10).The lithofacies between E8000T and E4000B display upward finning GR log (bell shape) motif and increasein shale thickness betweensand units (Fig.18 and 19). The E8000T is thus a transgressive (or marine flooding) surface. The E4000B approximately coincides with a surface that is dotted with different marine (both benthic and planktonic) foraminifera, ranging from bathyal to inner neritic. Thus the E4000B approximates a maximum marine flooding surface.The lithofacies sandwiched between E8000T and E4000B thus constitute transgressive systems tract. The lithofacies between E4000B and the top of the Agbada Formation form highstand systems tract.

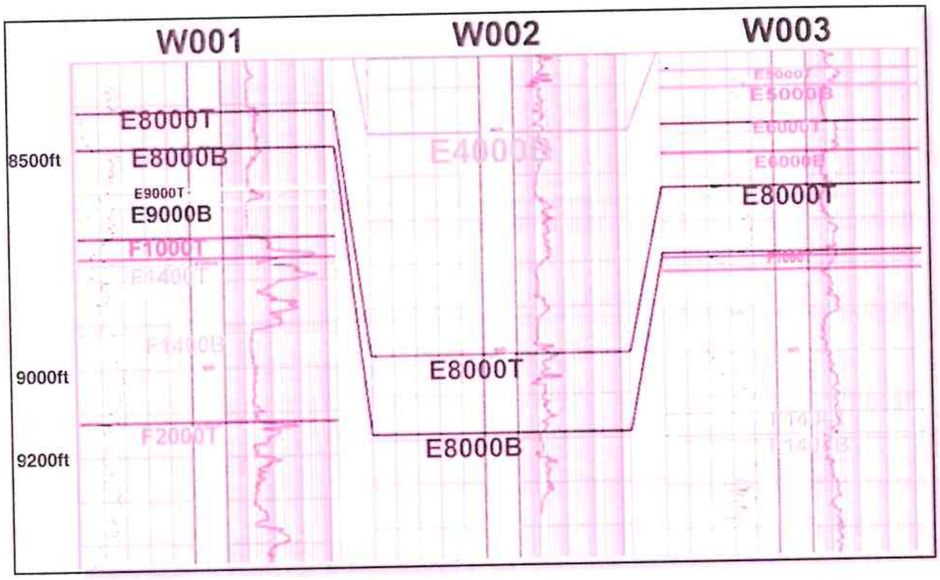

Fig. 16: Correlation of deeper sands(Eand F sands) for Wells 001, 002, 003

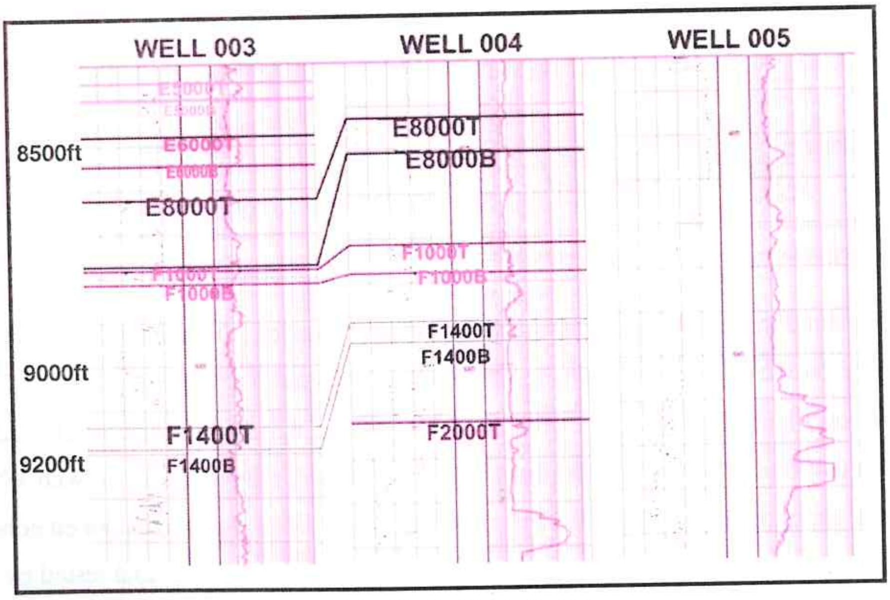

Fig. 17: Correlation of deeper sands(E and F sands) for Wells 003, 004, 005

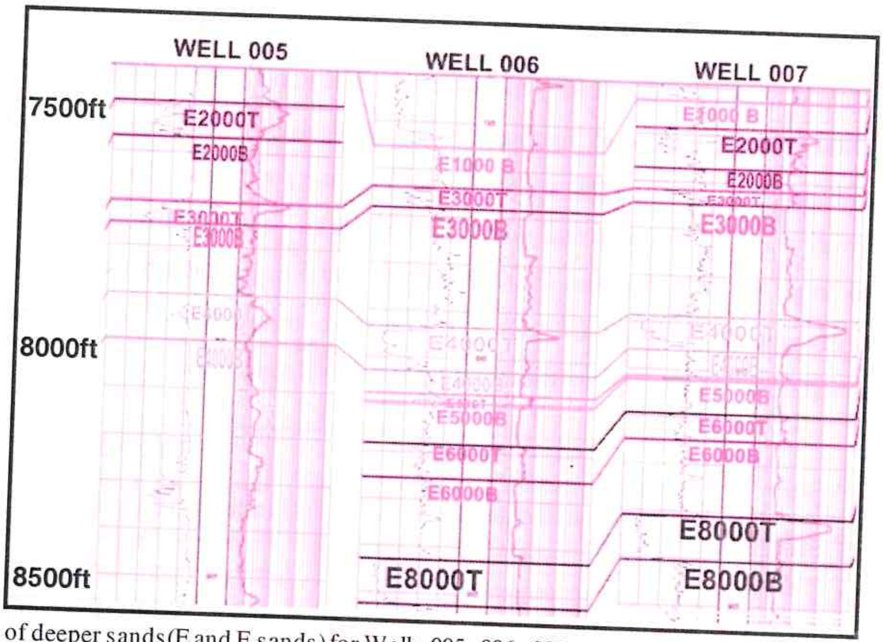

Fig. 18: Correlation of deeper sands(E and F sands) for Wells 005, 006, 007

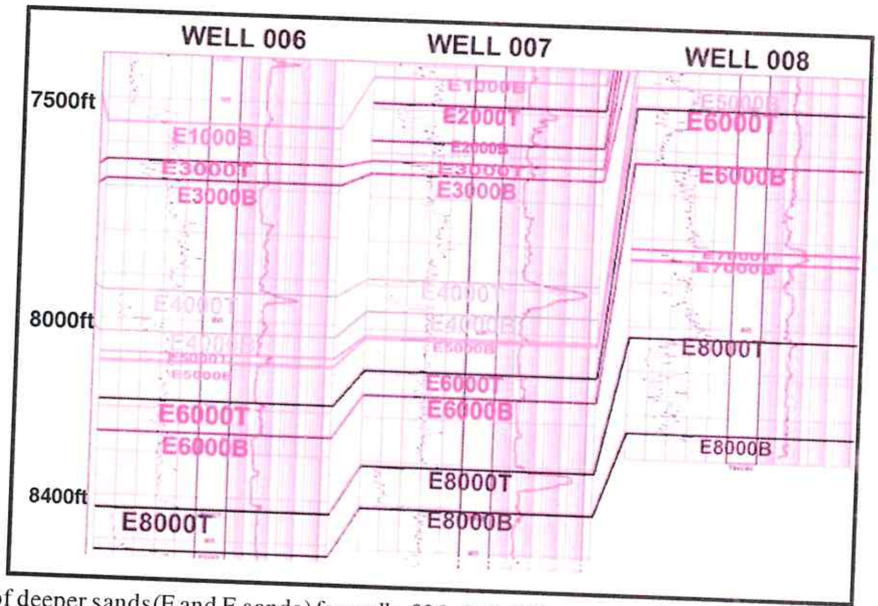

Fig.19: Correlation of deeper sands(E and F sands) for wells 006, 007, 008

The E8000 sand is a lowstand systems tract that is knwn to constitute major petroleum reservoirs in many areas and was clearly mapped here on the 3D seismic data. Its depth structure map is presented as figure 20 while the RMS amplitude mapisshoown on Figure 21.The depth structure map revealed that E8000 sand is affected by a major NW-SE trending growth fault that dips southwards. The sand body constitutes a rollover anticline with a NW-SE hinge line on the hanging wall. The anticline is further faulted by crestal and flank faults arranged in an en echelon pattern. The sand was tested by well 003on the western part of the hanging wall. This part of the sand tested by the well was dry. The sand was also dry in wells 005 and 006 drilled on the footwall of the anticline's crestal fault. Well 007 found petroleum in the sand within the three-way closure associated with the hanging wall of the crestal faults on the roll-over anticline. An analogous closure to this three-way closure exists on the east of the foot-wall of the major NW-SE trending fault. The RMS values for this structure are within the range associated with petroleum accumulations. This structure sshown on Figure 22 is yet to be tested and therefore has the status of a new petroleum prospect.

