Structural, Environmental deposition and well logs studies ofOMLXYblock,Offshore,NigerDelta, Nigeria

Abstract

The concept of sequence stratigraphy in explaining sediment accumulation and preservation trends within basin fills has become a highly successful exploration tool in the search for hydrocarbon resources. The sequence stratigraphy of OML XY block, Niger delta study approach involved the integration of lithostratigraphy, seismic stratigraphy, and biostratigraphy to help unravel the depositional environment and petroleum play concept within the block. The block covers an area of about 400sqkm in shallow water between 2m - 45m. Thirteen (13) fields have been discovered to date, they include: - Akam, Kita Marine, Inagha, North Oron, Oron West, Oron East, Adanga, Ebughu, Bogi, Ukpam, Mimbo, Antan, and Ebne fields. It is also necessary to note that about seventy (70) wells have been drilled to date. This paper aims to understand the depositional environment and structural trend within theassetusing3Dseismicdata,analysisofwirelinelogs,andbiostratigraphyanalysisandhow they aid in hydrocarbon accumulation, influence reservoir quality, and best describe the regional play concept within the block. Three predominantly prograding depositional sequences bounded by sequence boundaries were delineated. Biostratigraphy report indicates that sediment ages within the OML XY block range from Early Pliocene to Late Miocene. Depositional systems identified include prograding shoreline or delta and backstepping shoreline.Theenvironmentofdepositionidentifiedwithintheblockrangefromuppertolower shoreface.Sedimentarydepositswithintheblockinclude;marineshales,deltafrontsand,upper shoreface sands, lower shoreface sands, mouth bar sands, barrier bar sediments, and beach ridges sediments.

Keywords: Prograding depositional sequence, Backstepping shoreline; shoreface deposit; Beach sands sediments; Barrier bar sediment, hydrocarbon plays, structural trend.

1. Introduction

The Niger Delta is one of the most prolific hydrocarbon-producing regions in the world, with significant reserves of oil and gas. However, the geology of the region is complex, characterized by a series of depositional cycles that have produced a heterogeneous and compartmentalized reservoir architecture. Sequence stratigraphy has emerged as a powerful toolforunderstandingthedepositionalhistoryoftheNigerDeltaandpredictingthedistribution ofhydrocarbon-bearingreservoirs.Thesubdivisionofabasin'ssedimentarydepositsintotime stratigraphically constrained depositional packages is imperative in unravelling its development and inherent hydrocarbon potentials [10]. The lithostratigraphic subdivision of the Niger Delta sediments cut across timelines and their lateral associations suggest that the sedimentarydepositswerestronglyinfluencedbyachangeinsealevelandtectonics.Our analysis is based on the integration of high-quality 3D seismic data, well logs, and Biostratigraphydata.Weuseacombinationofseismicinterpretation,chronostratigraphic,and sedimentology to identify depositional sequences and systems tracts that are bounded by unconformities and characterized by distinct facies associations. Recent studies have highlightedtheimportanceofsequencestratigraphyforunderstandingthedepositionalhistory of the Niger Delta. For example, Ola-Buraimo [8] used sequence stratigraphy to predict the distribution of reservoir sands in the Niger Delta and found that the depositional cycles are related to changes in sea level and sediment supply. Similarly,Alimi [3] applied sequence stratigraphy to characterize the depositional environment of the offshore Niger Delta and identified several depositional systems that control the distribution of hydrocarbon-bearing reservoirs. Okosun [9] used sequence stratigraphy to unravel the stratigraphic architecture of the shallow marine deposits of the Niger Delta and identified the depositional systems that control the distribution of hydrocarbon reservoirs. Sequence stratigraphy thus facilitates the subdivision of the Niger Delta basin into packages of sediments that are essentially bounded together by Chronostratigraphicallysignificant surfaces. Our study builds on these recent advances in sequence stratigraphy and provides a comprehensive analysis of the OML XY block in the offshore Niger Delta. Our results have significant implications for hydrocarbon exploration and production in the region and can aid in the optimization of drilling locations and production strategies. The direction of this research is to define the structural trend and delineate Para sequence sets and sequences within the asset to better understand the depositionaltrendforreservoircharacterizationandprospectanalysis. Insummary,thisstudy providesacomprehensivesequencestratigraphicanalysisoftheOMLXYblockbyelucidating thedepositionalenvironment,structuraltrend,parasequences, andsequenceswithintheasset through the use of 3D seismic data, wireline log analysis, and biostratigraphy analysis, and demonstrating how these factors contribute to hydrocarbon accumulation, affect reservoir quality, and provide the best description of the regional play concept within the block.

2. GeologicalSettingand TectonicEvolution ofNigerDelta

2.1 Geological setting

The Niger Delta Basin is located in Nigeria (Fig 1.) and is one of the most prolific hydrocarbon basins in the world [7]. The basin is composed of sedimentary rocks that were deposited over a period of approximately 70 million years [12]. The geological setting of the Niger Delta Basin is characterized by a thick sequence of sedimentary rocks that were deposited in a variety of environments, including marine, deltaic, and estuarine settings [7]. Thebasin is underlain by basement rocks ofPrecambrian age and is bounded to thenorth and eastbyhighlandareasofcrystallinerocks[7].ThesedimentaryrocksoftheNigerDeltaBasin weredeposited in aseries ofcycles that weredriven by changes in sealevel, tectonicactivity, and climate [12]. These cycles resulted in the deposition of alternating layers of sandstone, shale, and mudstone that are collectively referred to as the Niger Delta Formation [7]. The sedimentaryrocksofthe NigerDeltaBasin containsignificant amountsoforganicmatterthat have been converted to hydrocarbons over millions of years [7]. This has resulted in the formationofextensiveoilandgasreservesthatareeconomicallyimportanttoNigeriaandthe world as a whole. The tectonic evolution and structural style of the Niger Delta Basin are the result of a complex interplay between geological and tectonic processes that have occurred overmillionsofyears.ThetectonicevolutionoftheNigerDeltaBasincanbebroadlydivided intothreemajorstages:rifting,passivemargindevelopment,andcompression[13].Duringthe

LateJurassictoEarlyCretaceous,thebasinexperiencedriftingduetothebreakupofthe supercontinent Gondwana (Fig.2) [6]. This rifting led to the formation of grabens and horsts, whichweresubsequentlyfilledwithsedimentaryrocks.Thepassivemarginstagebeganinthe mid-Cretaceousandcontinueduntilthe Palaeocene[12].Duringthistime,thebasinwas characterizedbyastablemarginwithalowrateofsubsidence,whichallowedfortheaccumulation of thick sequences of sedimentary rocks. The compression stage began in theLate Eocene to Early Oligocene, and it was associated with the collision of the African andEurasianplates [6].This compression ledto theinversion ofsomeoftheearlierfaults and the formation of new thrust faults. The structural style of the Niger Delta Basin is dominated by growthfaulting,whichistheresultofdifferentialsubsidencebetweenthebasementand sedimentarylayers[12].Thesefaultsactastrapsforhydrocarbonsandarethemaintargetsfor exploration and production in the basin.

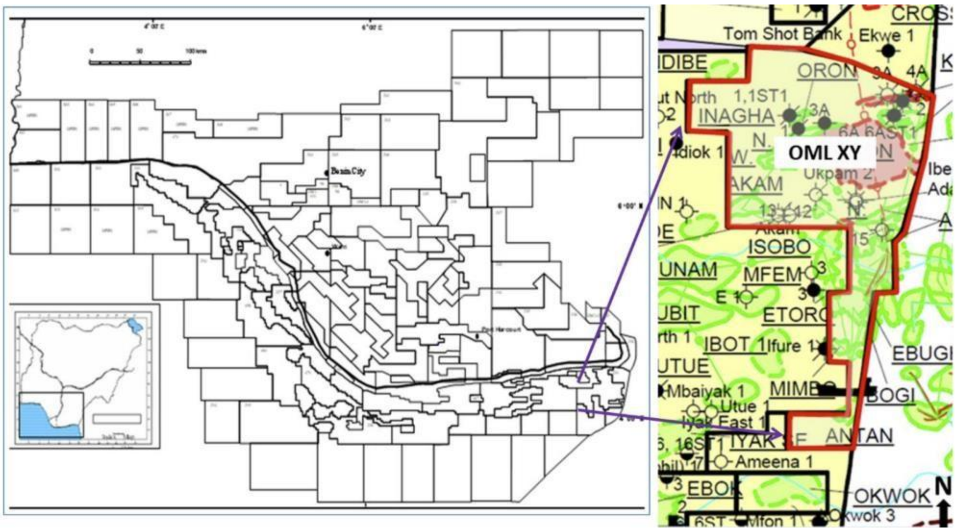


Figure1: LocationMap ofOML XY.

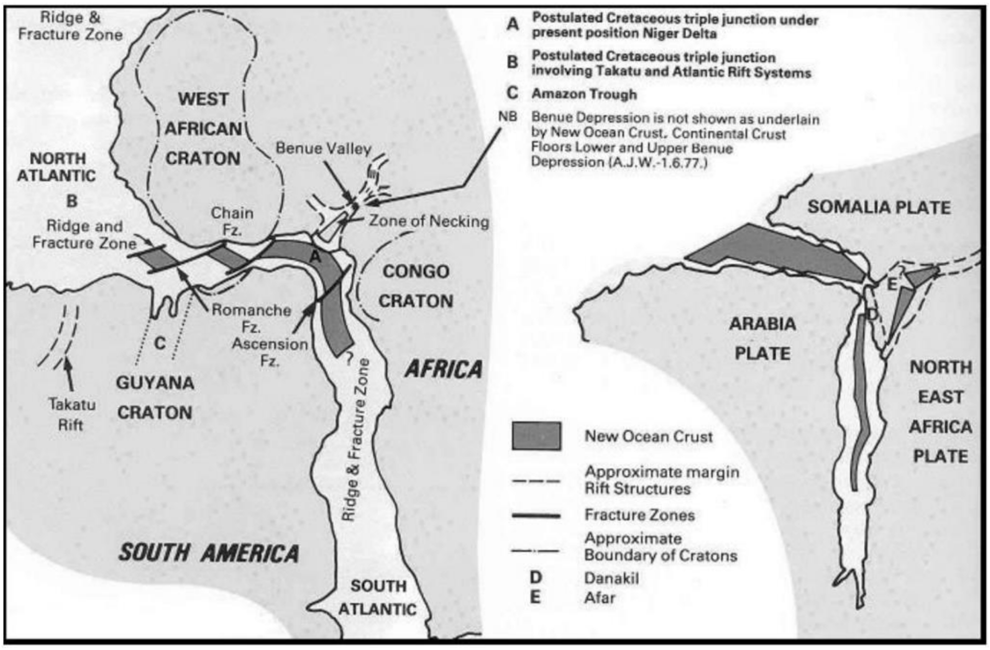


Figure 2: Shows the Cretaceous to Recent Palaeographic evolution of the Nigerian rift and Continental margin deltas.

2.2 Stratigraphy

Thetectono-stratigraphyoftheNigerDeltaBasincanbedividedintofourmainunits:theAkata Formation, the Agbada Formation, the Benin Formation, and the Older Coastal Plain Sands(Fig.3). The Akata Formation is the oldest unit of the Niger Delta Basin, dating back to the LateCretaceousperiod.Itconsistsofshaleandmudstonedepositsthatwereformedina deepwatermarineenvironment.TheAkataFormationisknownforitshighorganiccontent, whichhasledtotheformationofextensivehydrocarbonreserves.Recentstudieshavefocused onthesedimentologicalandgeochemicalcharacteristicsoftheAkataFormation,revealingits potentialforunconventionalgasexploration[13].TheAgbadaFormationisthemostextensive unit of the Niger Delta Basin, consisting of interbedded sandstones, siltstones, and shales. It wasdepositedduringthePalaeocenetoEoceneperiodsinadeltaicenvironment,andis characterized by its high reservoir potential. Recent studies have focused on the stratigraphy andsedimentologyoftheAgbadaFormation,aswellasitsreservoirqualityandheterogeneity [1].TheBeninFormationisarelativelythinunitoftheNigerDeltaBasin,consistingof sandstones and shales that were deposited during the Oligocene to Miocene periods. It wasformed in a deltaic environment and is known for its shallow marine deposits. Recent studies havefocusedonthedepositionalenvironmentandsedimentaryarchitectureoftheBenin Formation,aswellasitsreservoirproperties[2].TheOlderCoastalPlainSandsarethe youngestunitoftheNigerDeltaBasin,datingbacktotheLateMiocenetoPleistoceneperiods. It consists of well-sorted, medium to coarse-grained sands that were deposited in a fluvial to shallow marine environment. Recent studies have focused on the sedimentary architecture,depositional environment, and provenance of the Older Coastal Plain Sands, as well as their potential for hydrocarbon exploration [4].

