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Research Article

BIOCHRONOLOGICAL CORRELATION AND STRUCTURAL INTERPRETATION OF 'X' AND 'Y' FIELDS, CENTRAL DEPOBELT, NIGER DELTA, NIGERIA

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Abstract

The objective of this paper is to present stratigraphical results in a new developing trend by using bio chronological datum/events in carrying out correlation of five wells belonging to the 'X' and 'Y' field in the Niger Delta. High impact biostratigraphic interpretation of the wells was undertaken utilizing events/biozones, wireline log motifs, maximum flooding surfaces as well as the absolute ages. These results were further correlated to the third order cycles in other to establish a regional sequence stratigraphic framework of the studied area. When the interpreted datum was employed in the correlation panel across the wells however, possible fault displacement was observed with varying thickness. The correlation of these five wells within the two fields along the strike direction showed that the juxtapositioning of wells - 'B', 'C'and'E' exhibited a distinctive fault throw with the following average displacements, thus wells -'BC' showed about 394m with well - 'B' on the up-thrown side relative to well - 'C'; wells - 'CA' - 415m with well - 'A' on the up-thrown side relative to well - 'C'; wells - 'AE' - 345m with well - 'E' on the down-thrown side relative to well - 'E'. Furthermore, well - 'D' which is situated in the up-dip section showed a high fault-throw value with wells - 'ED' - 413m average displacement relative to well - 'E'. As a result of this, it was further deduced that wells - 'C' and 'E' are on the down-thrown side relative to the correlative events and surfaces encountered in wells - 'A', 'B' and 'D'.

Keywords: Correlation, Biochronology, Sequence stratigraphy, Fault, Displacement, Depositional sequence, Central Depobeltand Niger Delta.

INTRODUCTION

The composite standard of correlation for the Niger Delta sediments has been largely built and utilized within the onshore and offshore environments. Therefore, both shallow and deep marine settings of the offshore correlation of turbidite packages and onshore setting rely specifically on a good biostratigraphic analysis. Correlating important surfaces (Sequence Boundary and Maximum Flooding Surfaces) with biostratigraphy (zones and absolute ages) is needed for control that places local observations into a basin-wide stratigraphic framework. A consistent biostratigraphic analysis makes it possible to build a sequence stratigraphic framework that explains known deposits and suggests undiscovered ones. The diachroneity sequences (Weimer 1990 and Udoh *et al.,* 2017) illustrate the need for a framework, founded on biostratigraphy/biofacies, and tied to log signatures and seismic resolution of wells for better results. Generally, each sectionanalysed are tied to achieve precise agreement between at least two of the three disciplines used (i.e. well log, palaeontology and seismic interpretations). Sequences are picked on individual well logs based on an interpretation of the relative sea- level signal for each particular location, correlated with biostratigraphy. Finzel *et al.* (2009)and Armentrout *et al .,* (2000) working in the Gulf of Mexico, which also typified the Niger Delta sedimentary environment, documented that biostratigraphic evaluation normally takes three types of biostratigraphic correlations datum namely; bio-events recognized by the first downhole occurrence (FDO) and last downhole occurrence (LDO) of chronostratigraphically significant species, maximum and minimum faunal abundance histograms or peaks and faunal discontinuities recognized by rapid changes in biofacies assemblages of fossil abundance and diversity. However, within the Niger Delta siliciclastic infill, sequence boundary peaks can come directly from well log interpretation of the key surfaces, aided by integration of paleobathymetric and biochronological information, which is associated with minimum gamma-ray and maximum spontaneous potential values correlated with a remarkable decease in the abundance foraminifera. Often, high gamma shales are used to pick genetic sequences (Galloway, 1989). These high gamma intervals are interpreted to represent very slow sedimentation. When sequences are below seismic resolution or occur within a seismically chaotic zone, well log interpretation and biofacies are the only tools that allow correlation with confidence. Detailed analysis of depositional cycles and seismic distribution within the Niger Delta begins with definition of depositional cycles boundaries. In the Tertiary offshore Niger Delta seismic profiles, depositional cycle boundaries are mostly clearly defined on seismic by moderate to high-amplitude and laterally continuous reflections Enikanselu and Omosuyi, (2003), such reflections are correlated to stratigraphic intervals rich in calcareous fossils, glauconitic materials and high total organic carbon. In the other hand Saller *et al.,* (2004)postulated that these sediments are interpreted to also correlate with the condensed sections associated with the maximum flooding surfaces of the highstands in sea level (i.e. the depth where maximum gamma-ray values correlate with a marked increase in abundance of foraminifera). Correlation of mapping datum across faults within the Niger Delta is achieved initially by matching

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seismic packaged with similar reflection character, however, this is difficult where faulting is coincident with facies boundaries resulting in-equivalent stratigraphic intervals having different reflection configurations and attributes across the faults (Finzel *et al.,* 2009 and Udoh *et al.,* 2016). Age significant bio-events provide chronostratigraphic control points that permit correlation between wells and a test of the seismic stratigraphically defined correlations within the Niger delta. However, changes in the application of biostratigraphy in the reservoir appraisal and development arena have greatly increased the impact and value of the discipline within the Niger Delta, giving it a central role in integrated reservoir description(Oyede *et al.,* 2005;McNeil et al.,1990and Udoh *et al.,* 2017). These changes include placing emphasis on local field-scale bioevents to erect a reservoir framework of time-slices through which reservoir heterogeneity can be modeled, and the application of biosteering to maximize reservoir penetration. High resolution biostratigraphy serves as template or engine block for sequence stratigraphic framework (Mangerud *et al.,* 1999). In addition, paleo-environmentally diagnostic benthonic microfacies are used to model the lateral continuity of intra-reservoir mudstones, in an attempt to understand their potential as baffles/barriers to fluid flow.

Field Location and Geological setting of Niger Delta

All the wells and log motifs used in this study were obtained from Nigerian Agip Oil Company Limited in Port Harcourt. The study area of these two fields ('X' and 'Y') occupied about 616.79 acres in the onshore Niger Delta. The Fields location and the respective well distances between the five study wells are shown in figure 1. These fields are pseudo-named 'X' and 'Y' based on signed confidentialities and is located within Latitude: 5^0 20'N, Longitude: $6^0$40'E.A total number of five wells were used in this study, of which four of these wells ('A', 'B', 'C' and 'E') belong to 'X' Field while well ('D') belongs to Field 'Y'.

The Niger Delta belt extends from the northwest offshore area to the southeast offshore and along a number of north-south trends in the area of Port Harcourt. This basin roughly corresponds to the transition between continental and oceanic crust and is within the axis of maximum sedimentary thickness. Oil and gas reserves in the Niger Delta basin occur mainly in sandstone reservoirs in Agbada Formation usually trapped in rollover anticlines associated with growth faults. (i.e., the largest oil volumes are contained in faulted anticlines, in which the fault may have been gas leakage paths thereby leaving oil in the traps while the largest gas volumes are found in hanging-wall closures and simple rollover). The Niger Delta basin hydrocarbon exploration and its related activities have been documented and explained by Chukwueke, (1997), Stacher, (1995), Doust and Omatsola, (1990), and Nwachukwu and Chukwurah, (1986) who showed that the distribution of petroleum is likely related to heterogeneity of source rock type (greater contribution from paralic sequences in the west) and segregation due to re-migration. Petters, (1984) and Weber and Daukoru, (1975) on the other hand also documented that hydrocarbons are distribution within the clay filled channels including ancient submarine canyon fills in the Miocene – Oligocene age of the western and eastern Niger Delta. This basin preserves a succession of sedimentary rock that contains reservoir, seal and potential source rocks. Weber and Daukoru, (1975) apart from proposing that the deeply buried shales of the Akata Formation as the main source rocks of the Delta, they also pointed out that the shallow hydrocarbon accumulations were as a result of long-range vertical migration of the crudes from the deep-seated source beds. Evamy *et al.* (1978) elucidated that the oil generating zone lies well above the Akata shales in the western Delta while it is mainly within the continuous shale sequence in the eastern part of the Delta. The role of diapiric structures in the migration and trapping of the hydrocarbons in reservoirs formed part of the work carried out by Merki, (1972). He also showed that the Benin Formation is hardly affected by the growth faults.