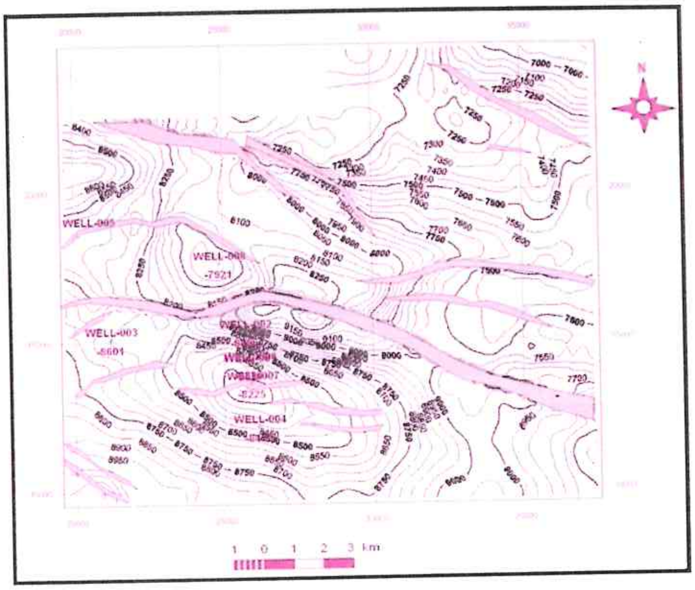

Fig. 20: Depth- structure map for top of E8000 sand

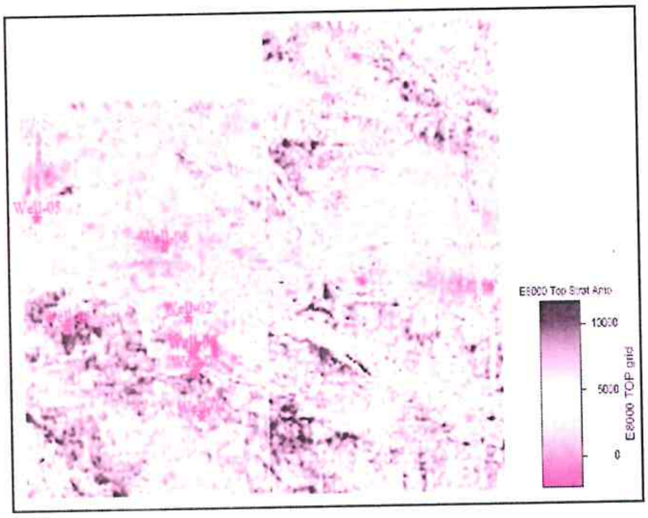

Fig. 21: RMS amplitude variation along top of E8000 sand

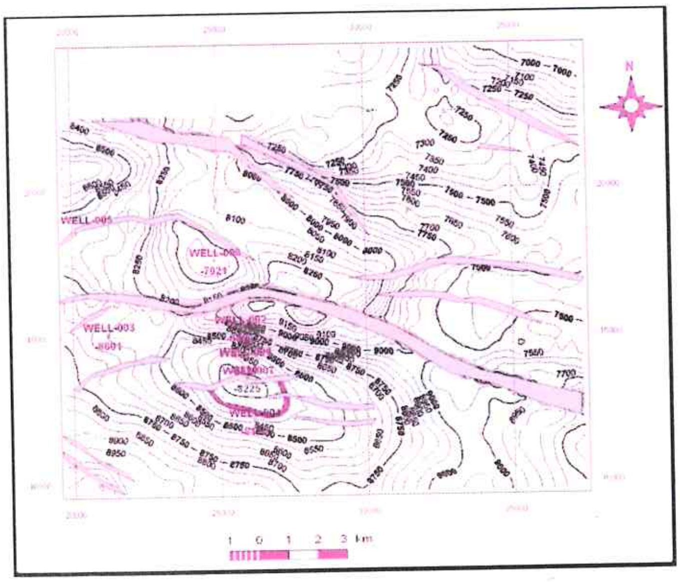

Fig. 22:Areal extent of hydrocarbon accumulation and new prospect (shown in yellow) in E8000 sand

The E1000 sand is one of the HST sands between E4000T and the Agbada Formation top. The depth structure map obtained from mapping the E1000T horizon on 3D seismicdata set is shown on Figure 23 while the RMS amplitude and instantaneous frequency maps for the horizon are displayed on Figures 24 and 25 respectively. Petroleum accumulation (characterisedby medium RMS amplitude and instantaneous frequency values) is contained in a rollover anticline on the hanging wall block of the major NW-SE trending fault that affected the E1000-sand (Figure 26). The crestal faults on the anticline did not affect the distribution of petroleum within it. Thus the anticline is a four-way closure.The depth structure map revealed a 3-way closure on the NW of the anticline. This closure is a new prospect that is yet to be tested. Similar new prospects are revealed on the SE andNW of the foot-wall block. Like the hydrocarbon accumulation within the rollover anticline, these new prospects are characterised by medium values of RMS amplitude and instantaneous frequency.