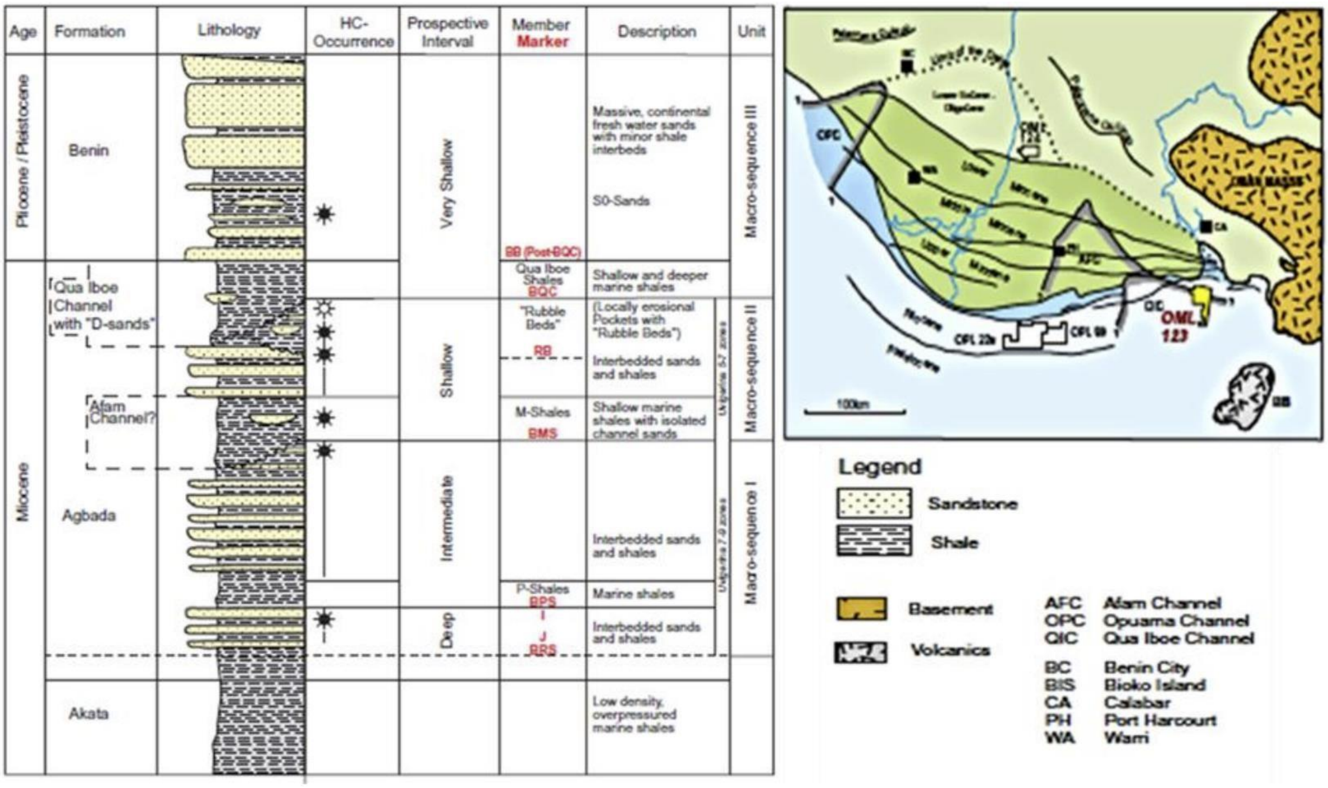


Figure3:TheStratigraphycolumnoftheNiger DeltashowingThreeFormations.

2.3 Depo Belts

TheNigerDeltaBasinischaracterizedbyaseriesofdepo-beltsthatrepresentdifferentphases of sedimentary deposition and hydrocarbon accumulation. Akata-AgbadaDepo-Belt is the most significant and extensive in the Niger Delta Basin. It comprises a thick sequence of sedimentaryrocks,includingsandstones,shales,andcoals,depositedinadeltaicenvironment duringtheOligocenetoEarlyMiocene.TheAkata-Agbadadepo-beltisthemainhydrocarbon reservoir in the Niger Delta Basin and has been the focus of extensive exploration and productionactivities[6].TheBeninFlankdepo-beltisanarrowbeltofsedimentaryrocksthat runs along the western margin of the Niger Delta Basin. It was formed during the Late Cretaceous to Early Paleogene, and consists of sandstones, shales, and limestone deposited in a shallow marine environment [5]. The Anambra Basin depo-belt is a relatively small and isolated depo-belt located in the south-eastern part of the Niger Delta Basin. It comprises a sequenceofsedimentaryrocks,includingsandstones,shales,andcoal,depositedinafluvialto deltaicenvironmentduringtheCretaceoustoPaleogene[1].TheAbakalikidepo-beltislocated in the north-eastern part of the Niger Delta Basin and consists of a sequence of sandstones, shales,andcoalsdepositedduringtheLateCretaceoustoEarlyPaleogeneinafluvialtodeltaic environment [8]. The Calabar Flank depo-belt is a narrow belt of sedimentary rocks located alongthesouth-easternmarginoftheNigerDeltaBasin.Itcomprisesasequenceofsandstones, shales, and limestone deposited during the Late Cretaceous toPaleogene in a shallow marine environment [10].

3. Methods

3.1 DataavailabilityandQuality checking

The data available for the study are: (i) Fairly good 3D Seismic data (SEGY) that covers an approximate area of about 400sqkm. (ii) Well log Data (Composite logs, deviation data andCheckshotdata)(iii)Biostratigraphydata(iv)Wellreport(table1).Thedatasetwere analysed using Schlumberger Petrel software package. The 3D Seismic data quality is fairly good but a poor data zone exists in the northern part of the concession (Fig 4).

3.2 WellLog Interpretation

Lithologies were identified with the aid of gamma ray logs and Biostratigraphic reports. A rangeof0to150APIwasusedfortheGammaRaylog.GammaRayvalueswithdeviationto the left of the shale baseline were delineated as sand units while shale was delineated with deviation to the right.

3.3 Biostratigraphy

Thesequencestratigraphytopsweredelineatedfromforaminiferalcontents,comprisedof benthic and planktonic forams. The stratigraphic tops were integrated with the log motifs of theGamma-ray(Fig5)toreconstructthepossibledepositionalenvironments,developa lithofaciesmodelforeachwell,anddelineateSequenceStratigraphicSurfacessuchasSequence Boundary, Flooding surfaces, and Maximum Flooding Surfaces.

Available Data set for OML-XY Regional Studies					
			Available	Complete?	Comment
Reports	Well report & Biostratigraphic report and Previous studies report	Well report	Inagha-3A, Adanga-16, ADS-7H, ADNG-2A, ADNH-11hst1, Bogi-5H, Ebughu 13P & 13H, North Oron-2 & 2st, Oron East-1 & 1st, Oron West-1A	No	Well reports not available for wells with biostrat data
		Biostratigraphic report	Inagha-3A & 4A, Akam-1, Ebughu-1	No	Biostrat reports for wells from only 3 fields out of 13
		Previous Studies report	OPL 90/225 Prospectivity Evaluation, OML XY prospectivity review 2004 & enclosures	No	
		Sedimentological report		No	
		Geochemical report		No	
		Seismic processing report		No	
		Pressure study report	Niger Delta pressure study Phase2	yes	
Well	Well information, Wireline logs, Deviation, Location etc	Wireline logs and MWD/LWD	NOR-2, ORE-1, ADNH-11st1, ADS-7H, Ebughu-13H, Bogi-5H	No	Wireline logs for wells from 6 fields out of 13. Not available for wells with biostrat reports. Most logs incomplete
		Well header (X&Y, KB, TD)		No	
		Deviation survey	Oron West-1A, ADS-2A, Ebughu-13P, Bogi-5P, NOR-2, ORE-1, ADNH-11st1, Ebughu-13H, Bogi-5H	No	Deviation survey received for wells from 7 fields out of 13. Not given for wells with biostrat report
		Checkshot		No	
Seismic	Seismic survey data	3D seismic volume	400sqkm 3D seismic	yes	Quality is fairly good
		2D seismic lines		No	

Table1:Data availabilityforOML-XY regionalstudies

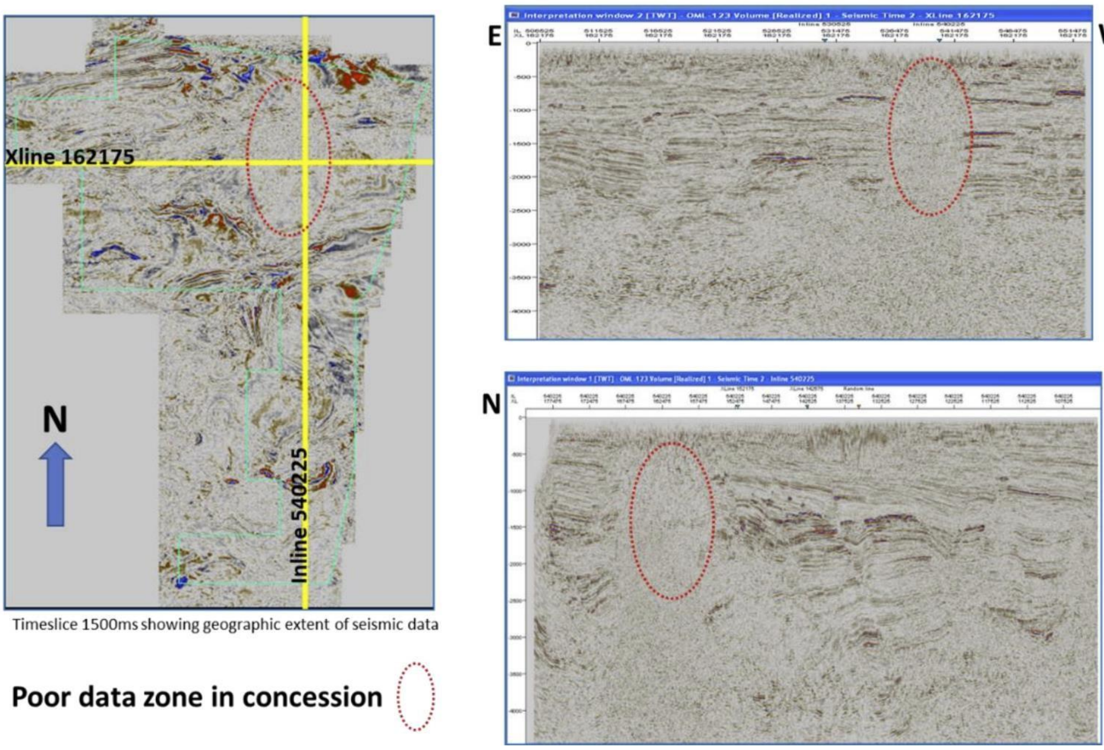


Figure4:Seismicdata coveragearea anddataquality.

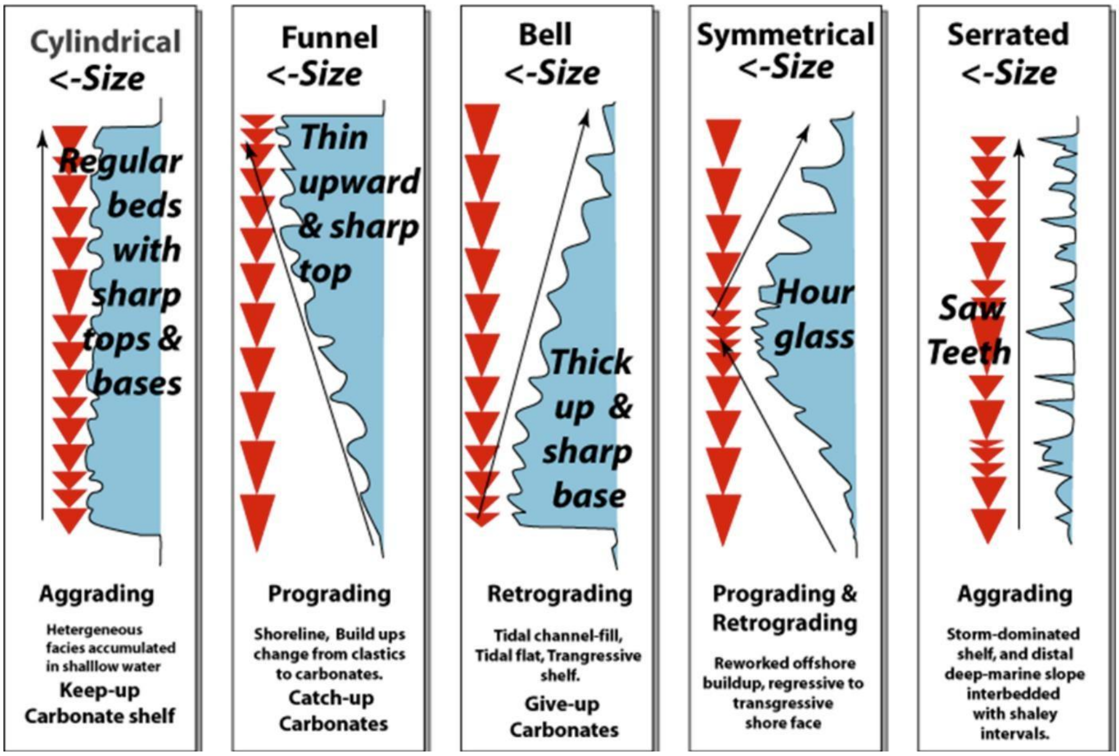


Figure5:Lithologiclogsandcorrespondingstratigraphicinterpretation.

3.6Seismic toWell Tie

Thetime-depth information obtained from check-shot datawas used in the conversion ofthe welltopsfromthelogdata,fromdepthtotime,andposttheequivalenthorizononthelineat the proper times on the seismic data which is in two-way time.