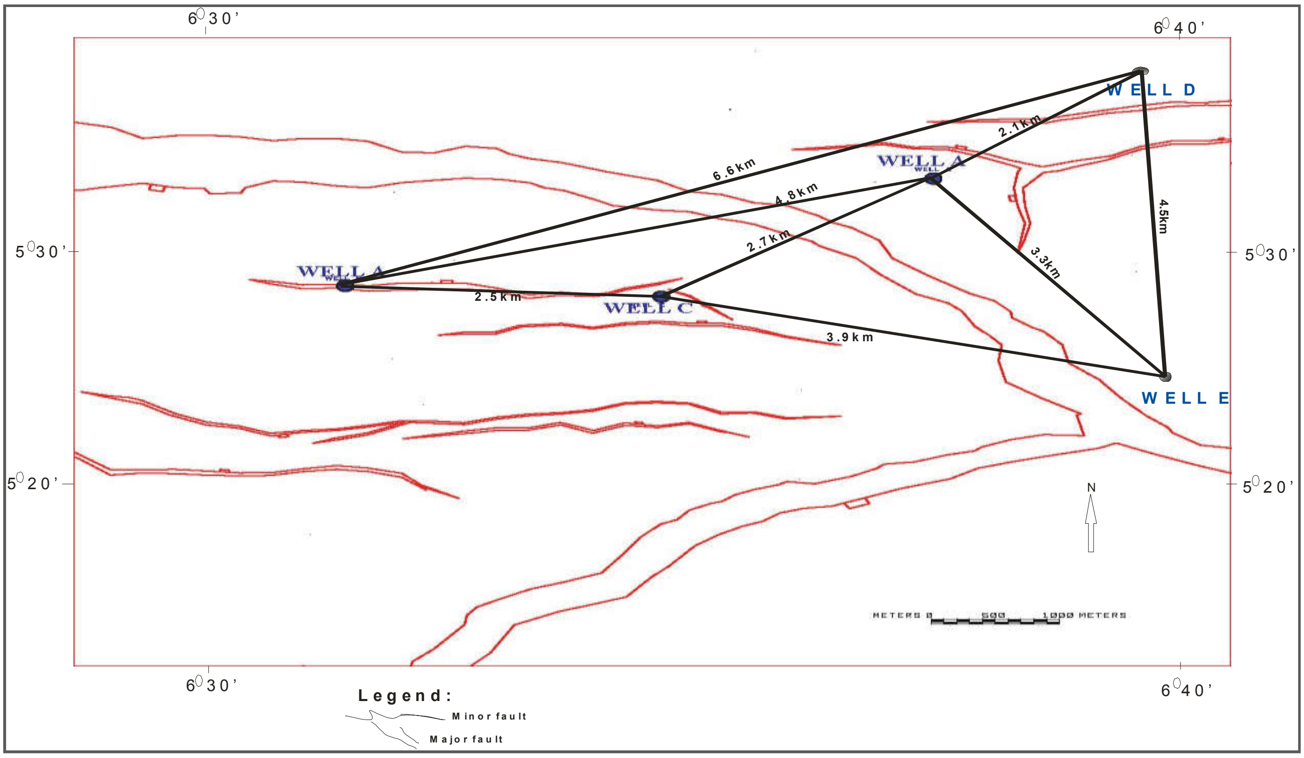

Fig.1. Wells location and their distances within the two Fields in the Central Niger Delta

Studies on aspects of geophysics of the Niger Delta have been variously carried out by Hosper, (1975), Onuoha, (1981) and several others which still showed the reliability of hydrocarbon within the Niger Delta. These hydrocarbon deposits are trapped in rollover anticlines associated with growth faults. In addition to these growth faults related structural and stratigraphic traps, there are paleo-channel fills, regional sand pinch-out and truncation occurrences. The gross reservoirs properties are a function of depth, sand/ shale percentage ratio and the sealing potential of faults, often providing lateral seals with faults, while the transgressive marine shales form important regional top seals. Due to the stacking pattern of the sand /shale alternations, most oil fields in the Niger Delta have multiple reservoir levels with oil column heights averaging between 15 to 50m. To the southeast, the top of the oil window is stratigraphically low (up to 400m below the upper Akata/lower Agbada sequence). Beka and Oti, (1995) suggested that the outer realm of the delta complex, deep sea channel sands, lowstand sand bodies, and proximal turbidites bodies create potential reservoirs while Clark *et al.,* (2000) related that reservoir quality in turbidites fans measured at higher porosity and permeability improves with increasing reservoir thickness. Burke, (1972) described three deep water fans that have been likely active through history and therefore suggested that these fans are smaller than those associated with other large deltas because much of the sand of the Niger-Benue system is deposited on top of the delta and buried along with proximal parts of the fans as the position of the successive depobelt moves seaward. In a similar development, mature Eocene to Miocene shales of the Akata Formations constitutes the major source rock. However, crude oil from Niger Delta originates mostly from land plant materials (Evamy *et al.,* 1978).

The influence of basement tectonics on the structural evolution of the Niger Delta was largely limited to movement along the Equatorial Atlantic Ocean fracture zones that later extended beyond or beneath the delta (Whiteman, 1982 and Weber and Daukuro, 1975). Growth faults, triggered by pen-contemporaneous deformation of deltaic sediments are the dominant structural features in the Niger Delta (Weber, 1987 and Hosper, 1975) and the same phenomenon has been documented by Su *et al.* 2011 and Crews *et al.* 2000 in the evolution of Bohai Bay, China and in the intraslope basins of the Northern Gulf of Mexico. They further suggested that fault linkage is a significant event in basin evolution, and its process may be very rapid, adding that fault linkage exerted considerable control on sedimentation and evolution of basins. In this same vein therefore, it has been further discovered that rapid sand deposition along the edge top of under-compacted clay of the Niger Delta has resulted in the development of a large number of syn-sedimentary gravitational faults. They are generated by rapid sedimentation load and the gravitational instability of the Agbada sediments pile accumulating on the mobile, uncompacted Akata shales. There is little or no growth faulting episode extending into the Benin Formation.

Toe thrusting at the delta front, lateral flow and extrusion of the Akata prodelta shales during growth faulting and related extension, also accounted for the diapiric structures on the continental slope of the Niger Delta in front of the prograding depocenter with paralic sediments. Khani and Back, 2012, Magbagbeola and Wills, (2007) and Adeogba *et al.,* (2005) confirmed that from the outer shelf to the slope (deep water setting) of the Niger Delta, the deformation is strictly characterized successively by (1) the zones undergoing extension, (2) zones undergoing only translation featured with shale ridges and diapirs and (3) zones that are affected by compression with imbricate toe-thrust structures beneath the lower slope and rise. Sediments within this environment are complicated by syn-depositional listric normal faults that formed as prograding deltaic sediment load underlying the under-compacted marine shales. The complexity of these structures is dependent on the overall sediment burden however, increased overburden and horizontal displacements makes accommodation to be more complex. Growth faults comprise of antithetic faults and the major structure building faults (some of which bound the depobelt) and steep, parallel crestal faults which cut the rollover structures (Fig. 2).

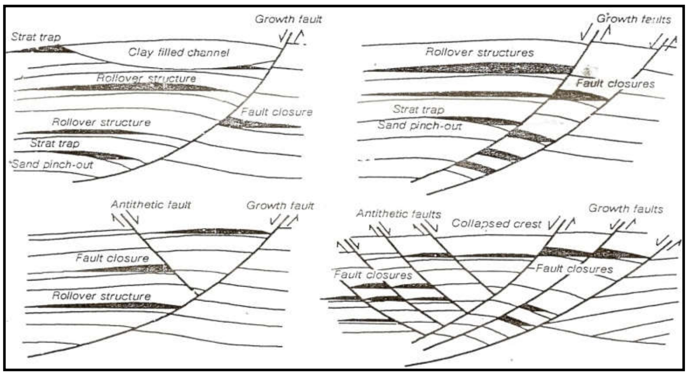

Fig. 2. Typical fault and trap structures of Niger Delta

These major growth faults which exhibit throws of several hundred meters are arcuate in plain view, concave basinward and are generally tens of kilometres in length while the antithetic faults that cut collapsed rollover anticline crests have throws generally less than 100m (330ft), can be linear or arcuate in plain view, and rarely exceed a few kilometres in length (Cathles *et al.,* 2003). Also associated with the structure building faults (SBF) are the rollover anticlinal structures. Growth faults and related rollover structures are the dominant hydrocarbon traps in the Niger Delta and these have been recognized as a controlling factor in fluid distribution within fields in the delta (Tegbe and Akaegbobi, 2000). This is similar to structures in the First Wilcox Sandstone, Livingston field in Louisiana (Johnston and Johnson, 1987) and in the Mississippi fan sediments of the Gulf of Mexico (Weimer, 1990). The complexity of the structures is dependent on the overall sediments burden in the initial phase of the growth faulting while displacement only occurs along the major bounding faults; with increased overburden and horizontal displacement, accommodation becomes more complex and finally occurs along numerous small faults which form the typical collapsed crest structures. Aspect of computer simulation of basin fill is used increasingly in the Niger Delta sedimentary basin analysis both as a tool for attempting to stimulate known geometries within the basin and to predict the stratigraphic and facies distributions in poorly constrained areas. Modeling packages have been developed at a variety of scales to suite a range of purposes from stimulation of the entire basins fill to replicating growth patterns of small sand-body distribution in a submarine fan. Three-dimensional (3-D) models provide insights into the distribution, the external and internal geometry of sedimentary deposits, and the sedimentologic processes that generated reservoir intervals. The structural highs and general structural trend had a significant impact on the distribution and orientation of the complexes deposited. This depositional pattern and connectivity analysis may suggest an overall aggradation of shallow-marine deposits during pulses of relative sea level rise followed by deepening setting (Posamentier *et al.,* 1988).

Snedden *et al.,* 1994 have shown that in recent years, geo-statistical and stochastic methods of modeling have been introduced and applied in characterizing reservoirs within the Niger Delta basin; combined with neural network modeling to predict lithofacies curves from well logs, however, stochastic simulations provide an opportunity to model the internal external, geometry and spatial distribution of the Niger Delta sedimentary reservoirs in 3-Ddimensions. The distribution of internal properties and heterogeneity of this reservoir can be quantitatively described as the relationship of a reservoir body (flow unit) to a sediment body (facies unit) within a sequence-stratigraphic framework. Improved facies distribution of the Niger delta deposits provides a better understanding of the controls on geometry and distribution of the reservoirs, and the spatial distribution, continuity, and connectivity of flow units within the deposits.