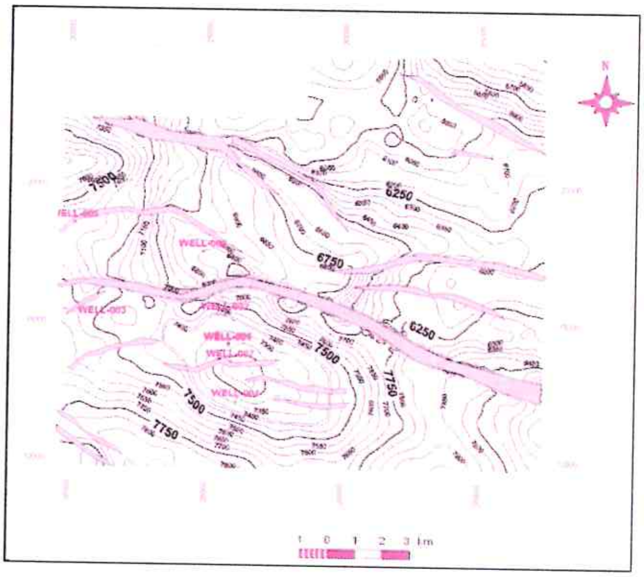

Fig. 23: Depth structure map for top of E1000 sand

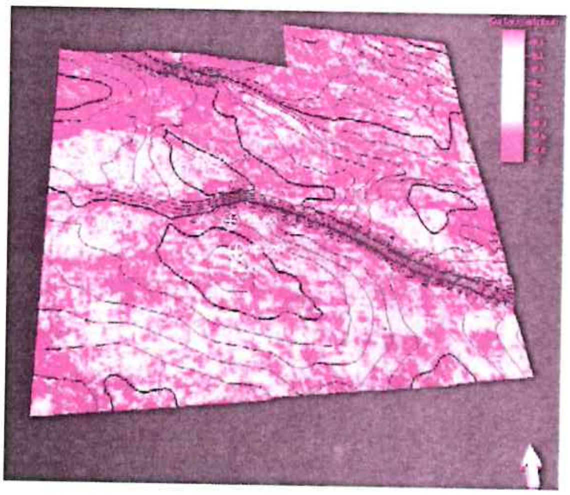

Fig.24: RMS amplitude variation along top of E1000 sand

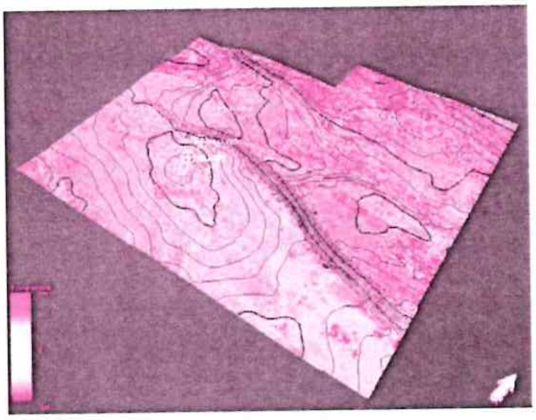

Fig.25: Instantaneous frequency variation along top-of E1000 sand

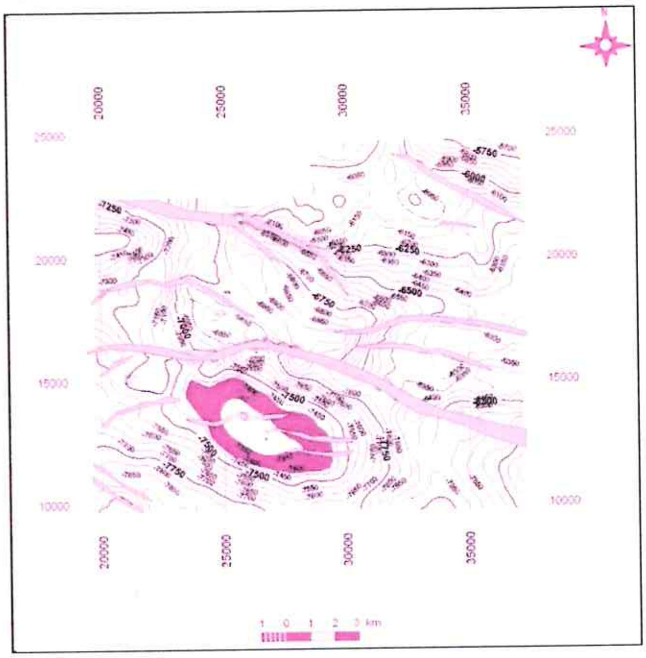

Fig.26: Areal extent of proven oil(red) and gas(green) and new structural prospects(yellow) along top of E1000 sand

Figures 27 and 28 display an unconformity surface below total depth for some of the wells. This surface is defined along the seismic horizon where discontinuous low amplitude reflection facies directly overlie continuous parallel medium to high amplitude reflections. Such a regional unconformity surface has the status of a sequence boundary(Hubbard *et al.*, 1985; Adejobi and Olayinka, 1997; Magbagbeola and Willis, 2007). Figure 29 is the depth structure map from mapping the seismic horizon on 3D seismic sections. Figures 30 and 31 are respectively the RMS amplitude and instantaneous frequency variation map along this surface. This surface is on the hanging wall block map of the field's major NW-SE trending fault (Fig. 29) while the delineated prospect along this surface is shown on Figure 32.