3.8MappingofFaultsand Horizons

Identification of horizons is based on reflection continuity. This implies that most recognizable and continuous event will be easily traced throughout the seismic section. Mapping of horizons on the seismic section have to do with the proper understanding of the seismic attributes such as amplitude, coherency etc. Major faults wereidentified and mapped along the dip lines. The faults were picked on the inline first before being traced across the crosslines.Scrollincrementsof8and16lineswasemployedonbothin-linesandcross-lines, care was taken in determining the consistency of the fault traces, as faults tend to die out and can be mistaken for another in a complexly faulted field. Faults were identified based on the following criteria; Abrupt termination of reflectionevents; Breaks in reflection events; Abrupt lateral velocity changes; Overlapping of reflection events; Pattern change of reflectioneventsacrossafault;Structuraldeformationinbedsabovethezoneoffaultingand Anomalous dip near the fault zone.

3.9SeismicStratigraphyInterpretation

Sequencestratigraphy was first carried out on the well logs to interpret depositional systems andthenfurtherinterpretedthesystemtractsanddepositionalsurfaces(sequenceboundaries and maximum flooding surfaces). The interpreted sequence boundaries were then tied to the seismic section and interpreted across the seismic data.

4. ResultsandDiscussion

4.1 WellCorrelation

The well correlation was done using the Gamma Ray log and Biostratigraphic markers identified in the reports provided. The major surfaces delineated are the shale marker beds whichwerecorrelatedacrossthewholeblock.Figuresbelowshowsthecorrelationbyfields in the block in the strike and dip direction. (Fig 6 to Fig 8). The wells with Biostratigraphic information are summarized below:

Inagha3A

• Depthinterval3660–4170ft

• Age–Early Pliocene

• Environmentofdeposition-outershelforiginbeingpredominantlyassociatedwithOuter Neritic biofacies. Inagha-4A

• Depthinterval1500–6880ft

• Age–Late MiocenetoEarly Pliocene

• Environmentofdeposition-coastal/shelffaciesassociatedwithCoastalDeltaictoOuter Neritic biofacies.

• 1MaximumFloodingSurfacecondensedsection recognized.

Akam-1

• DepthInterval2640-7270ft

• Age-LateMiocenetoEarly Pliocene

• 3MaximumFloodingSurfacecondensedsections recognized

• Environment of deposition - regressive succession of coastal/shelfalfacies associated mainlywithInnerNeriticwithoccasionalCoastalDeltaicbiofaciesovertheupperhorizons

Ebughu-1

• Depthinterval3430-8430ft

• Age-LateMiocenetoEarly Pliocene

• Environmentofdeposition–Coastal deltaic/estuarine

OronNorth-1

• Depthinterval2010-8830ft

• Age-LateMiocenetoEarly Pliocene

• Environmentofdeposition–Outerneritictolowerdeltaicplain

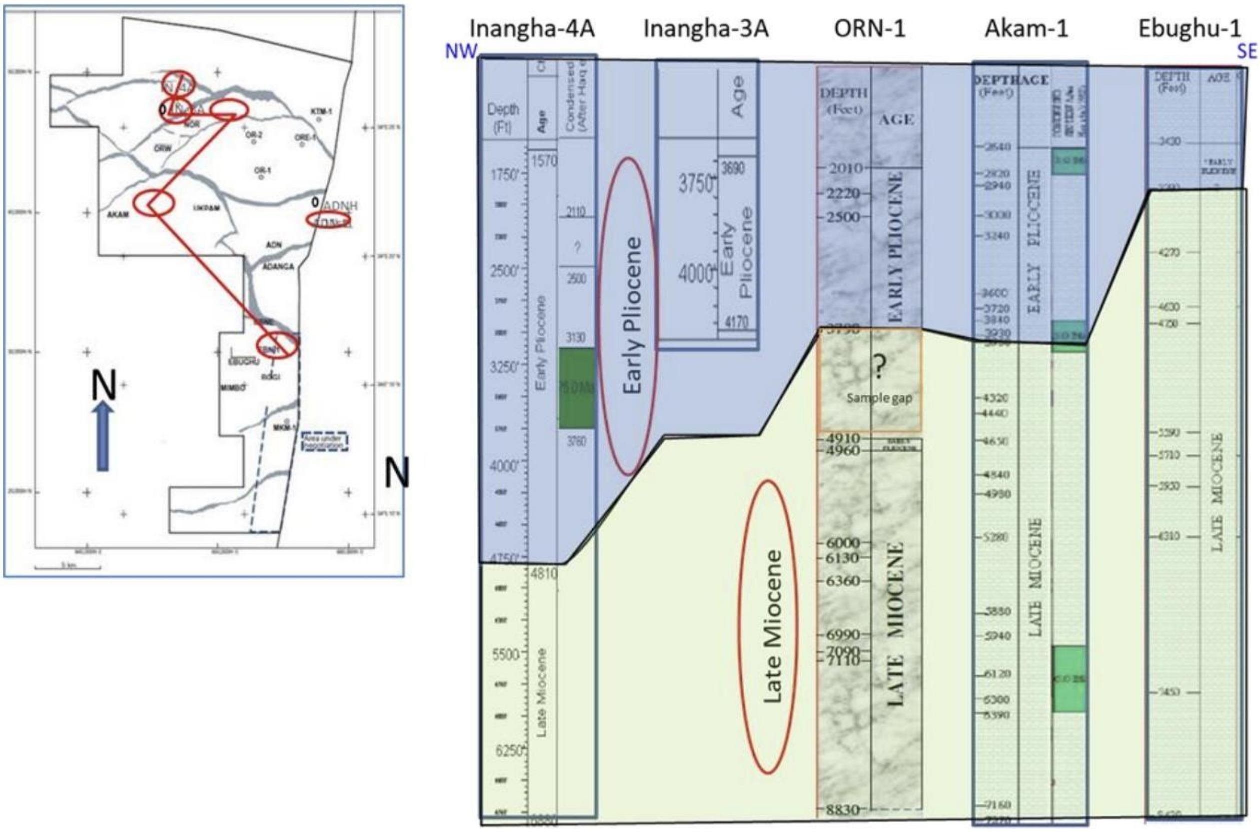


Figure6:BiostratigraphyCorrelationofthewellsacrosstheOMLXY Field.

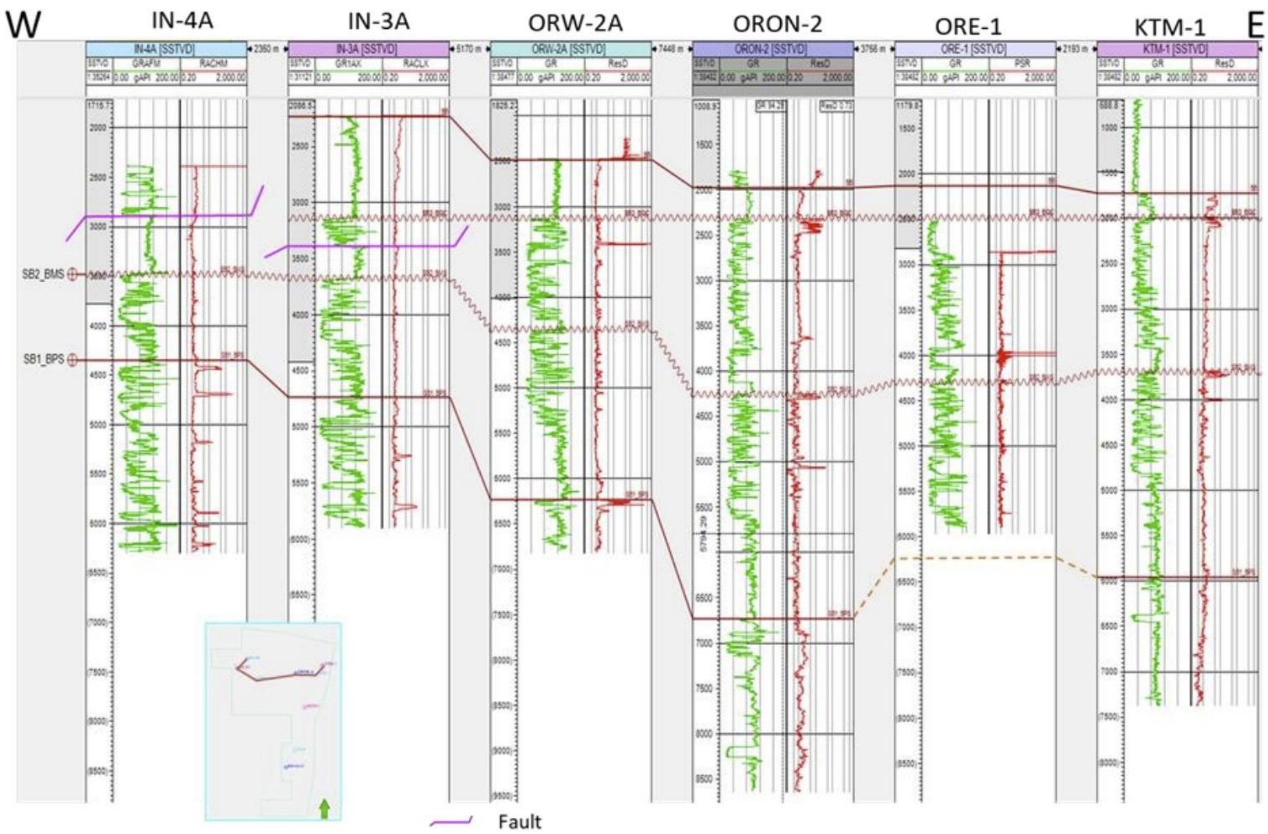


Figure7:Correlationsectionofselectedcandidatewellsalongstrikeof OMLXY block.

AdangaNorth-1

• Depthinterval4720-7000ft

• Nonannofossildetected

• Environmentofdeposition–Shallow marine.

4.1.1Environmentof Deposition

OML XY block is located within the offshore depobelt area in Niger delta. Regionally, sedimentdispersalwascontrolledbymarinetransgressive/regressivecyclesrelatedtoeustatic sea-level changes with varying duration. The various sea-level cycles were in or out of phase with each other and with local subsidence, and interfered with each other and thus influenced the depositional processes. At the high inflection points of the long-term eustatic sea-level curve, floodings took place that resulted in delta-wide shale markers. Three macro-sequences wereidentifiedwithsequenceboundaries:BPS(BaseP-Shale),BMS(BaseM-Shale)andBQC (Base Qua-Iboe Channel). The macro-sequences contain regional transgressive units (TST) followedbyarangeofheterogeneousfine-to-coarseprogradationoraggregationalsiliciclastic (para)sequence sets (HST) (Fig 9 and Fig 10).

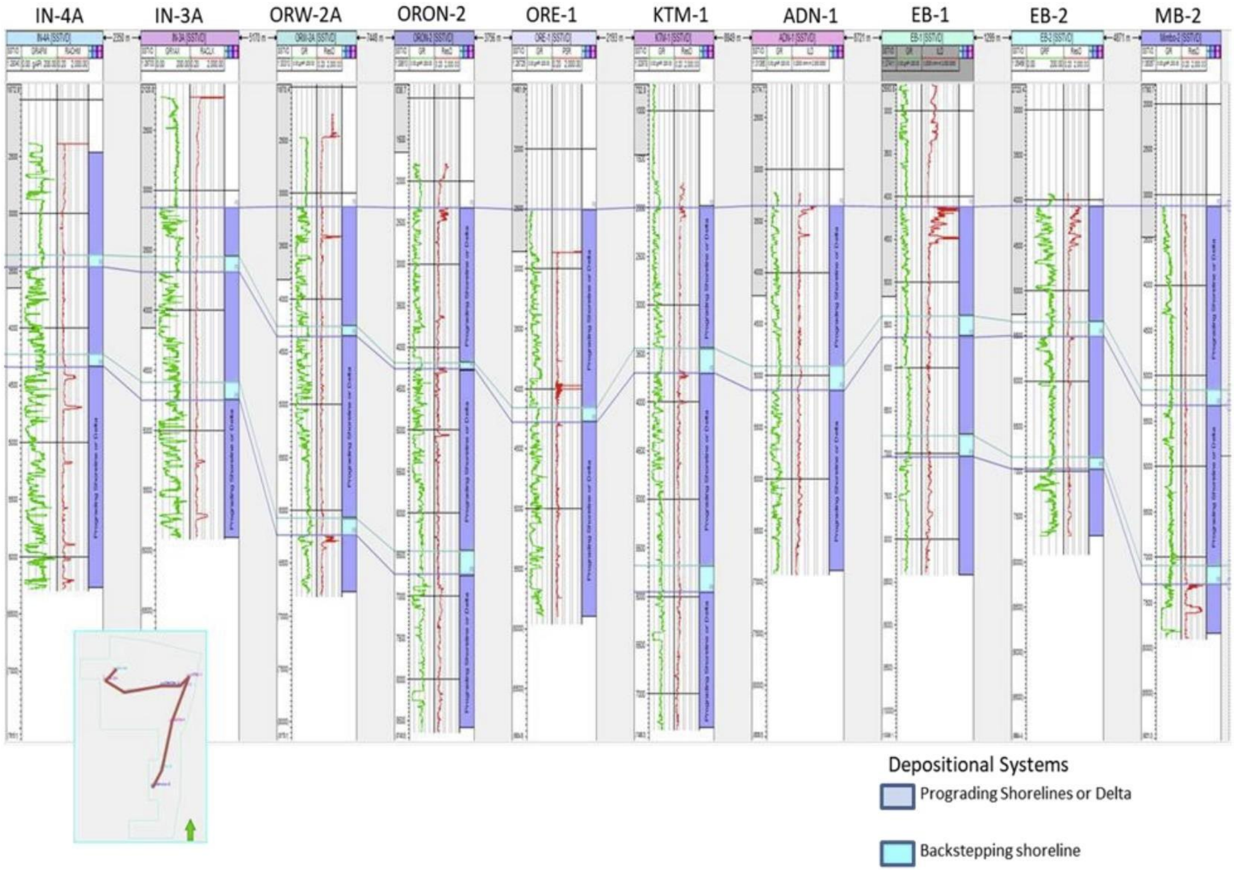


Figure8: Depositionalsystem OMLXY block.