MATERIALS AND METHODS

Biostratigraphic Analysis

The different taxa (foraminifera and associated macrofauna) recovered during the picking exercise were grouped into their respective genus and species, (where possible) and were mounted temporarily by the use of gum in the micropaleontological slide cavity. Micropaleontological cover slips were used in covering the slide to avoid spillage and were arranged serially according to their depth in a slide tray for analysis.

Sequence Stratigraphy

The following approach was employed in the sequence stratigraphic analysis and interpretation. However, the integration of biostratigraphic/biofacies (where available), sedimentologic attributes and wireline log data sets allowed for:

(a) The identification and chronostratigraphic dating (where possible) of all the key stratigraphic surfaces amongst; transgressive surface (TS), sequence boundary (SB) and maximum flooding surface (MFS). The ability to recognize these key surfaces helps to unravel the stacking pattern thereby giving a clue in the understanding and interpretation of the sequence stratigraphic framework of the environment. (b) With the observed wireline logs and biofacies, respective systems tracts were correctly delineated. (b) Depositional environments were defined using logs signatures and biostratigraphic data sets. (c) The sequence stratigraphic summary and foraminiferal distribution charts were generated using StrataBug and Corel softwares respectively. However, the sequence stratigraphic analysis was carried out independently as a first step from biofacies and log data sets, and results were subsequently compared and integrated. Well logs interpretation involved detailed subdivision of the successions into the constituent parasequences types and parasequences sets, from which lateral facies changes and the creation of accommodation space with changes in relative sea level were interpreted. These models therefore explain the types and distribution of reservoir sand body within the individual systems tracts, which have been applied reliably in this interpretation.

Correlation

Correlation of the sand geometries was carried out in this study in otherto determine stratigraphic units (sand packages) that may be equivalent in time, age and stratigraphic position thereby bringing to bear the visualization of all possible structures within the respective fields. It involves pattern recognition on well logs and matching of such pattern of curves from one to another. Accurate correlation provides subsurface information such as lithology, reservoirs thickness, formation tops and bases, porosity and permeability of the production zones. This exercise in this study serves as excellent aids in determining the lateral continuity of reservoir sand bodies within the study area. Good sand units were looked out for while utilizing the gamma ray and Deep Induction resistivity logs suites from the five wells provided. However, Gamma ray log signatures were preferred in this exercise and were given adequate attention for the correlation of all the wells within this study area. A datum was taken across the five wells while the shale and sand were accordingly marched with the Gamma ray log signatures

RESULTS AND DISCUSSION

Correlation, Structural and Chronostratigraphic framework

Correlation of all the key chronostratigraphic horizons within the fields (‘X’ and ‘Y’) was based on biostratigraphic/biofacies and sequence stratigraphic datasets from the five analyzed onshore wells as well as, well log interpretation of flooding surfaces and unconformities bounding large scale successions of the onshore area. For the fact that they were abundant biofacies; and well log data were excessively helpful in these wells, therefore identification and correlation of all the key surfaces have been a success. Using the sequence stratigraphic interpretation techniques of Herna´ndez-Mendoza *et al.,* 2008 and Van Wagoner *et al.,* (1990), a total of forty-four key surfaces (twenty maximum flooding surfaces and twenty-four sequence boundaries (although varied in the respective wells) were identified and correlated (from the above number, seven inferred major maximum flooding surfaces and eight sequence boundaries were observed in wells - ‘C’ and ‘A’) throughout the five wells (Table 1). These key surfaces extend from Late Eocene unconformity to Late Oligocene age. In addition to using paleontological data to locate stage boundaries, identification of large scale stratal stacking patterns to discern major depositional cycles between stage boundaries and thus dividing the respective ages into regionally traceable units was equally carried out. These depositional cycles occur as large scale, upward-fining and upward-coarsening successions respectively. The thickest intervals or section occurs in the expanded zone of the western part of the section while the thinnest section is observed in the eastern part of the study area.Apparently, the study within these wells are focused on reflection ranges between 1863 – 3014 milliseconds (i.e., 1.9 – 3.0secs TWT) coincident with an inference based regional studies to be from the Agbada Formation (Adegbenga *et al.,* 2003). The encountered interval within this study is calculated to be approximately 3.0km (Table 2).

Table 1. Chronostratigraphic surfaces encountered in all the wells in this study

Wells	'A'		'B'		'C'		'D'		'E'	
Key Surfaces (Ma)	MFS	SB	MFS	SB	MFS	SB	MFS	SB	MFS	SB
1.	28.1	27.3	28.1	27.3	28.1	29.3	26.2	24.9	28.1	27.3
2.	31.3	29.3	31.3	29.3	31.3	32.4	28.1	27.3	31.3	29.3
3.	33.0	32.4	33.0	32.4	33.0	33.3	31.3	29.3	33.0	32.4
4.	-	33.3	34.0	33.3	34.0	35.4	33.0	32.4	34.0	33.3
5.	-	-	-	35.4	-	-	34.0	33.3	-	35.4
6.	-	-	-	-	-	-	-	35.4	-	-

Table 2. Conversion of depth (m) to time (millisecs.) for all the Key candidate surfaces (MFS and SB) in wells - 'B', 'D', 'E', 'C' and 'A'.

Age	Wells	'B'		'D'		'E'		'C'		'A'	
	Key Dated Surfaces (Ma)	**Depth (m)**	**Time (millsecs)**	**Depth (m)**	**Time (millsecs)**	**Depth (m)**	**Time (millsecs)**	**Depth (m)**	**Time (millsecs)**	**Depth (m)**	**Time (millsecs)**
	SB_6 (24.9)	-	-	2215	1888	-	-	-	-	-	-
Late Oligocene	MFS (26.2)	-	-	2280	1930	-	-	-	-	-	
	SB_5 (27.3)	2180	1862	2325	1944	2280	1914	-	-	-	-
	MFS (28.1)	2558	2092	2488	2062	2810	2266	2500	2062	-	-
	SB_4 (29.3)	2685	2194	2875	2308	3120	2452	2645	2164	2170	1862
Middle Oligocene	MFS (31.3)	2940	2352	2920	2338	3200	2510	2930	2338	2470	2048
	SB_3(32.4)	3240	2524	3115	2452	3280	2554	3050	2424	2600	2136
	MFS (33.0)	3390	2626	3190	2496	3560	2728	3330	2410	2850	2294
Early Oligocene	SB_2(33.3)	3630	2768	3300	2568	3960	2926	3520	2704	3160	2482
	MFS (34.0)	3740	2830	3496	2686	4050	2970	3700	2806	3340	2582
Late Eocene/E. Oligocene	SB_1(35.4)	3870	2852	3710	2806	4140	3014	3980	2948	3470	2656

This section of the study presents two different aspects, that is, the stratigraphic and structural correlation (Figures. 3a & b) of all the five wells ('A', 'B', 'C', 'D' and 'E') undertaken from the two fields ('X' and 'Y'). The tools used in this investigation include biostratigraphic events/biozones, wireline (Gamma ray/Deep induction Resistivity) log motifs, Maximum flooding surfaces as well as their absolute ages. Correlation was carried out within these wells along the strike and dip directions since they are all located in the same macrostructure. The correlation of these five wells within the two field blocks along the strike direction showed that the juxtapositioning of wells - 'B', 'C', and 'E' exhibited a distinctive fault throw. The following average displacements were observed, wells -'BC' - 394m with well - 'B' on the up-thrown side relative to well - 'C'; wells - 'CA' - 415m with well - 'A' on the up-thrown side relative to well - 'C' while wells - 'AE' - 345m with well - 'E' on the down-thrown side relative to well - 'E'. Furthermore, well - 'D' which is situated in the up-dip section showed a high fault-throw value with wells - 'ED' therefore possess an average displacement of 413m relative to well - 'E'. As a result of this, it was further deduced that wells - 'C' and 'E' are on the down-thrown side relative to the correlative events and surfaces encountered in wells - 'A', 'B' and 'D' respectively.

Below are the respective correlation templates of the wells in this study in both strike and dip directions.

Deductions from Correlation of wells ′B′ – ′C′ - 'E' along the strike direction

The most reliable stratigraphically datum encountered within this strike section was the First Downhole Occurrence (FDO) of *Chiloguembelina cubensis* and/or *Globorotalia opima opima* dated 28.1/Ch*1Ma, Acme of *Spiroplectammina wrightii* dated 31.3/Ru*2Ma, Last Downhole Occurrence (LDO) of *Spiroplectammina wrightii* dated 33.0/Ru*1Ma and the LDO of *Hopkinsina bononensis* dated 34.0/Ru*1Ma. These regional shalemarkers was delineated from well - 'B' at 2246m, 3222m, 3602m and 3740m and were integrated with wireline log signatures (Gamma ray/Deep Induction Resistivity). However, this information was therefore conspicuously extrapolated across well - 'C' at 2470m, 2850m, 3325m and 3700m; and well-'E' at 2810m, 3200m, 3560m and 4050m respectively (Figs. 4a & b). Conversely, wells - 'C' and 'E' also show similar datum as mentioned above at their respective depths. The stratigraphic positions as well as log signatures were relied upon in inferring all the MFS's in these wells. The 34.0/Ru*1Ma MFS, delineated at 3740m in well-'B' was probably encountered in a little shallower depth of 3700m in well - 'C' (that is, well - 'C' is on the down-thrown side of well - 'B'). This correlation further showed that well 'B' had an average displacement of about 394m relative to well - 'C' which is on the down-thrown; while well - 'C' showed an average displacement of about 400m on the up-thrown side relative to well - 'E' respectively.