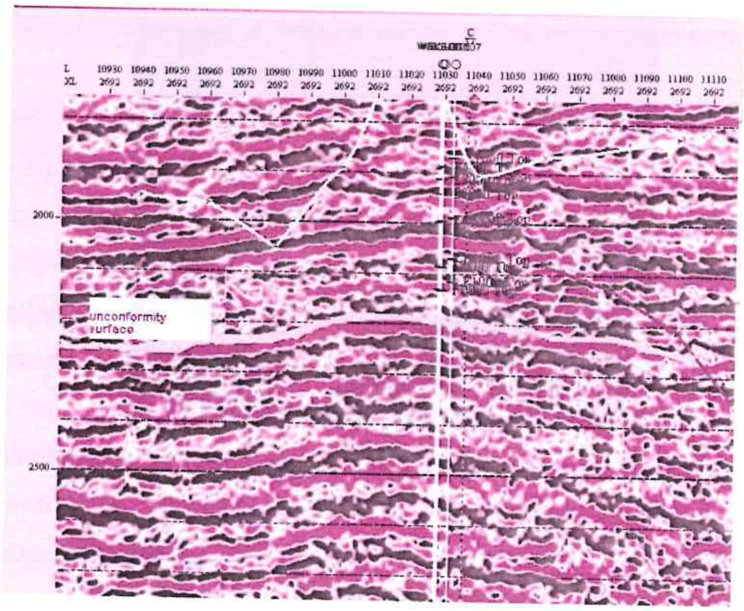

Fig.27 Unconformity surface beneath wells along XL2962

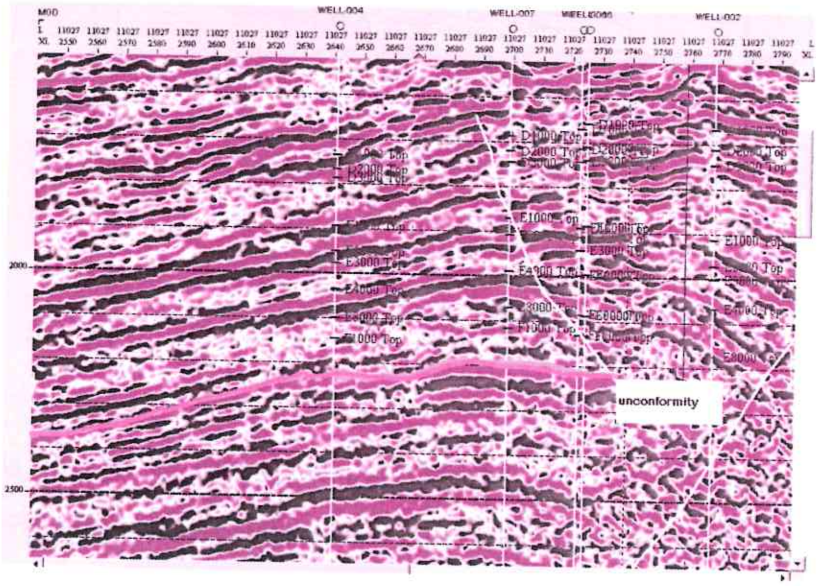

Fig.28: Unconformity surface beneath wells along L11027

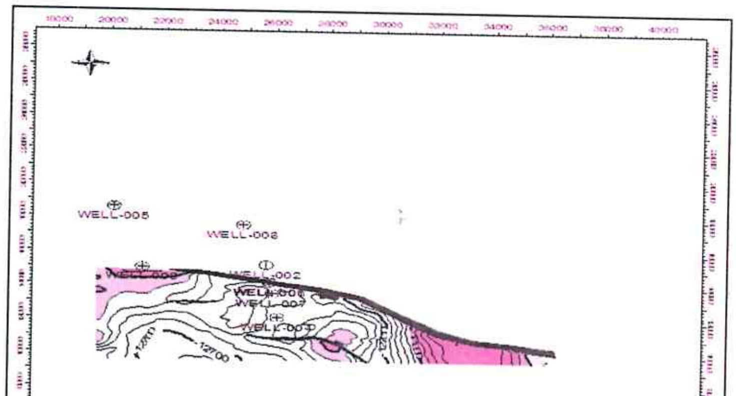

Fig. 29: Depth-structure map of deep unconformity surface beneath the wells

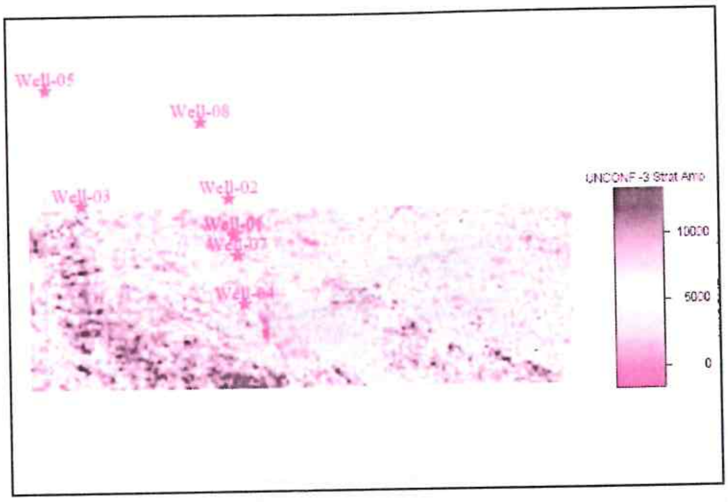

Fig.30: RMS amplitude variations along unconformity surface below well depths

Fig.31: Instantaneous frequency variations along unconformity surface below well depths

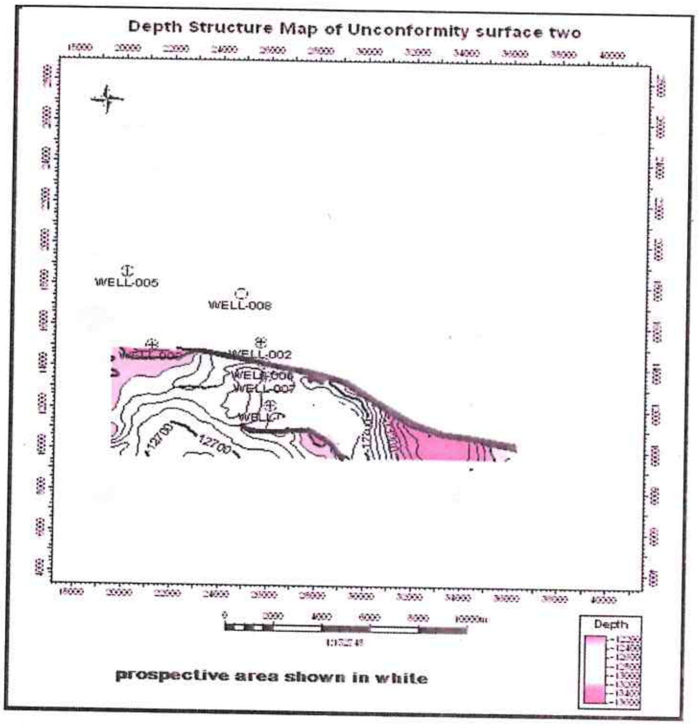

Fig.32: Stratigraphic prospects along unconformity surface below well depth

CONCLUDING REMARKS

The Afenmai Field is an old field originally discovered on the basis of the interpretation of 2D seismic data. In this study,known petroleum accumulations in the field were revealed to be characterised by medium values of RMS and instantaneous seismic attributes. Grouping the sands into systems tracts enabled unconformity related new plays to be identified along the top of Agbada Formation and below drilled total depth in wells 002, 003, 004, 006 and 007. New unconformity subtle traps were generated from depth structure and seismic attribute maps of these unconformity plays. Sand tops corresponding to top of LST, and TST are chronostatigraphic surfaces. New 3-way petroleum prospects were revealedwithin the footwall on the eastern part of E8000 sand's structure building fault.The E1000 sand contains petroleum in a rollover anticline on its hanging wall block. New 3-way closure prospects were also revealed one to the NW of this anticline and others within the SE and NW of the footwall block of the E1000 sands' structure building fault.The following procedure is recommended for identifying new petroleum plays and generating new prospects in an old petroleum field:

1. Known petroleum accumulations in an old field should be characterised using seismic attributes.
2. Sequence stratigraphic techniques should be employed to identify unconformity surfaces and classify the sands into LST, TST and HST systems tracts.
3. Depth structure and seismic attribute maps should be generated for the unconformity surfaces, sand top corresponding to top of LST and TST systems tracts. Similar maps should also be generated for sands within the upper section of HST and lower section of TST systems tracts.
4. New petroleum prospects should be identified as untested structural highs associated with seismic attributes that characterize petroleum accumulations in the old field.

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