4.2 SeismicInterpretation

ThefaultsandidentifiedkeystratigraphicsurfaceswereinterpretedacrosstheOMLXY block (Fig 9 and Fig 10). Time and depth structural maps were generated as seen in the figures below.

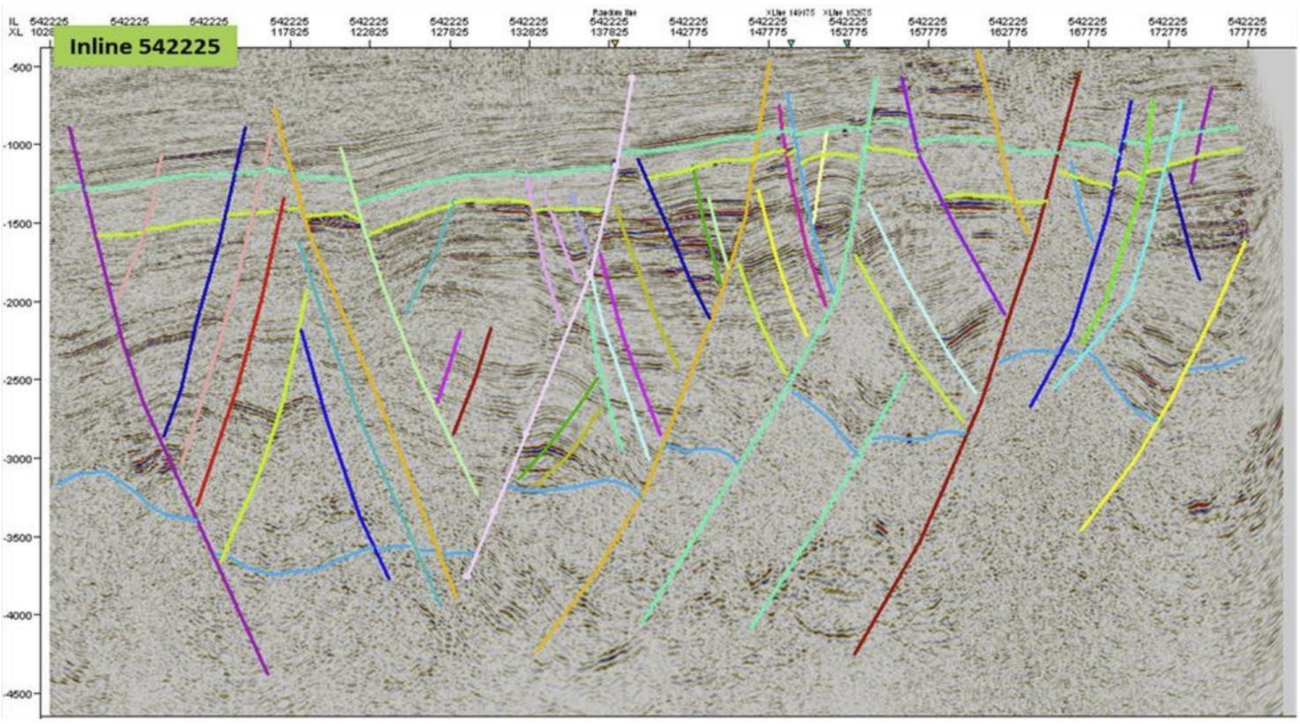


Figure9:Faultinterpretationandhorizoninterpretationofsomestratigraphicsurface.

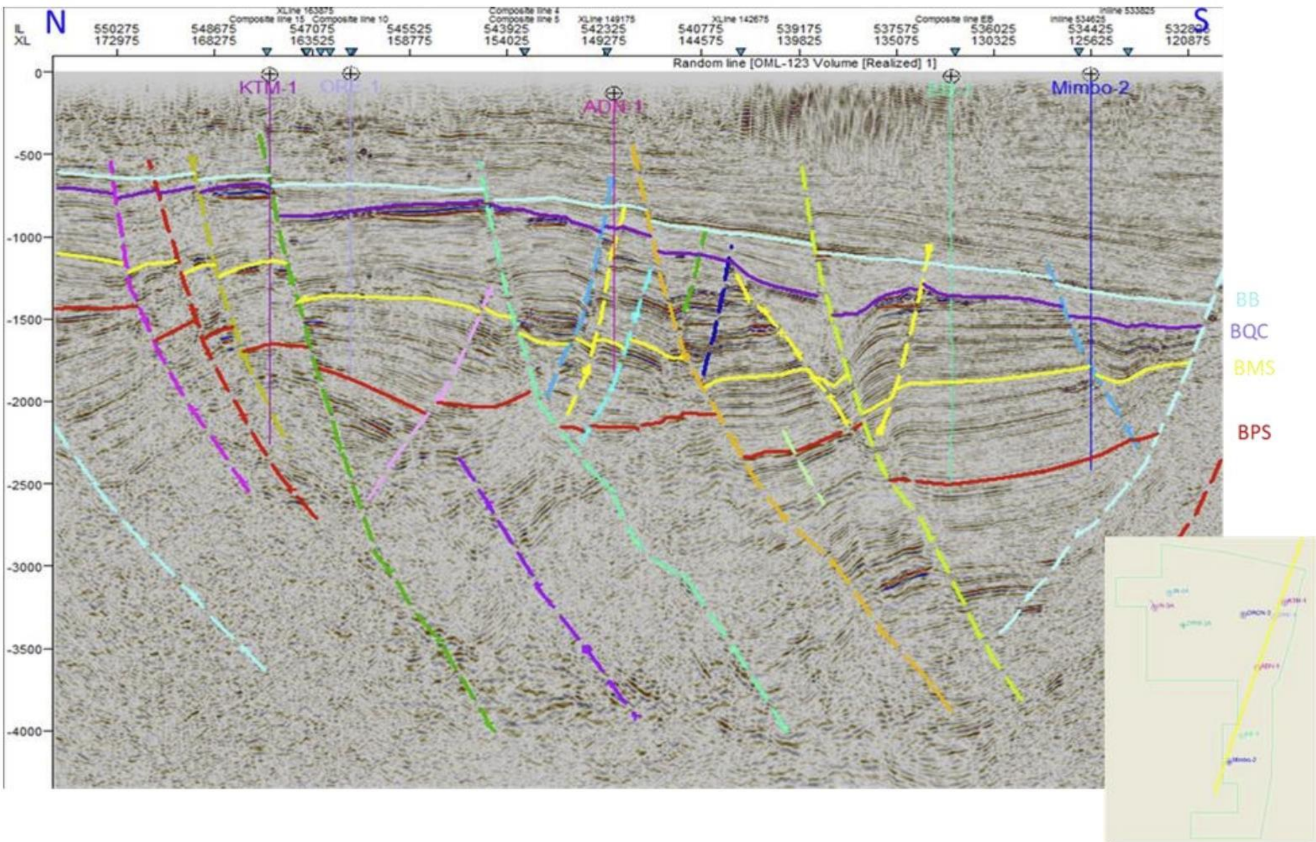


Figure10:Seismic stratigraphicpanel alongdip direction.

Chronostratigraphic ages for the key stratigrphic surfaces BQC, BMS and BPS were first identifiedfrombiostratigraphicreportofInangha 3,Inangha4,Oron1,Akam1andEbughu1 well.BB,BQCandBMSwereinterpretedtobeearlypliocenewhileBPSservesasthe boundary between early Pliocene to late Miocene (Fig 10). Bathymetric ranges of the block wasidentifiedinthebiostratigraphicreportprovided.Theenvironmentwasreportedtobe between the inner to outer neritic (Fig 11).

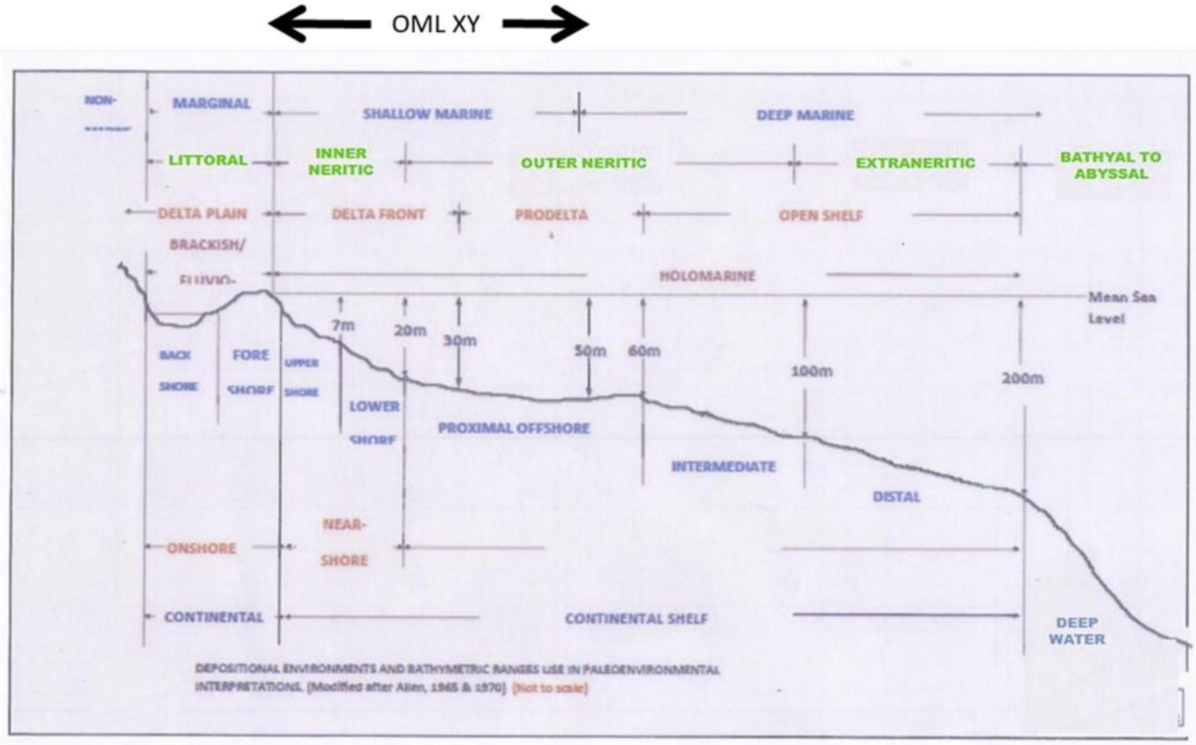


Figure11:Bathymetric RangeofOMLXY Block.

4.3 HydrocarbonPathway,SequenceandSeals

Theyoungest hydrocarbon-bearingreservoirwith economicpotentialis S0-9reservoirin Benin Formation,whichcontainsgasandoilatadepthofapproximately3,000fttvdssinEbnefield. Oldest reservoirs penetrated (in Adanga, Ukpam and Inagha) are J-sands, which are expected at approximately 12,000 fttvdss in the Antan prospect in the southernmost part of the license block. Three major shale sequences of regional importance act as regional top seals to the underlying reservoirs: Qua IboeShales, M-Shales and Pshales (Fig 12). Hydrocarbon migrationisexpectedtotakeplacealongthemajorfaults,fromdeep-seatedshalesintheAkata Formation or early Agbada Formation, into fault-controlled structural traps (four-way dip rollover or fault seal) primarily within the Agbada Formation and locally in the Benin Formation. Traps classified as structural or stratigraphic, or as a combination of the two are foundwithintheOMLXYblock(Fig 12).Attopofshallowreservoirinterval(directlybelow the Qua IboeShales) traps are typically stratigraphic (erosional truncation) or of a combined natureofbothstructuralandstratigraphictrap.Trapsaregenerallystructuralatdeeperreservoir levels, mostly formed by fault closure and rollover with four-way dip closures. Fault closures may occur in both the footwalls and in the hanging walls. There is a stepwise deepening of stratigraphic levels from north to south. The main structural trends within theblock areNorth West-South East and East North East-West South West, closely spaced East-West trending faultsalsooccurinKTMarea.Attopofshallowreservoirinterval(directlybelowtheQuaIboeShales) traps aretypically stratigraphic (erosional truncation) or of a combined nature of both structuralandstratigraphictrap.Trapsaregenerallystructuralatdeeperreservoirlevels,mostly formed by fault closure and rollover with four-way dip closures. Fault closures may occur in both the footwalls and in the hanging walls. There is a stepwise deepening of stratigraphic levels from north to south. The main structural trends within the block are North West-South EastandEastNorthEast-WestSouthWest,closelyspacedEast-Westtrendingfaultsalsooccur in KTM area (Fig 12).