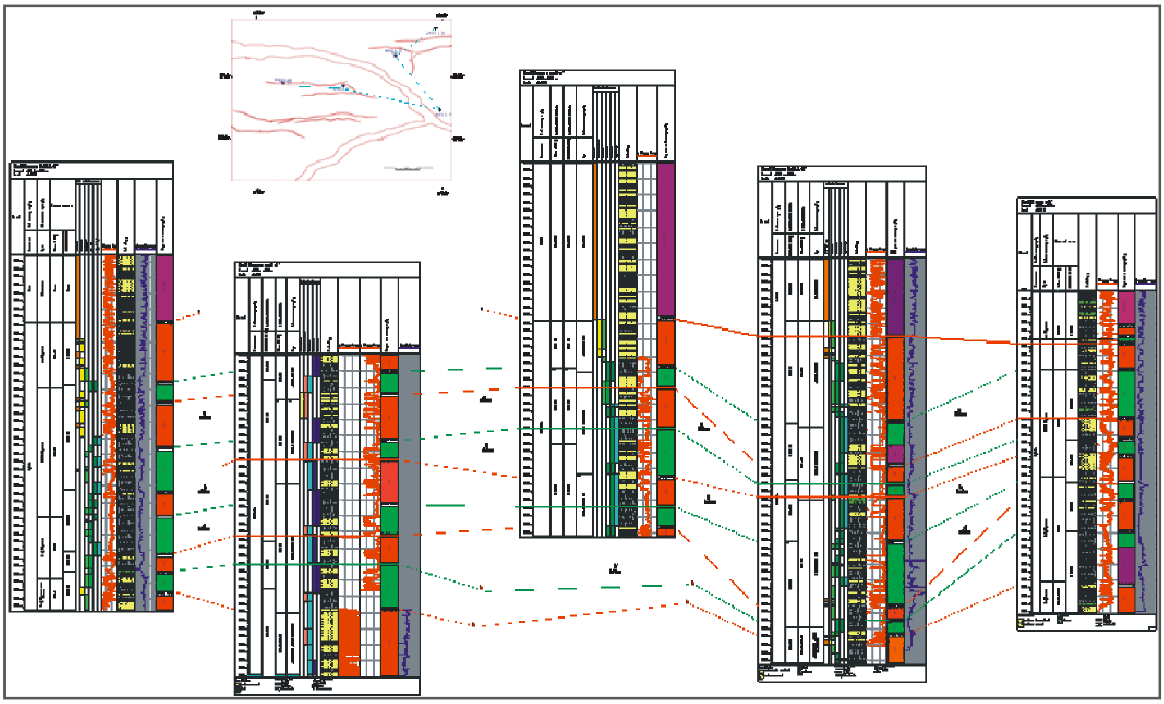

Fig. 3a Stratigraphic Correlation for wells 'B', 'C', 'A', 'E' and 'D'

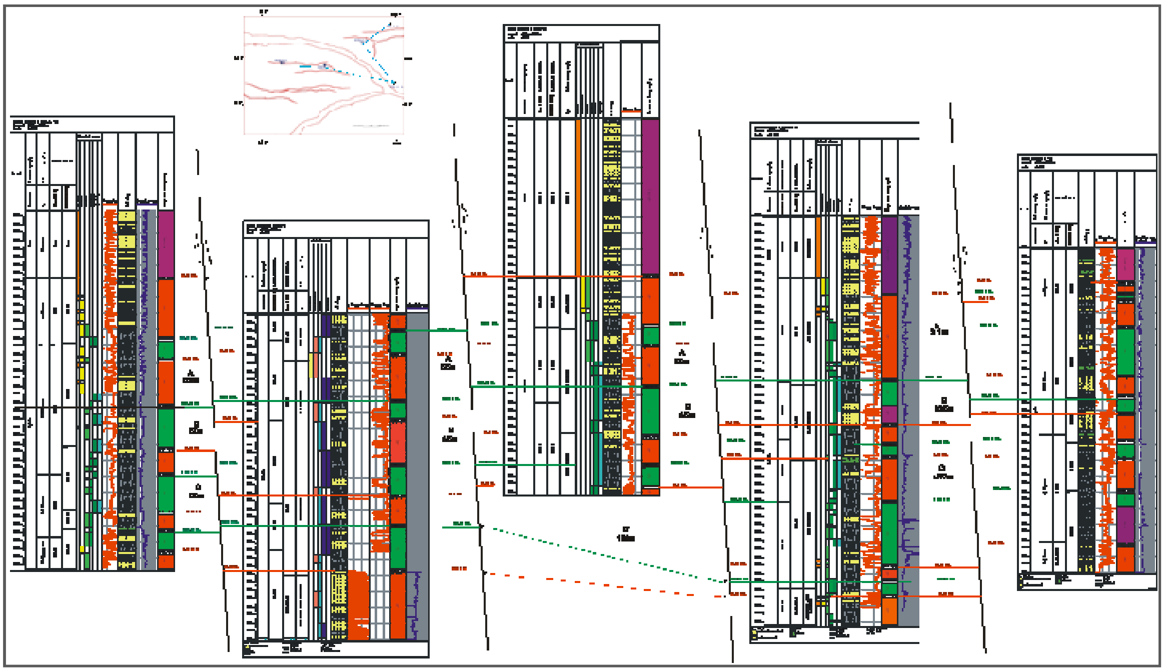

Fig. 3b Fault correlation for wells - 'B', 'C', 'A', 'E' and 'D'

Observation made from the interpretation on the seismic sections utilizing time – depth conversion in other to achieve the time equivalent of the surfaces (see Table 2 above) for each of the wells ranges are as follows; wells - 'B' and 'C' (2.1 – 2.8secs.), well - 'A' (2.0 – 2.6secs.), well - 'D' (1.9 – 2.7secs.) and well - 'E' (2.3 – 3.0secs.) respectively.

Correlation of wells along the dip direction

(i) Deductions from wells - 'C' – 'A' – 'D':

It was observed that the correlation of wells - 'C' - 'A' - 'D' along the dip direction in this study encountered the following datum, FDO of *Globorotalia opima opima* (28.1/Ch*1Ma), inferred stratigraphic position(31.3/Ru*2Ma), LDO of *Spiroplectammina wrightii* (33.0/Ru*1Ma)and LDO of *Hopkinsina bononensis* (34.0/Ru*1Ma), this formed the basis of this correlation as well as their associated Gamma ray/Deep Induction Resistivity log signatures. These bioevents were delineated at well 'C' at 2500m, 2930m, 3330m and 3700m; well 'A' at 2470m, 2850m and 3340m and well - 'D' at 2280m, 2488m, 2920m, 3190m and 3496m respectively. Wells - 'C' – 'A' could not attest the undefined ?26.2/Ch*2Ma MFS bioevent as recorded in well - 'D'. Moreover, the inferred 34.0Ma datum (LDO of *Hopkinsina bononensis)* was not encountered in well - 'A' (Figures 5a & b) therefore, this shows that well 'A' is in the up-thrown block while wells - 'C' and 'D' are on the down-thrown side relative to it. An average displacement of about 400m was observed between wells - 'A' – 'C' while wells - 'A' - 'D' showed about 435m with an

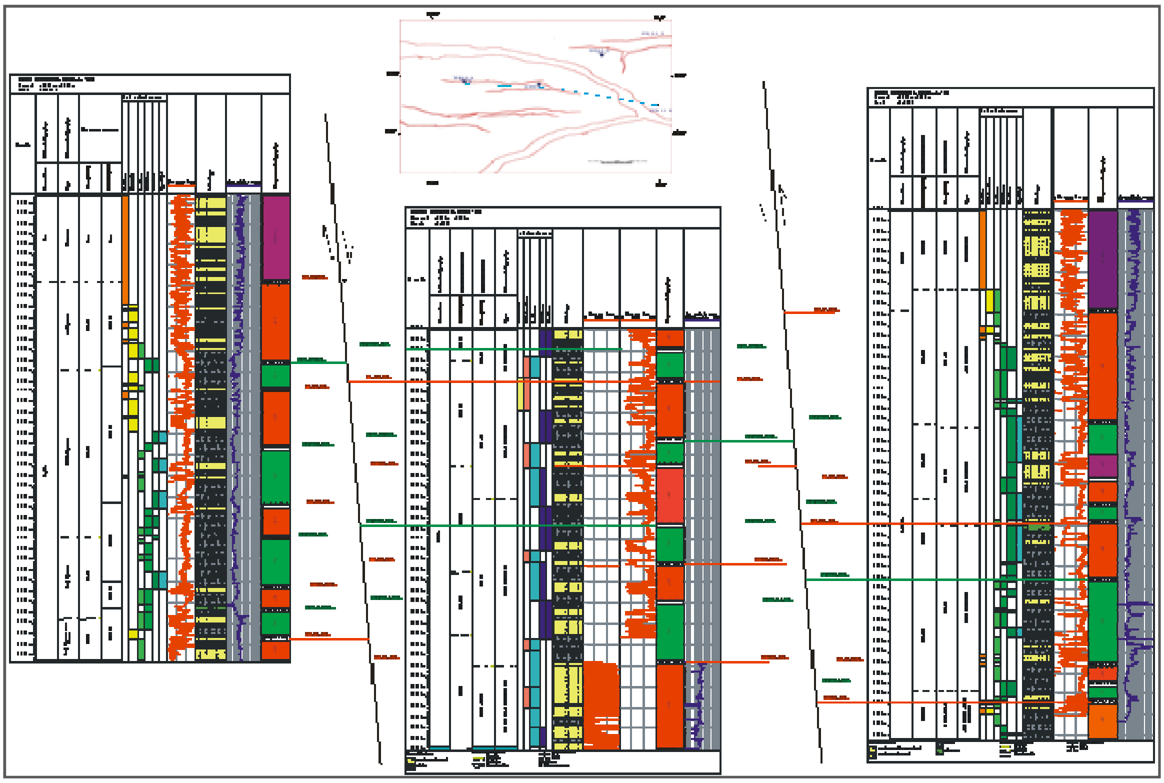

Fig. 4a. Structural correlation along strike section with wells - 'B', 'C' and 'E

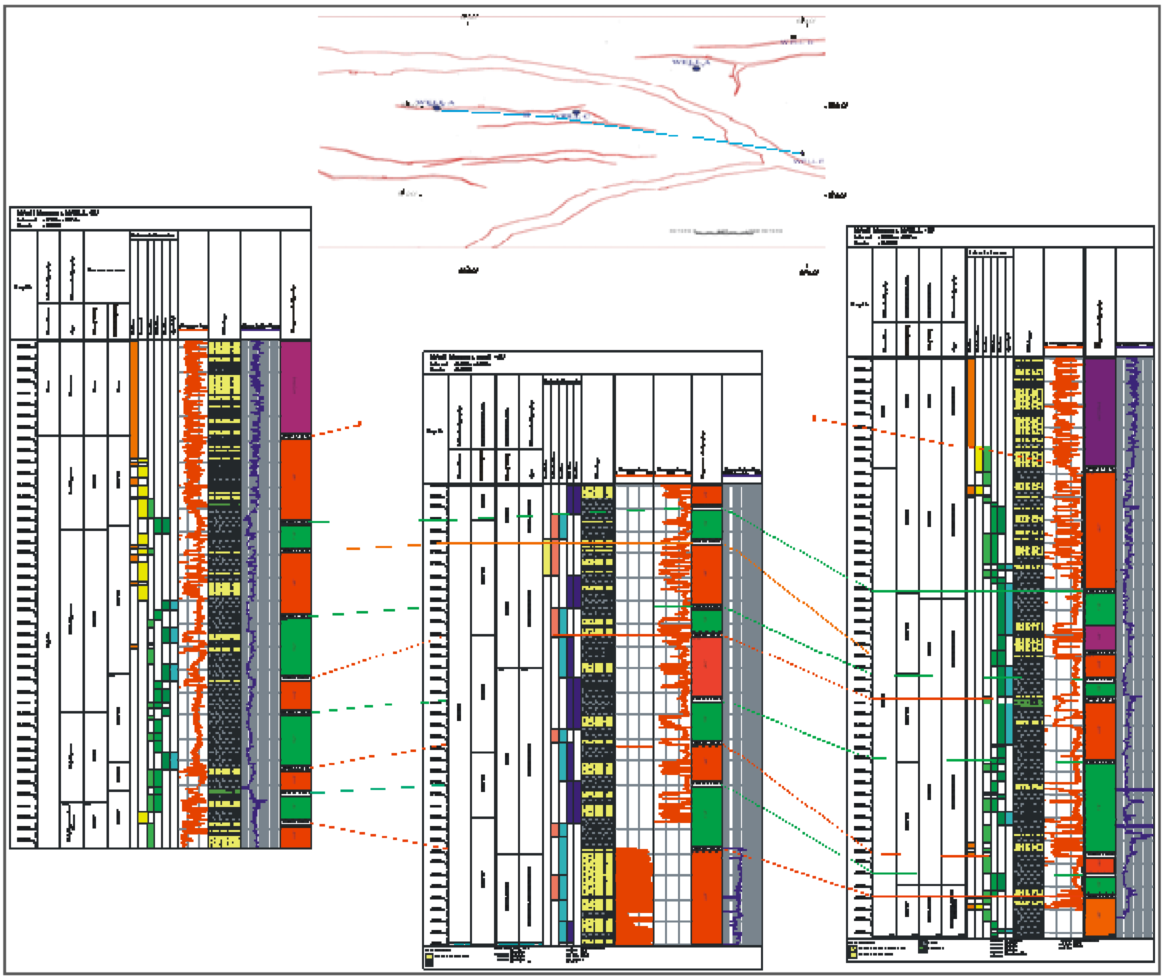

Fig. 4b. Stratigraphic correlation along strike section with wells - 'B', 'C' and 'E'

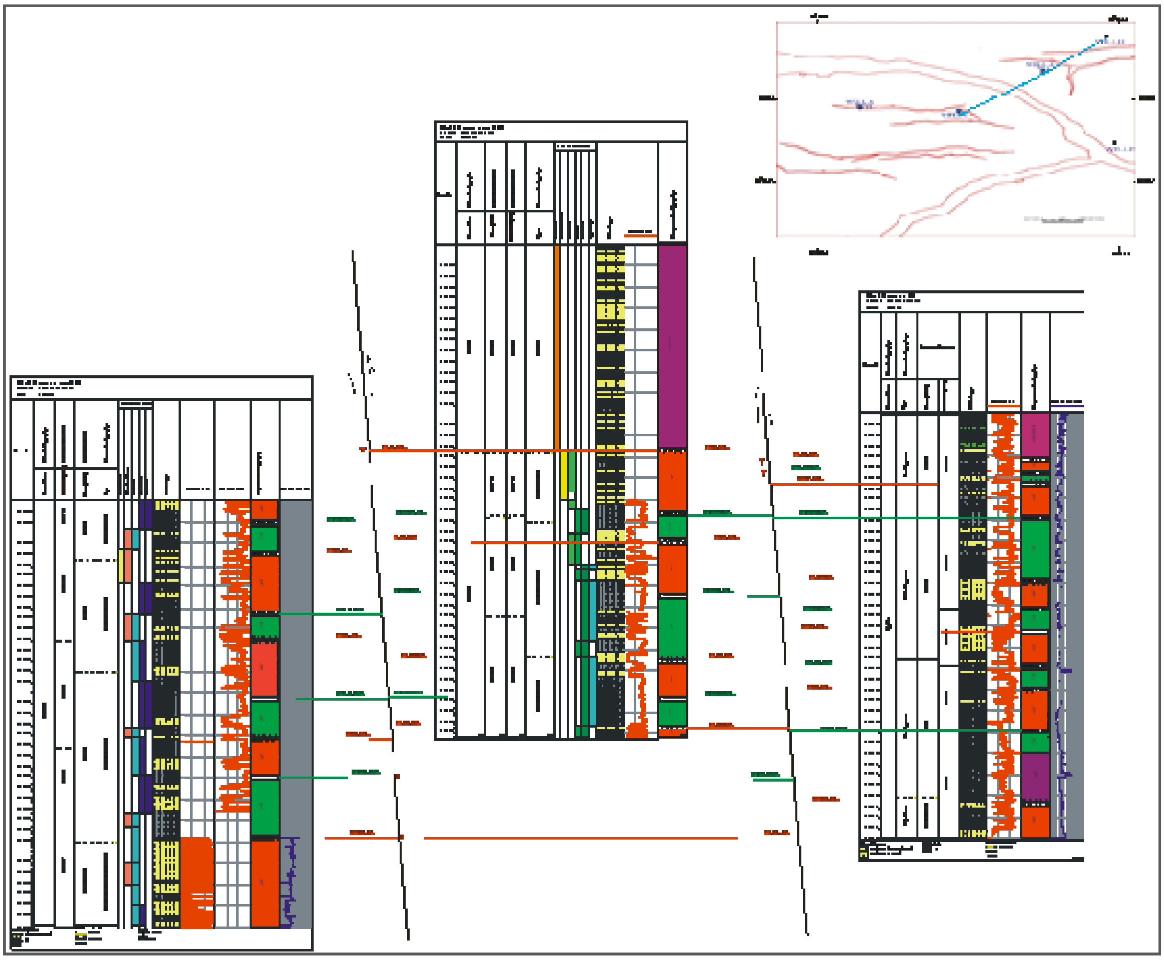

Fig. 5a Fault correlation along dip section with wells - 'C' - 'A' – 'D'