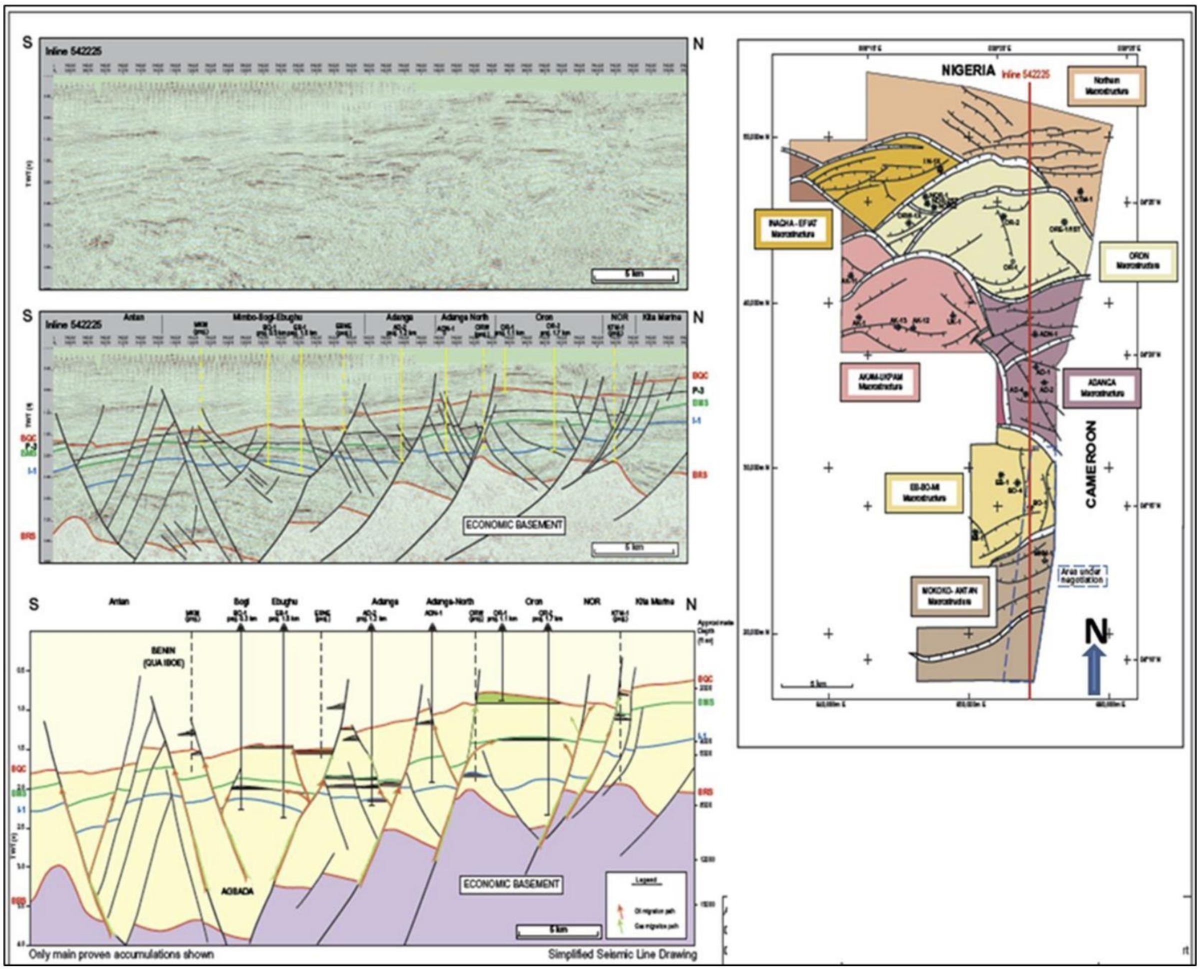


Figure12: Trappingstylesandhydrocarbondistributionof theOML XYblock.

4.4 EnvironmentofDeposition Model

Aftercarefullyinterpretingthedataandintegratingwiththeavailablereports,anenvironment of deposition model was developed. Various environment identified within the block include upper to lower shoreface. Sedimentary deposits within the block include; marine shales, delta front sand, upper shoreface sands, lower shoreface sands, mouth bar sands, barrier bar sediments,andbeachridgessediments.Thedepositionalmodelwithintheblock.Environment of deposition distribution was done using the conceptual model and the various distribution maps for the key stratigraphic surfaces are observed Fig 13 and 14.

4.5 PetroleumPlayConceptsofOMLXYBlock

Thepetroleumplayconceptcanbedefinedbythreecharacteristicsatthreelevels –

Level 1: The charge linked to stages in basin history

– Level2:The hydrocarbonbearingreservoir definedeither bytheformationname/age or lithofacies

– Level3:ThetraptypeOnlytwocharacteristics(formationageandtraptype)areusedinthis study since the charge is believed to be common (Akatafomation).

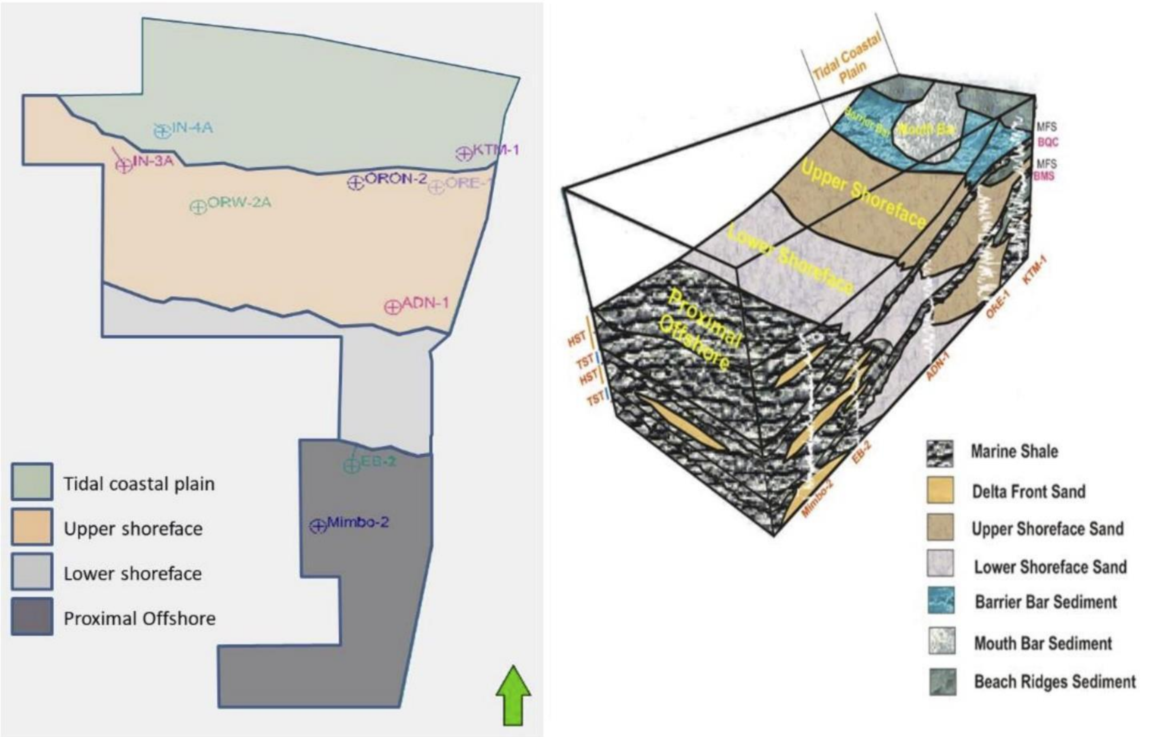


Figure13:EnvironmentofdepositiondistributionmapbelowBQC.

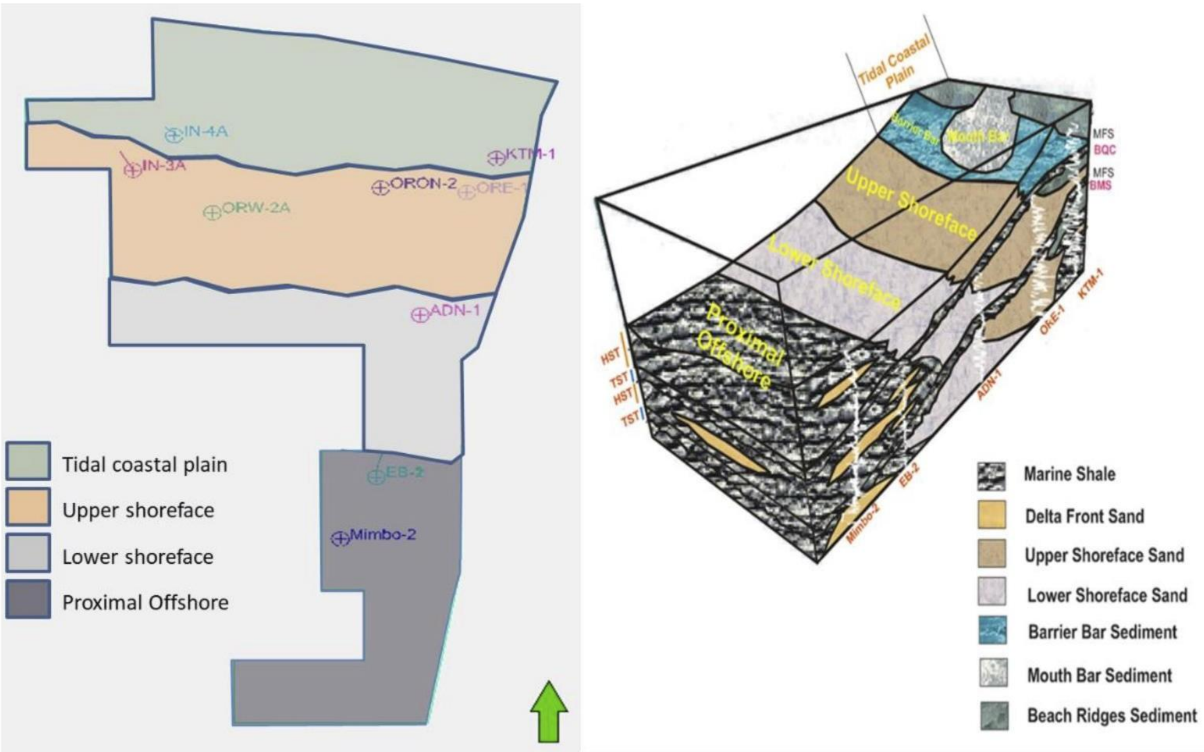


Figure14:Environmentof Depositiondistributionmap belowBMSand BPS.

Only two characteristics (formation age and trap type) are used in this study since the charge is believed to be common (Akatafomation).

Playtypes identifiedin OMLXYinclude:

– EarlyPliocenehanging-wallandfootwall plays

– ORW-2A(P.05)–Late Miocenehanging-wallandfootwallplays-IN-3A(I-3.2)

– EarlyPlioceneAnticlinalplays

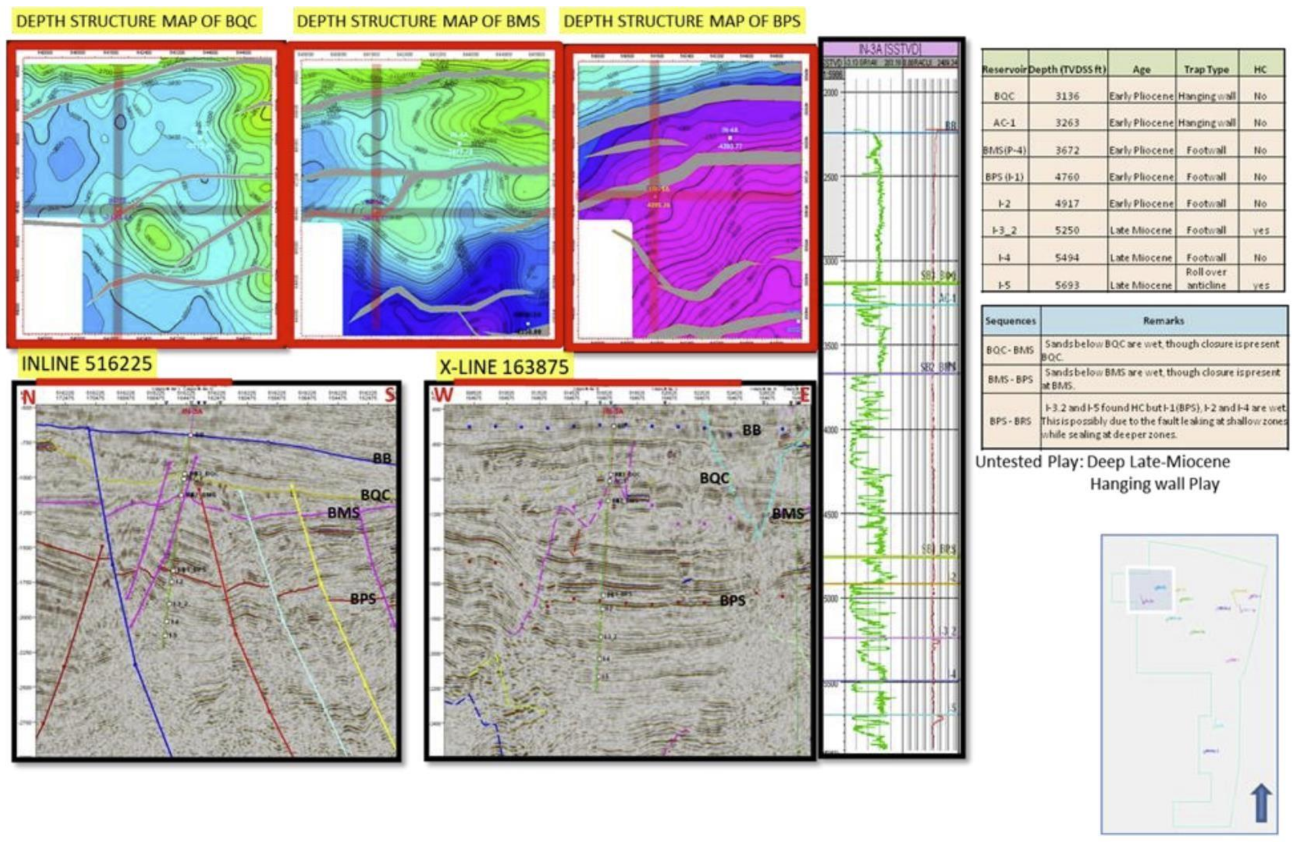
– EarlyPliocenerollover anticlineplays -KTM-1(BQC, P-4,P-6)

– EarlyPlioceneCombinationplays-NOR-1

– EarlyPlioceneAngularunconformityplays-ADN-1(BQC),EB-1(BQC), EB-2(BQC)

– DeepLateMiocenehanging-wallandfootwallplays.

Figures15to25belowexplainstheidentifiedpetroleumplayconceptsinterpretedinOML XY block listed above.



Reservoir	Depth (TVDSS ft)	Age	Trap Type	HC
BQC	3136	Early Pliocene	Hanging wall	No
AC-1	3263	Early Pliocene	Hanging wall	No
BMS(P-4)	3672	Early Pliocene	Footwall	No
BPS (I-1)	4760	Early Pliocene	Footwall	No
I-2	4917	Early Pliocene	Footwall	No
I-3_2	5250	Late Miocene	Footwall	yes
I-4	5494	Late Miocene	Footwall	No
I-5	5693	Late Miocene	Roll over anticline	yes

Sequences	Remarks
BQC - BMS	Sands below BQC are wet, though closure is present BQC.
BMS - BPS	Sands below BMS are wet, though closure is present at BMS.
BPS - BRS	I-3.2 and I-5 found HC but I-1(BPS), I-2 and I-4 are wet. This is possibly due to the fault leaking at shallow zones while sealing at deeper zones.

Figure 15: Inagha- Efiat Macro Structure (INAGHA 3A) : Late Miocene Hanging Wall and Rollover Anticline Plays.

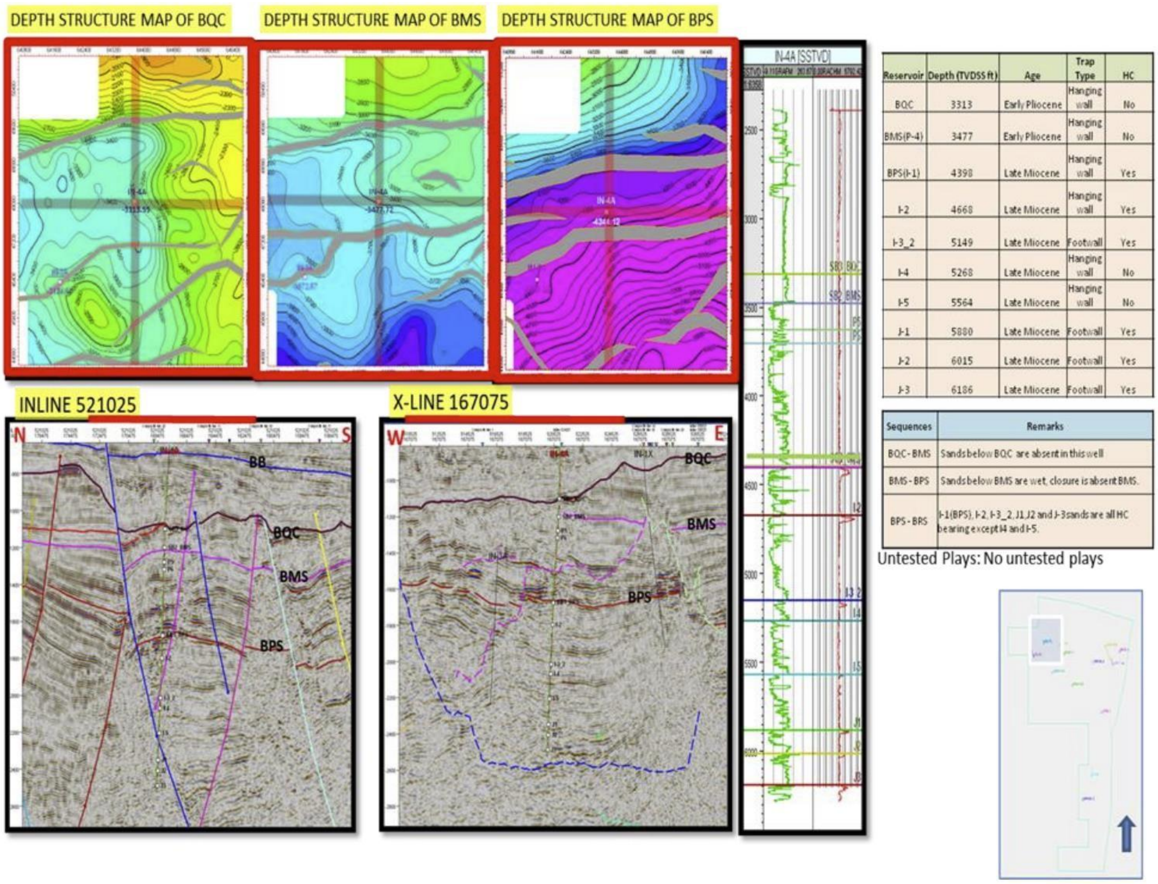


Figure 16: Inagha- Efiat Macro Structure (INAGHA 4A) : Late Miocene Hanging Wall and Foot wall plays.

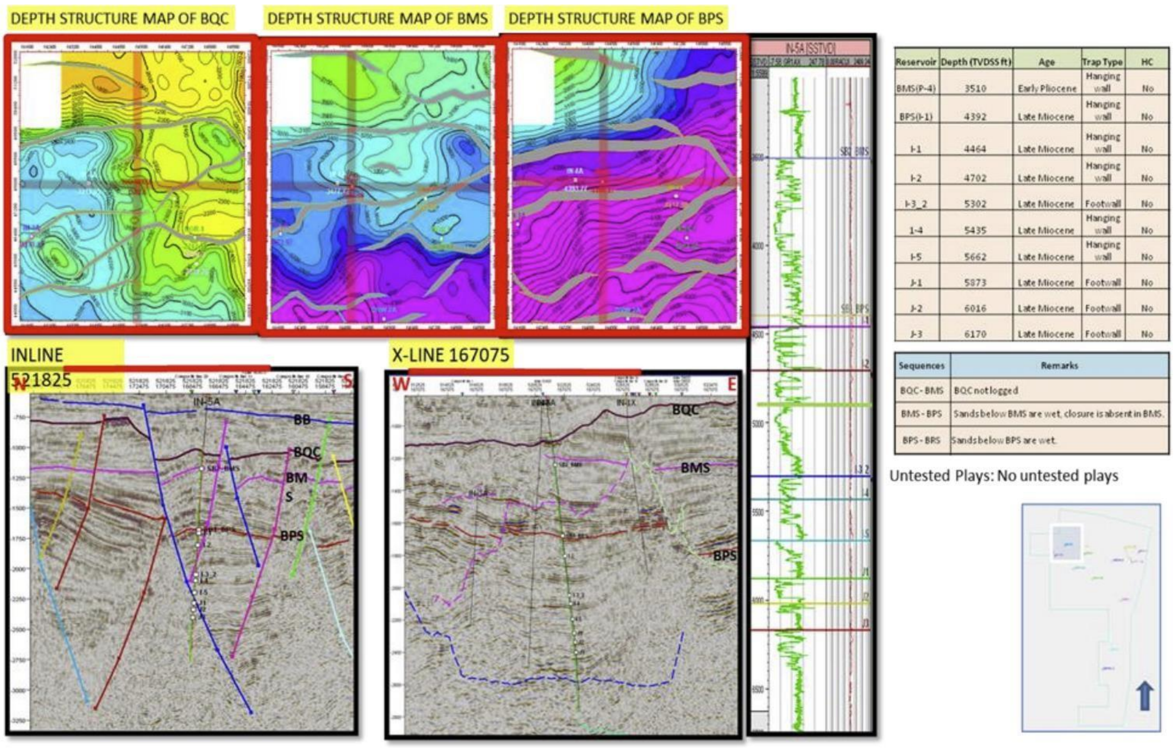


Figure17:Inagha-EfiatMacroStructure(INAGHA5A).

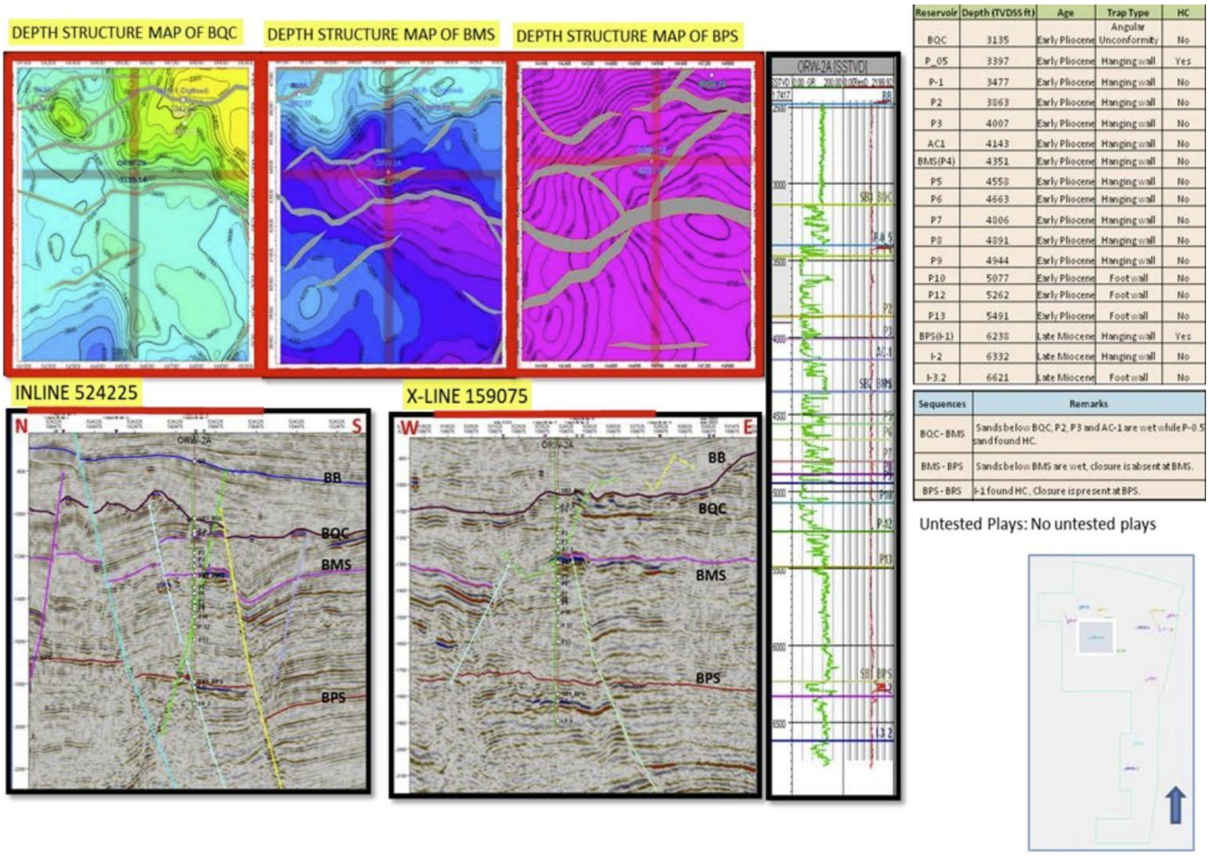


Figure18:OronMacroStructure(ORW-2A):EarlyPlioceneandLateMioceneHanging walls Plays.