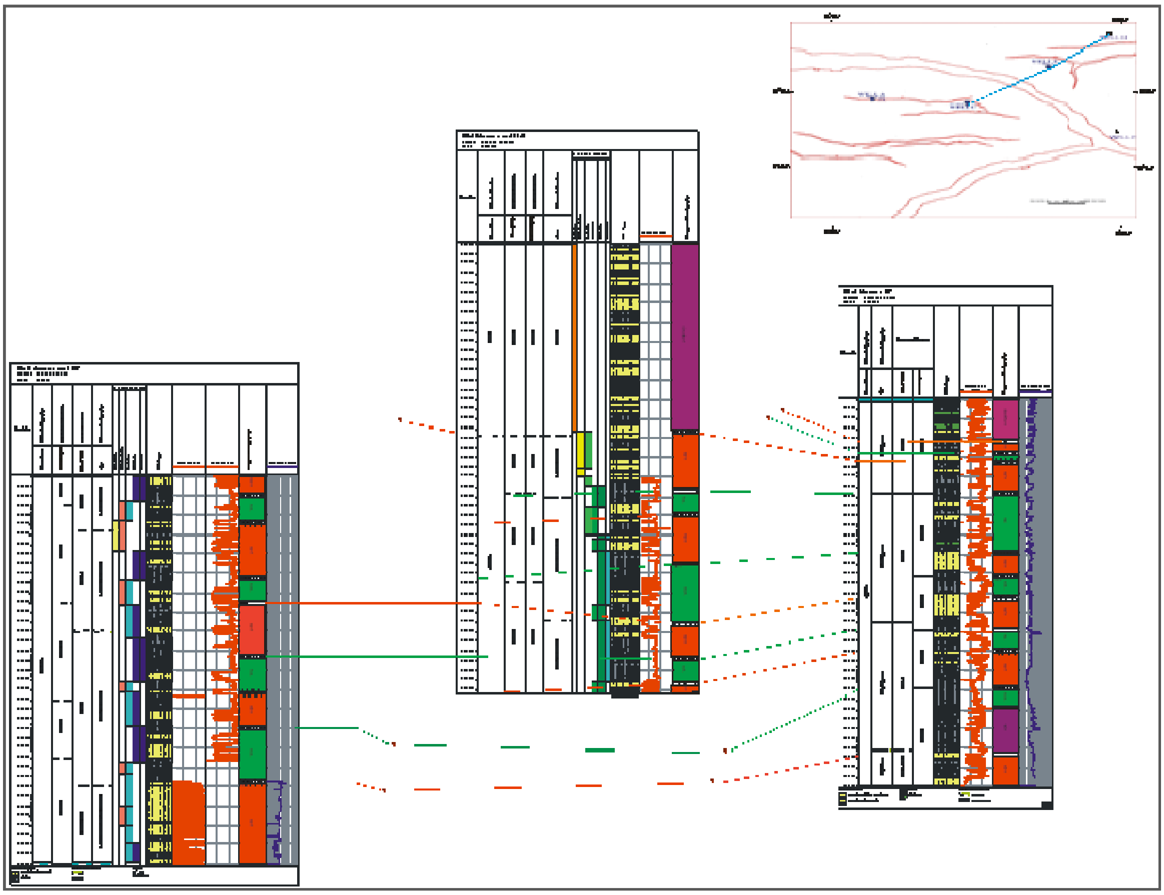

Fig. 5b Stratigraphic correlation along dip section with wells - 'C' - 'A' – 'D'

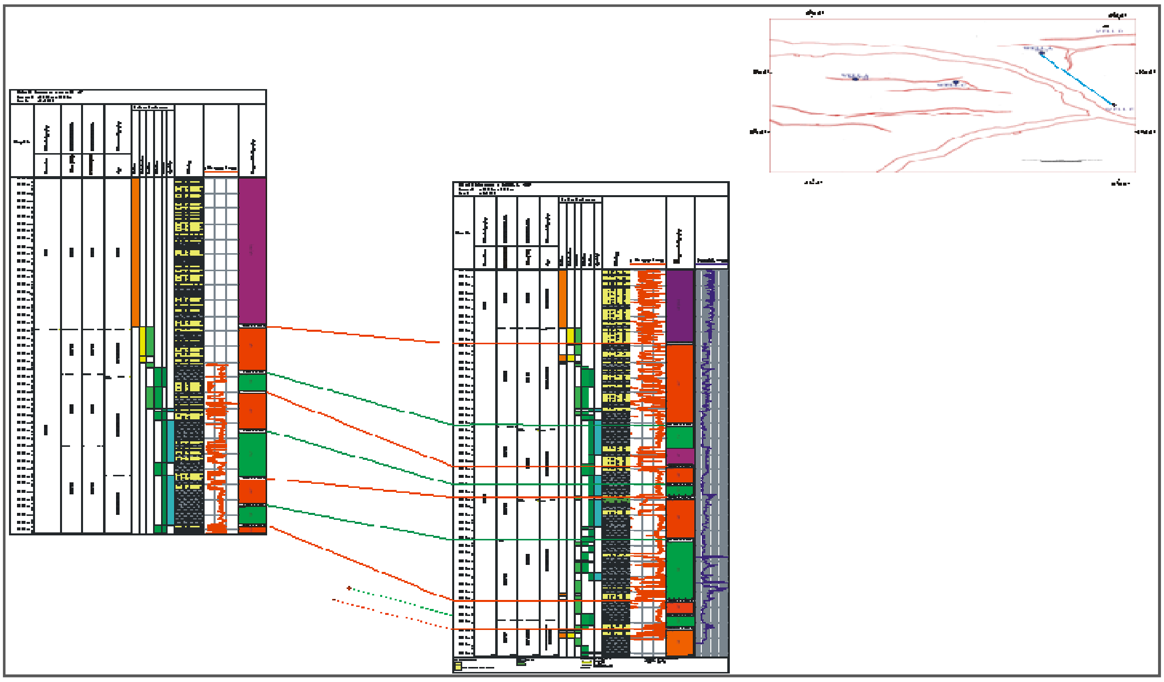

Fig. 6a Stratigraphic correlation along dip section with wells - 'A' – 'E'

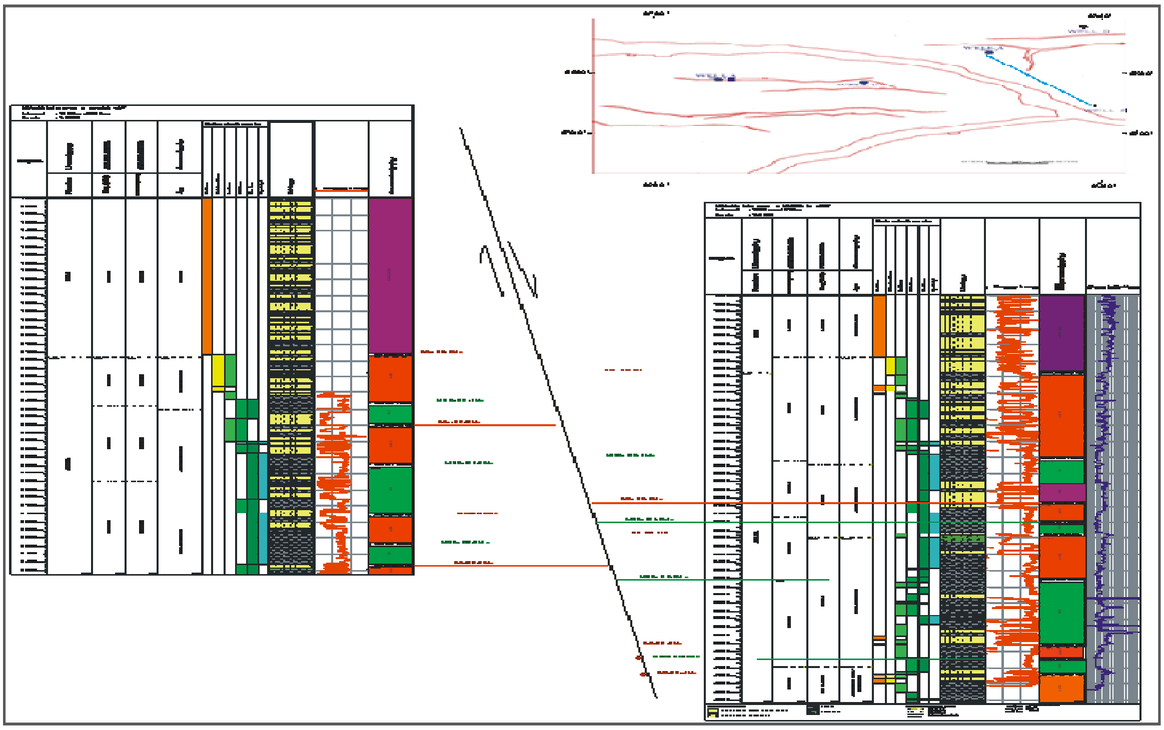

Fig. 6b Fault correlation along dip section with wells - 'A' – 'E'

approximate average displacement of 370m between wells - 'C' – 'D' at a deeper section beyond the total depth (3500m) of well - 'A'. The time equivalent of these datum deduced on the seismic section and as shown on Table 2 are, well - 'C' (2.1 – 2.8secs), well - 'A' (2.1 – 2.6secs) and well - 'D' (1.9 – 2.7secs) respectively.

(ii) Deductions from wells 'A' – 'E', 'D' - 'E' and 'B' – 'A' – 'D':

The most reliable datum encountered in this section ('A' – 'E') was the inferred bioevents datum of the FDO of *Chiloguembelina cubensis* (28.1/Ch*1Ma), Influx of *Uvigerinellasparsicostata* (31.3Ru*2Ma), LDO of *Spiroplectammina wrightii* (33.0/Ru*1Ma) which was delineated in the two wells at 2470m, 2850m and 3340m (well - 'A') and 2810m, 3200m, 3560m and 6960m (well - 'E') respectively. It was further observed that the 34.0/Ru*1Ma MFS (LDO of *Hopkinsina bononensis*) bioevent encountered at 4050m in well - 'E' was not observed in well - 'A' (Figs. 6a & b). Based on this scenario, inference could be drawn that well - 'A' is situated on the upthrown block relative to well - 'E' with an average displacement of about 435m. This is indicated on the seismic section reduction Table 2 and was found to occur between the ranges 2.1 – 2.6secs in well - 'A' and 2.3 – 3.0secs in well - 'E' respectively. Conversely, the dip section of wells - 'D' – 'E' observed almost the same bioevents datum as in wells - 'E' – 'A'.