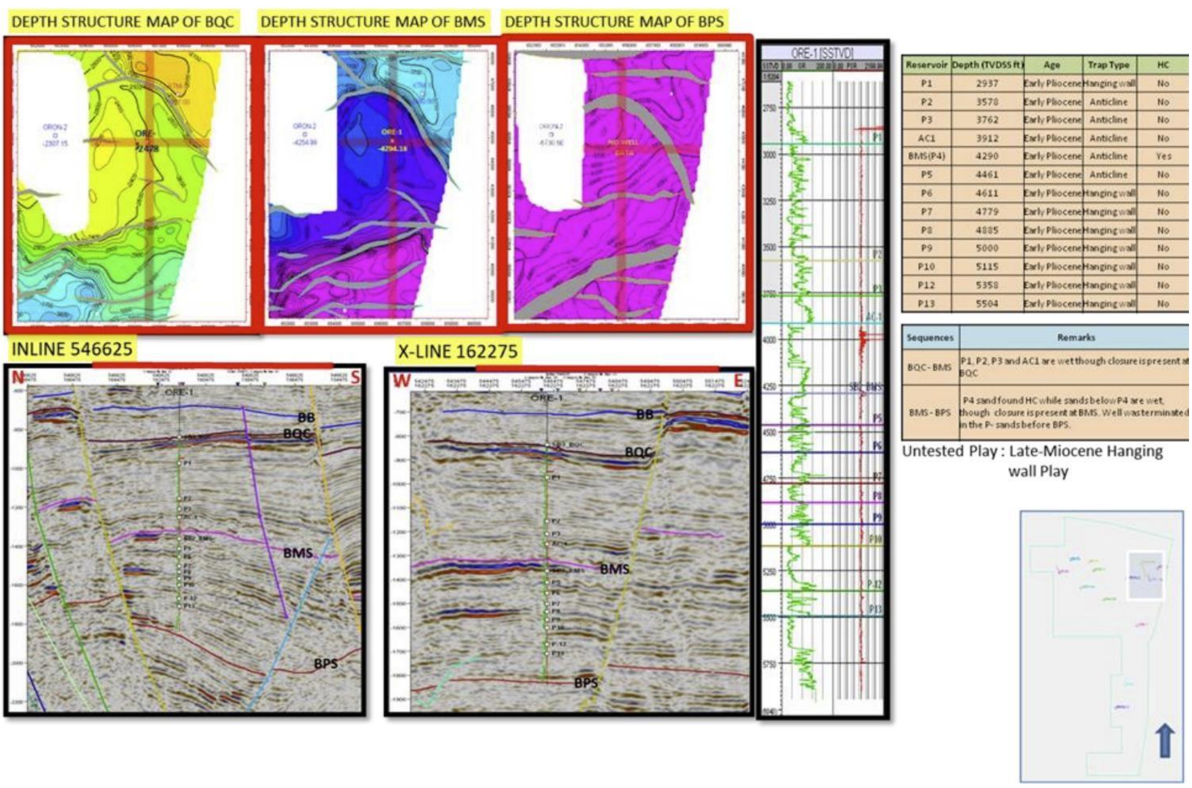
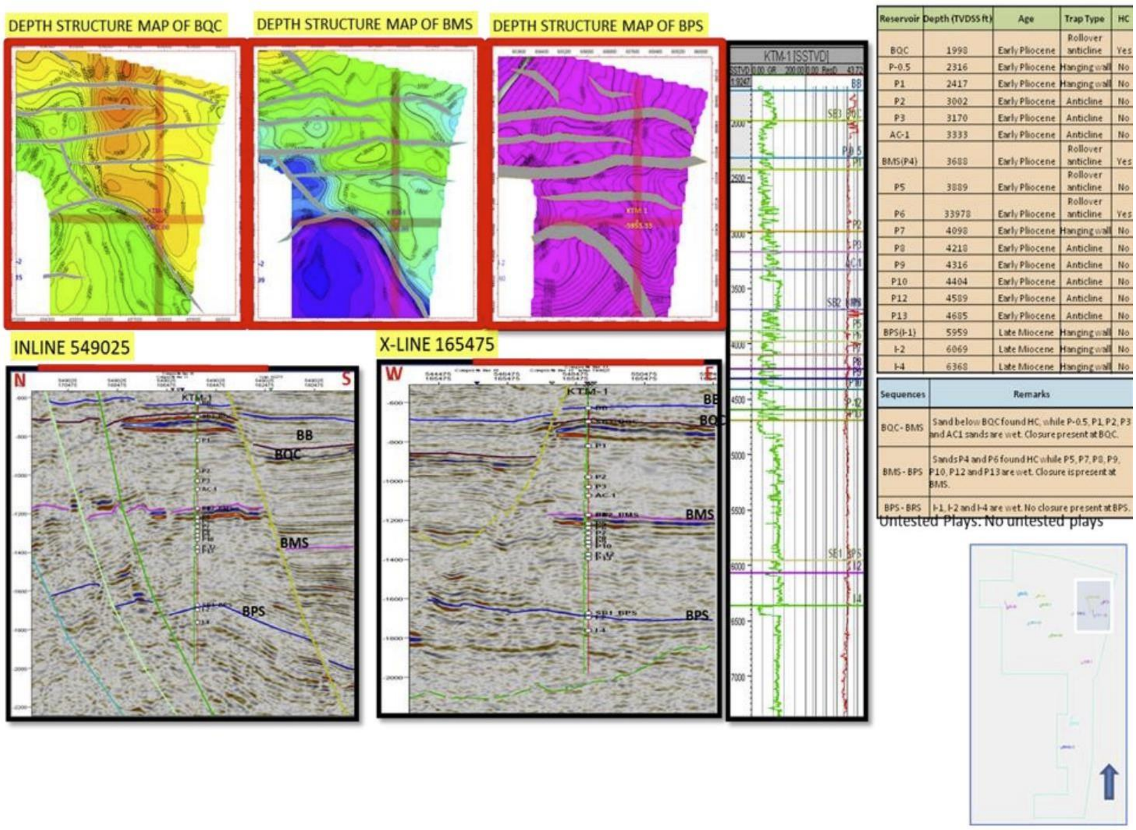


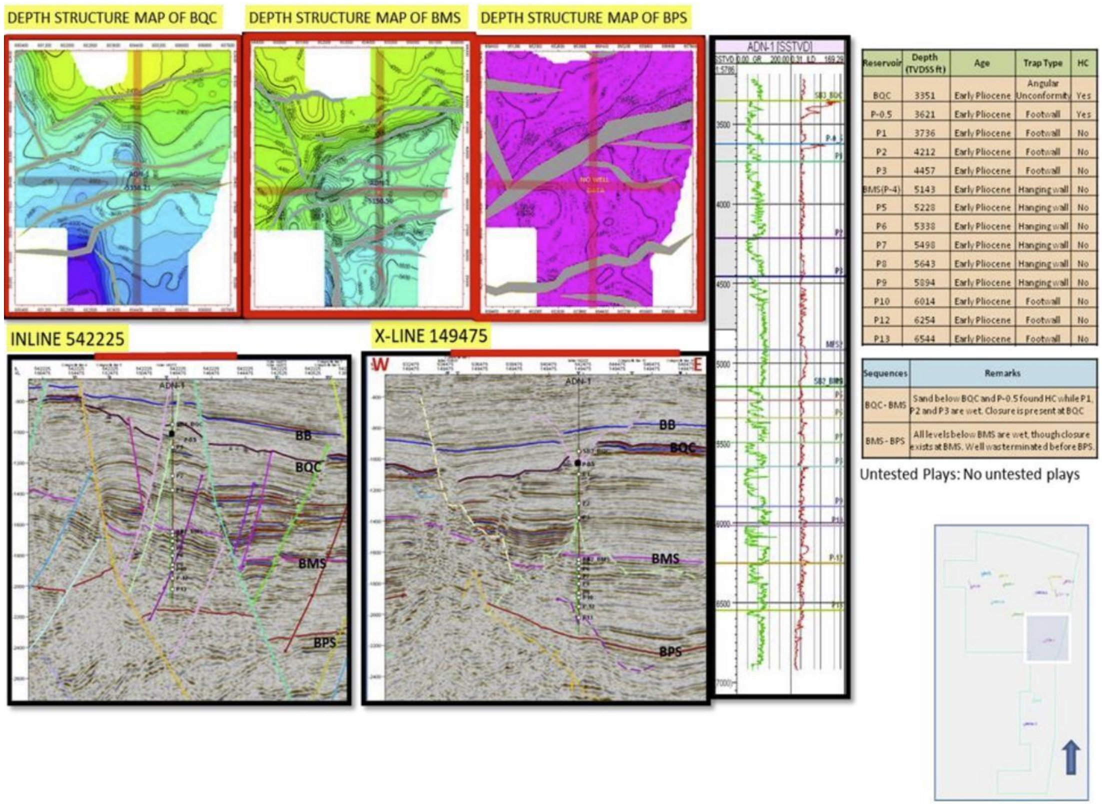
Figure19:OronMacro Structure(ORE-1):EarlyPlioceneAnticline Plays.



Reservoir	Depth (TVDSS ft)	Age	Trap Type	HC
BQC	1998	Early Pliocene	Rollover anticline	Yes
P-0.5	2316	Early Pliocene	Hanging wall	No
P1	2417	Early Pliocene	Hanging wall	No
P2	3002	Early Pliocene	Anticline	No
P3	3170	Early Pliocene	Anticline	No
AC-1	3333	Early Pliocene	Anticline	No
BMS(P4)	3688	Early Pliocene	Rollover anticline	Yes
P5	3889	Early Pliocene	Rollover anticline	No
P6	33978	Early Pliocene	Rollover anticline	Yes
P7	4098	Early Pliocene	Hanging wall	No
P8	4218	Early Pliocene	Anticline	No
P9	4316	Early Pliocene	Anticline	No
P10	4404	Early Pliocene	Anticline	No
P12	4589	Early Pliocene	Anticline	No
P13	4685	Early Pliocene	Anticline	No
BPS(I-1)	5959	Late Miocene	Hanging wall	No
I-2	6069	Late Miocene	Hanging wall	No
I-4	6368	Late Miocene	Hanging wall	No

Sequences	Remarks
BQC - BMS	Sand below BQC found HC, while P-0.5, P1, P2, P3 and AC1 sands are wet. Closure present at BQC.
BMS - BPS	Sands P4 and P6 found HC while P5, P7, P8, P9, P10, P12 and P13 are wet. Closure is present at BMS.
BPS - BRS	I-1, I-2 and I-4 are wet. No closure present at BPS.

Figure20:NorthernMacroStructure(KTM-1): EarlyPlioceneRollover anticline plays.



Reservoir	Depth (TVDSS ft)	Age	Trap Type	HC
BQC	3351	Early Pliocene	Angular Unconformity	Yes
P-0.5	3621	Early Pliocene	Footwall	Yes
P1	3736	Early Pliocene	Footwall	No
P2	4212	Early Pliocene	Footwall	No
P3	4457	Early Pliocene	Footwall	No
BMS(P-4)	5143	Early Pliocene	Hanging wall	No
P5	5228	Early Pliocene	Hanging wall	No
P6	5338	Early Pliocene	Hanging wall	No
P7	5498	Early Pliocene	Hanging wall	No
P8	5643	Early Pliocene	Hanging wall	No
P9	5894	Early Pliocene	Hanging wall	No
P10	6014	Early Pliocene	Footwall	No
P12	6254	Early Pliocene	Footwall	No
P13	6544	Early Pliocene	Footwall	No

Sequences	Remarks
BQC - BMS	Sand below BQC and P-0.5 found HC while P1, P2 and P3 are wet. Closure is present at BQC
BMS - BPS	All levels below BMS are wet, though closure exists at BMS. Well was terminated before BPS.

Figure21:AdangaMacroStructure(ADN-1):EarlyPlioceneAngularUnconformityand Foot Wall Plays

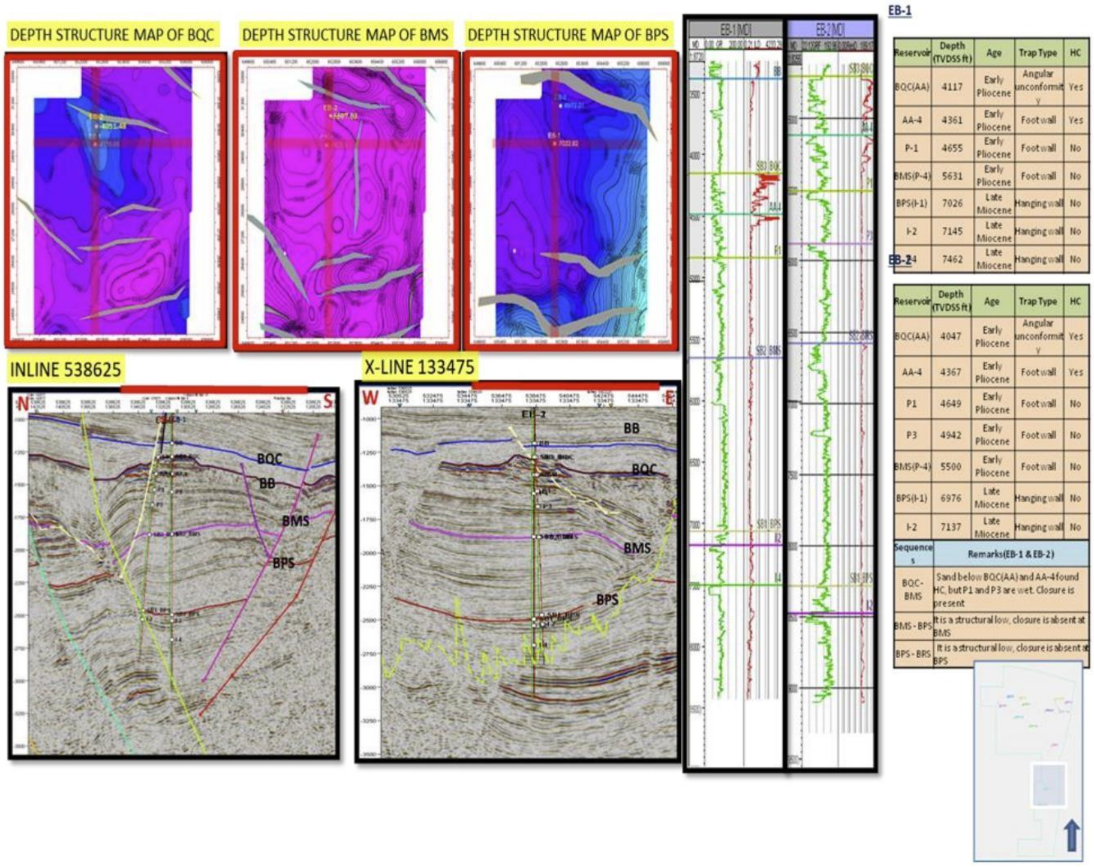


Figure22: EB-BO-MIMacroStructure(EB-1&EB-2):EarlyPlioceneAngular unconformity and Foot Wall Plays.