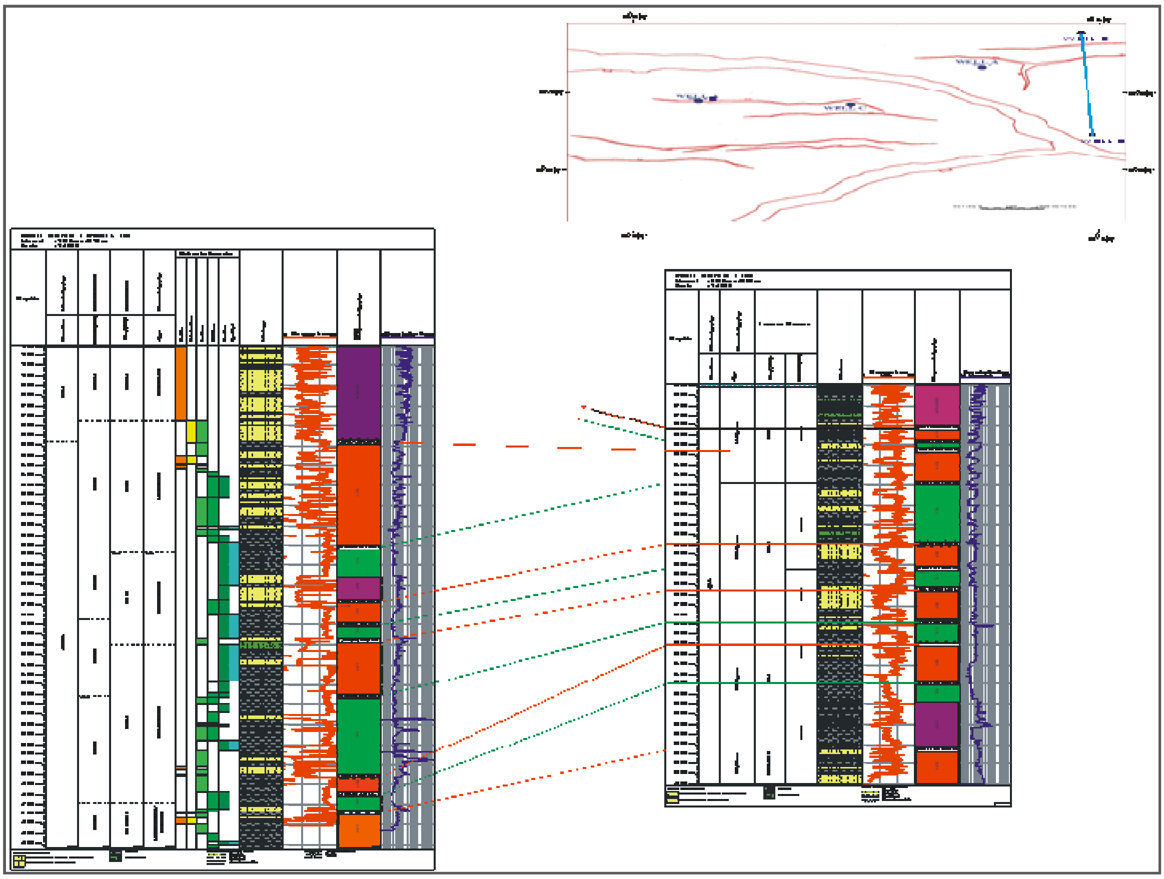

Fig. 7a Stratigraphic Correlation along dip section with wells - 'D' – 'E'

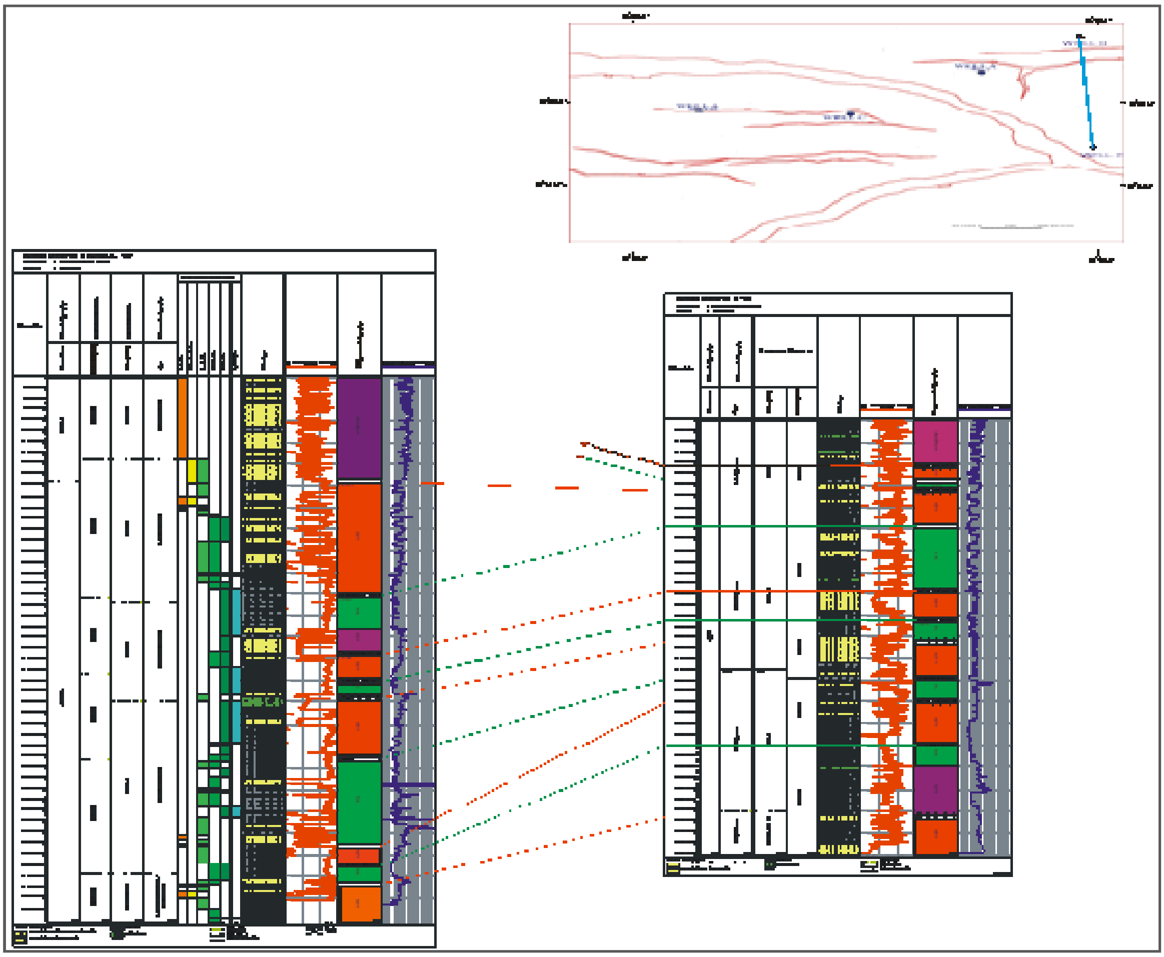

Fig. 7b Fault correlation along dip section with wells - 'D' – 'E'

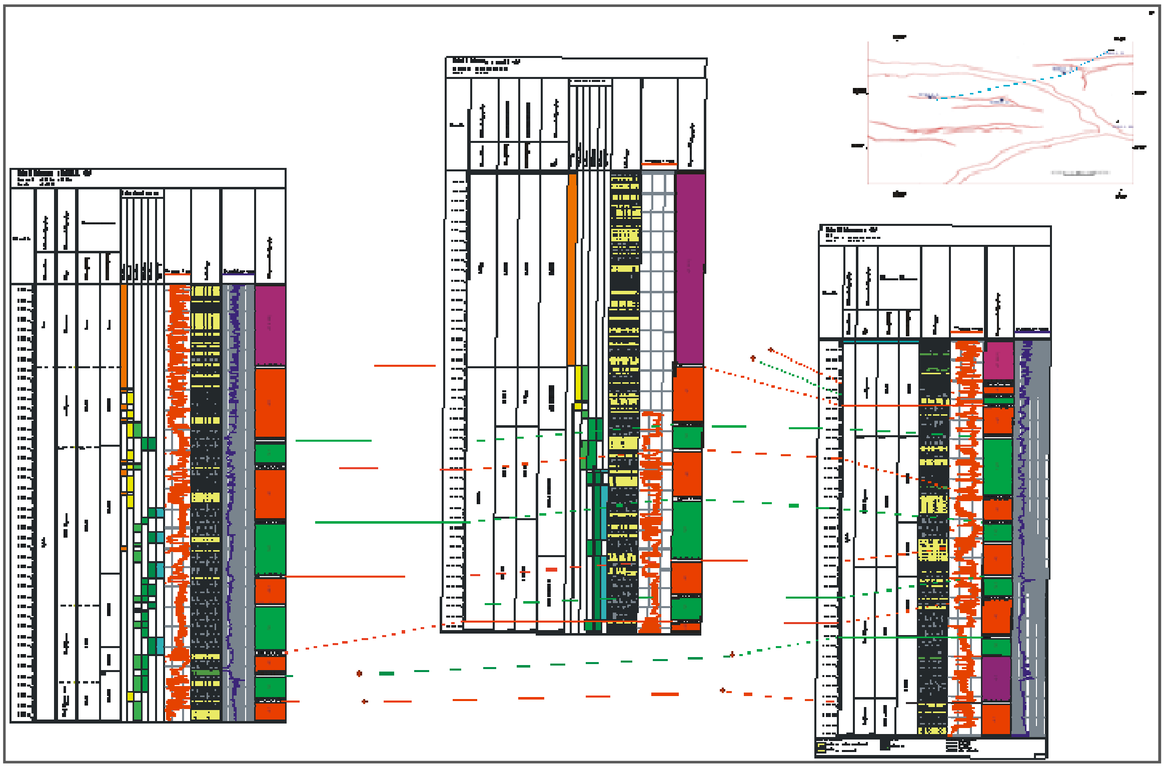

Fig. 8a. Stratigraphic correlation along dip section with wells - 'B' – 'A' –'D'

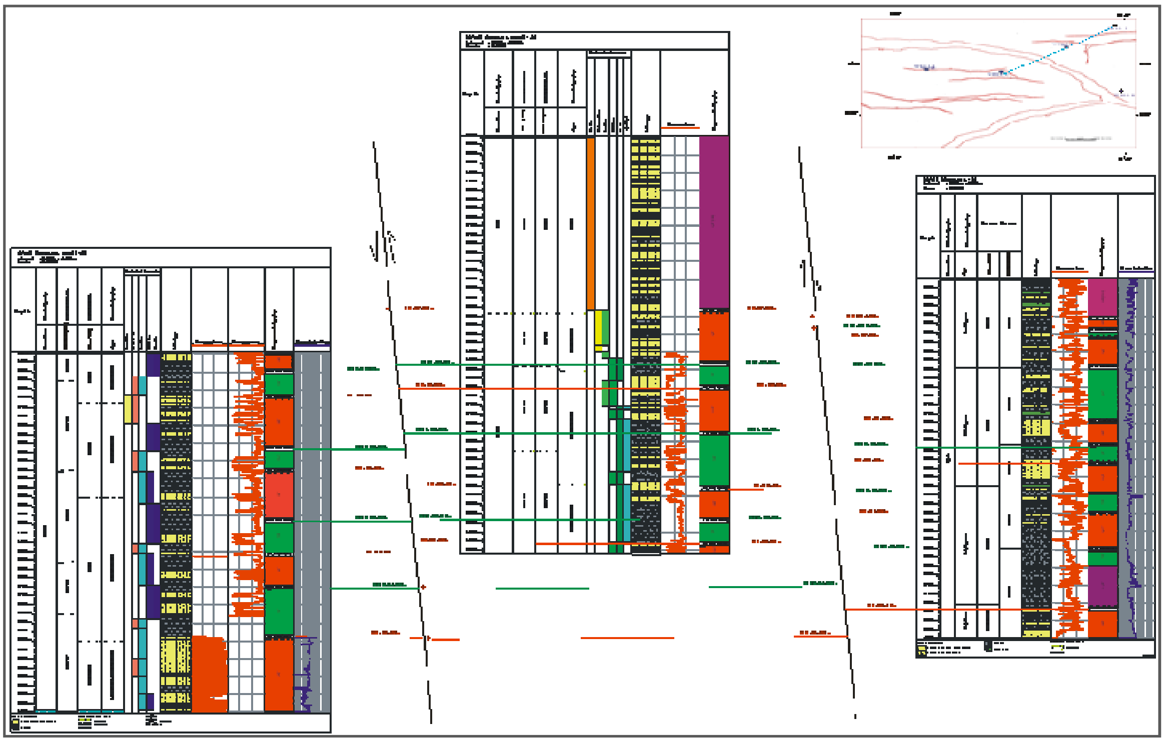

Fig. 8b. Fault correlation along dip section with wells - 'B' – 'A' –

However, the undefined ?26.2/Ch*2Ma MFS bioevent encountered in well - 'D' at 2280m was not encountered in well 'E' and as such could not be correlated (Figs. 8a & b). On the same vein, the 34.0Ma MFS datum was conspicuously not observed in well 'E' but encountered at 3497m in well - 'D' despite the fact that they are in the same macrostructure. With this development therefore, well - 'E' is on the up-thrown block relative to well - 'D' with an average displacement of about 413m. On the seismic section extrapolation, the two-way time equivalent as contain in Table 2 could be observed between the ranges 1.9 – 2.7secs for well - 'D' and 2.3 – 3.0secs for well - 'E'. The correlation of wells - 'B' – 'A' – 'D' along the dip direction showed that the juxtapositioning of wells - 'B', 'A',and'D' allow the understanding of the existing bioevents and its datum occurrences. The occurrence of the FDO of *Chiloguembelina cubensis* and/or *Globorotalia opima opima* (28.1/Ch*1Ma), Influx of *Uvigerinellasparsicostata* (31.3/Ru*2Ma), LDO of *Spiroplectammina wrightii* (33.0/Ru*1Ma) were encountered with the LDO of *Hopkinsina bononensis* (34.0/Ru*1Ma) which only occurred in wells - 'B' and 'D' but could not be observed in well 'A'. Again, the undefined ? 26.2/Ch*2Ma MFS bioevent encountered in well - 'D' at 2280m was not encountered either in well - 'B' or 'A' therefore could not be correlated (Figs. 8a & b). Well - 'B' experienced a down-thrown of the fault block relative to well - 'A' with an average displacement of about 427m; well - 'A' being on the up-thrown of well - 'D' (that is, well - 'D' is on the down-thrown) had an average displacement of 345m while well - 'B' correlates on the up-thrown of well - 'D' with an approximate average displacement of about 350m. The two-way time equivalent of the datum on the seismic section as shown on Table 2 are, well - 'B' (2.1 – 2.8secs), well - 'A' (2.1 – 2.6secs) and well - 'D' (1.9 – 2.7secs).

Conclusion

Correlation of key chronostratigraphic horizons within the analysed wells were based on biostratigraphic/biofacies, biozones data, as well as well log interpretation of flooding surfaces and unconformities bounding large-scale successions in the onshore area, and the identification of equivalent reflection packages within the 2-D seismic data set. Analysis from foraminiferal biostratigraphy yielded excessively abundant taxa coupled with analysis undertaken from all the well log data in these wells therefore make identification and correlation of key surfaces possible. Using the sequence stratigraphic interpretation techniques of Van Wagoner *et al.,* (1990) however, forty-four key surfaces were identified and correlated, representing twenty (20) inferred major maximum flooding surfaces (MFS) and twenty-four (24) sequence boundaries (SB). These key surfaces extend from Late Eocene unconformity to another regional erosion surface marking the top of the Late Oligocene. In addition to using micropaleontological data to locate stage boundaries, stratal stacking patterns which unveiled the genetic sequences were also identified within the wells. The correlation of the five wells within these two fields along the strike direction showed that the juxtapositioning of wells - 'B', 'C'and'E' exhibited a distinctive fault throw with the following recorded average displacements, thus wells - 'BC'- 394m with well -'B' on the up-thrown side relative to well - 'C'; wells - 'CA'- 415m with well - 'A' on the up-thrown side relative to well – 'C'; wells - 'AE'- 345m with well - 'E' on the down-thrown side relative to well -' E'. It was further observed that well - 'D' which is situated in the up-dip section showed high valued fault throw; wells 'ED' - 413m relative to well - 'E'. As a result of this, it was further deduced that wells - 'C' and 'E' are on the down-thrown side relative to the correlative events and surfaces encountered in wells - 'A', 'B' and 'D'. Conversely, the dip sections of wells - 'D' – 'E' showed almost the same bioevents/ datum as in wells - 'E' – 'A'. Most importantly, the undefined ?26.2/Ch*2Ma MFS bioevent encountered in well - 'D' at the depth interval of 2280m was not observed in well - 'E' as such this section could not be correlated. In the same vein, the 34.0/Ru*1Ma MFS datum was not observed in well - 'E' but encountered at 3497m in well - 'D' despite the fact that they are in the same macrostructure. This development has therefore placed well - 'E' on the up-thrown block relative to well - 'D' with an average displacement of about 413m. On the seismic section template of Table 2,this could be observed between the range of 1.9 – 2.7secs for well - 'D' and 2.3 – 3.0secs for well - 'E' respectively. Also the correlation of wells 'B' – 'A' – 'D' along the dip direction unveiled that the juxtapositioning of wells - 'B', 'A'and'D' allow the understanding of the existing bioevents and its datum occurrences. The occurrences of the FDO of *Chiloguembelina cubensis* and/or *Globorotalia opima opima* (28.1/Ch*1Ma), *Uvigerinellasparsicostata* (31.3/Ru*2Ma) and LDO of *Spiroplectammina wrightii* (33.0/Ru*1Ma) were encountered alongside LDO of *Hopkinsina bononensis* (34.0/Ru*1Ma) which only occurred in wells - 'B' and 'D' but could not be observed in well - 'A'.

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