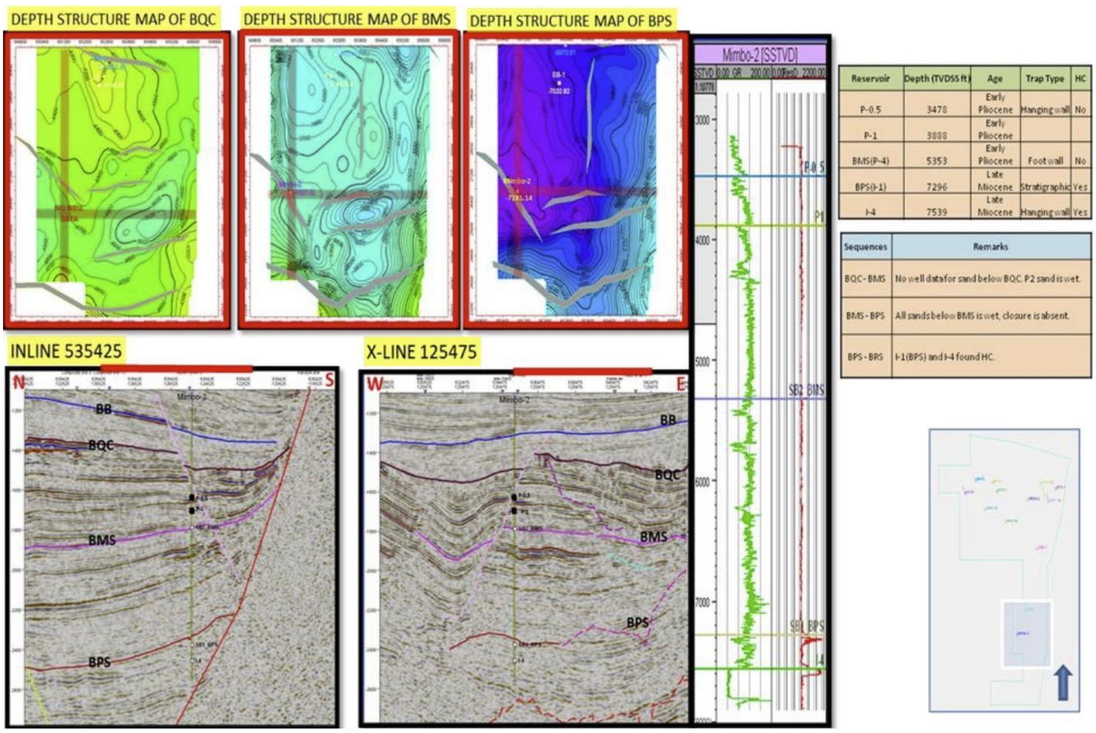
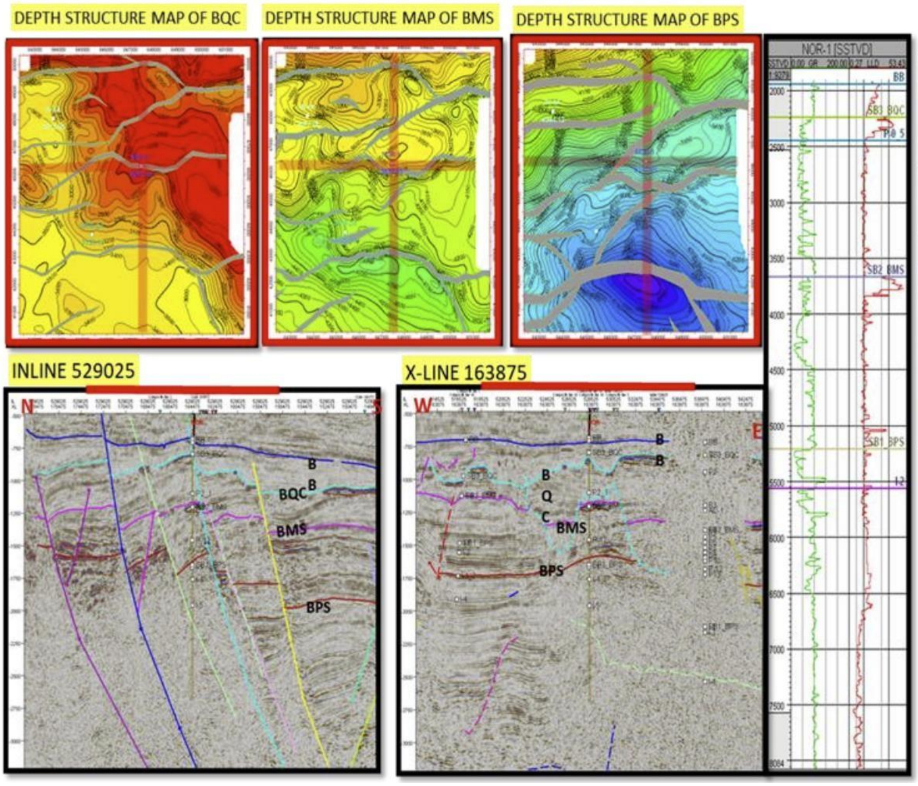


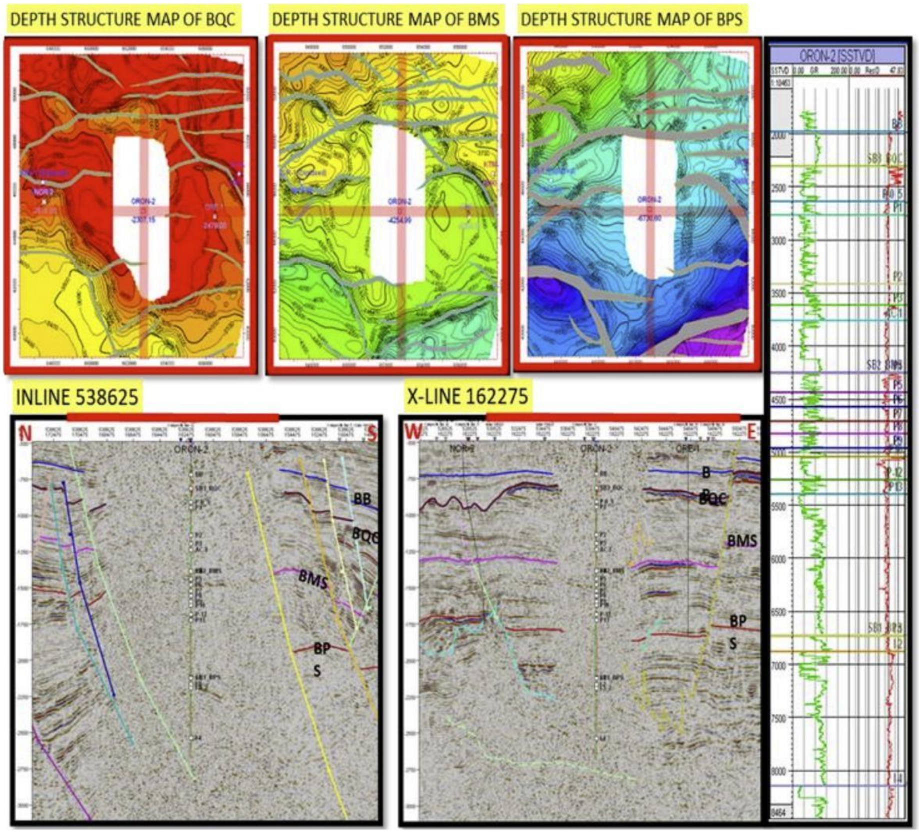
Figure23:EB-BO-MIMacroStructure(Mimbo-2):LateMioceneAngularUnconformity Plays.



Reservoir	Depth (TVDSS ft)	Age	Trap Type	HC
BQC	2250	Early Pliocene	Combination	Yes
P-0.5	2450	Early Pliocene	Foot wall	No
BMS(P-4)	3687	Early Pliocene	Foot wall	Yes
BPS(I-1)	5173	Late Miocene	Foot wall	No
I-2	5581	Late Miocene	Foot wall	No

Sequences	Remarks
BQC - BMS	Sand below BQC found HC, but P-0.5 is wet. Closure is present.
BMS - BPS	P4(BMS) sand found HC. Closure is present.
BPS - BRS	All levels below BPS are wet, though closure is present.

Figure24:OronMacroStructure(NOR-1):EarlyPlioceneCombinationPlays.



Reservoir	Depth (TVDSS ft)	Age	Trap Type	HC
BQC	2304	Early Pliocene		Yes
P-0.5	2632	Early Pliocene		No
P1	2758	Early Pliocene		No
P2	2768	Early Pliocene		No
P3	3606	Early Pliocene		Yes
AC-1	3758	Early Pliocene		Yes
BMS(P4)	4250	Early Pliocene		Yes
P5	4448	Early Pliocene		No
P6	4565	Early Pliocene		No
P7	4703	Early Pliocene		No
P10	5041	Early Pliocene		Yes
P12	5245	Early Pliocene		No
P13	5395	Early Pliocene		No
BPS(I-1)	6730	Late Miocene		No
I-2	6884	Late Miocene		No
I-4	8139	Late Miocene		No

Figure25:OronMacro Structure(ORON-2)

5. Conclusions

• ThebaseofBeninformationandthreekeystratigraphicerosionalsurfaces;BQC(BaseQua ibo channel), BMS (Base M shale), and BPS (Base P Shale) were identified in this study.

• Three predominantly prograding depositional sequences bounded by sequence boundaries were also delineated.

• BiostratigraphicreportindicatesthatsedimentageswithinOMLXYblockrangefromEarly Pliocene to Late Miocene.

• Depositional systems identified include prograding shoreline or delta and backsteppingshoreline

• Environment identified within the block range from upper to lower shoreface. Sedimentary depositswithintheblockinclude;marineshales,deltafrontsand,uppershorefacesands,lower shoreface sands, mouth bar sands, barrier bar sediments, and beach ridges sediments.

Abbreviations

3D Three dimensions; Sqkm: Square Kilometer; m: Meters; API: Unit of measuring gamma Ray log; SEGY: Seismic survey format; OML: Block concession in Niger Delta Basin; OPL: Block concession in Niger Delta Basin; MWD: Measurement while Drilling; LWD: Logging while Drilling; BPS: Base of P shale; BMS: Base of M shale; BQC: Base of qua-Iboe Shale; TST: Transgressive Sequence tract; HST: High system Tract; BB: Base of Benin; BRS: Base of R Shale.

Availability ofdata and materials

AllmaterialsanddatausedshouldbeavailableattheUniversityofLagos.Thedatasetsused

andanalyzedduringthecurrentstudyareavailablefromthecorrespondingauthoron reasonable request.

References

1. Akande, S.O., Adegoke, O.S., Akintola, A.I. et al. (2021). Depositional environments and sequence stratigraphy of the Lower Cretaceous Ajali Sandstone in the Anambra Basin, Southeastern Nigeria. Journal of African Earth Sciences, 175, 104207.

2. Adegoke, O.S., Oloto, I.N., Fadiya, S.A. et al. (2019). Sedimentary facies and sequence stratigraphy of the Oligocene-Miocene Akata Formation, Niger Delta Basin, Nigeria. Journal of African Earth Sciences, 154, 16-29.

3. Alimi, H.T., Adekoya, J.A., and Adeyemo, I.A., 2019. Sequence stratigraphy and depositional environment of the offshore Niger Delta. Journal of Petroleum Science and Engineering, 175, 468-486.

4. Ehirim,C.N.,Onuoha,K.M.,Okeugo,C.C.etal.(2020).Stratigraphicanalysisandsequence stratigraphy of the Imo Formation in the southeastern Anambra Basin, Nigeria. Journal of African Earth Sciences, 162, 103704.

5. Egbobawaye, E.O., Odeyemi, I.B., &Adelana, S.M. (2017). Facies analysis and sequence stratigraphy of the Benin Flank Depo-Belt, Western Niger Delta Basin, Nigeria. Journal of African Earth Sciences, 129, 119-133.

6. Kogbe,C.A.(2006).GeologyofNigeria'ssedimentarybasins.CSSBookshopLimited.

7. Nwajide, C.S., Adeleye, D.R., &Oladele, S.O. (2016). Petroleum geology of the Niger Delta: Past, present and future. Journal of Petroleum Technology and Alternative Fuels, 7(3), 1-17.

8. Ola-Buraimo, A.O., Afolabi, A.O., and Akinmosin, A., 2020. Sequence stratigraphy and reservoir prediction in the Niger Delta. Journal of African Earth Sciences, 163, 103690.

9. Okosun, E.A., Oyedele, K.F., and Olatunji, S.A., 2021. Depositional history and stratigraphicarchitectureofshallowmarinedepositsintheNigerDelta:Insightsfromsequence stratigraphy. Marine and Petroleum Geology, 124, 104884.

10. Oresajo, B. S. ,adekeye, A. O. And haruna, K. A., 2015 Sequence stratigraphy and structural analysis of the emifield,Offshoredepobelt, eastern niger delta basin, Nigeria, Ife Journal of Science vol. 17, no. 2 (2015).

11. Nwajide,C.S. (2016).Petroleum geologyoftheNiger Delta. Springer.

12. Odigi, M. I., Oluwajana, G. O., Olusiji, S. O., &Ojo, A. O. (2018). Sedimentology of the Niger Delta: A review of depositional environments and geological history. Journal of Petroleum Science and Engineering, 164, 456-472.

13. Olabode, S.O., Adekoya, J.A., &Oyedele, K.F. (2019). Structural evolution of the Niger Delta Basin: A review. International Journal of Geosciences, 10, 767-777. doi: 10.4236/ijg.2019.108042.

14. Ojo, O.A., Olorunfemi, M.O., Oyebamiji, A.S. et al. (2020). Stratigraphic and paleoenvironmental implications of foraminiferalbiofacies in the CenomanianTuronian sequence of the Niger Delta Basin. Journal of African Earth Sciences, 170, 103974.