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Research Article

PETROLEUM APPRAISAL STUDY OF POTA WELL, BAHIA FIELD, OFFSHORE COTE D'IVOIRE, WEST AFRICA

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ABSTRACT

Petroleum studies of the study area using Construction of synthetic seismogram to tie seismic to well helped to locate the top reservoir horizon. Velocity analysis and use of 'V0-k' depth conversion approach with probabilistic consideration helped to convert time to depth with base case structural crest at -6700fl TVDss. The approach generated three possible cases of GRV's that were incorporated with Petrophysical parameters to generate the volume of hydrocarbon in place. The GIP probabilistic ranges from the result are: low case (14.4 bcf), base case (22.6 bcf) and high case of 36.3 bcf. STOIIP base case calculation estimated a total volume of 3.40 mmstb. Petrophysical analysis estimated an average porosity of 21% in the discovery well with OWC at -6821 and GOC at -6813ff TVDss.Oil stain in core is from 6785-6801.6ft TVDss. The pressure-depth plot over the well show anomalous data points that probably related to supercharged' formation. Reliability of the pressure data to infer fluid contact presented high level of uncertainty. Core information from the well identified the reservoir Lithology to be medium to coarse grained arkosic sandstone interbedded with shak and siltstone. Core permeability is estimated at a geometric mean value of 3.1mD with carbonate cement affecting the reservoir quality in the water leg.

Keywords: Petroleum, Offshore, Cote d' Ivoire, Appraisal, Bahia Field

INTRODUCTION

Hydrocarbon resources remain very vital to the economy of many nations of the world. The high cost of exploration for this all-important resource makes it necessary for the attainment of high level of perfection in the methods adopted for its detection and quantification Since cost effectiveness is the driving factor in oil and gas industry, there is a great need to use effective method to quantify the reservoir with reduced level of uncertainty associated with geological models. Drilling of an oil well is a very costly venture coupled with the fact that hydrocarbon reserve are depleting. The deposits yet undiscovered are in more complex geological environments and hence it is important to exploit new development with higher resolution seismic reflection methods.

LOCATION AND STRATIGRAPHIC SETTING OF THE STUDY AREA:

The Study Area is called a POTA WELL located in Bahia Field, offshore Cote d'Ivoire, West Africa it is about 8km north east of the east espoir field of cote d'Ivoire basin

Geologically, The three-stage tectonic regimes in the Côte d'Ivoire basin allows the stratigraphic section to be divided into three main sequences (See figure 1):

1. Precambrian to Triassic intracratonic rocks and Jurassic to Lower Cretaceous continental to marginal marine rocks representing the pre-transform stage,

2. Lower Cretaceous Albian rocks representing the syn-transform stage and

3. Cenomanian to Holocene rocks representing the post-transform stage. Sedimentary fill within the Ivory Coast Basin is more than 6,000 m thick north of the Romanche fracture zone, which acted as a dam to the transport and accumulation of sediments to the south (Brownfield and Chapentier,2006).

General stratigraphic dip is dominantly to the south but the Albian tilted fault block strata dips to the north (Coteril et al,2002;. Blareze & Mascle, 1980)

The pre-transform sediments have not been penetrated by drilling in the basin but have been identified in neighbouring Ghanaian basin. The syn-tranform sediments of the Albian age are the main hydrocarbon bearing reservoirs in the basin and the Bahia reservoir is located in the Late Albian sand. The post-transform sediments of Late Cretaceous to Holocene are the youngest sediments in the basin. The stratigraphic divisions have been mapped seismically and biostratigraphicaily with unconformities surfaces that correspond to the following sequence boundaries: 25.5Ma sequence boundary (Miocene), 83 Ma (Senonian) sequence boundary (Post-transform), and 96.5 Ma (Albian) sequence boundary as Syn-transform sequence boundary

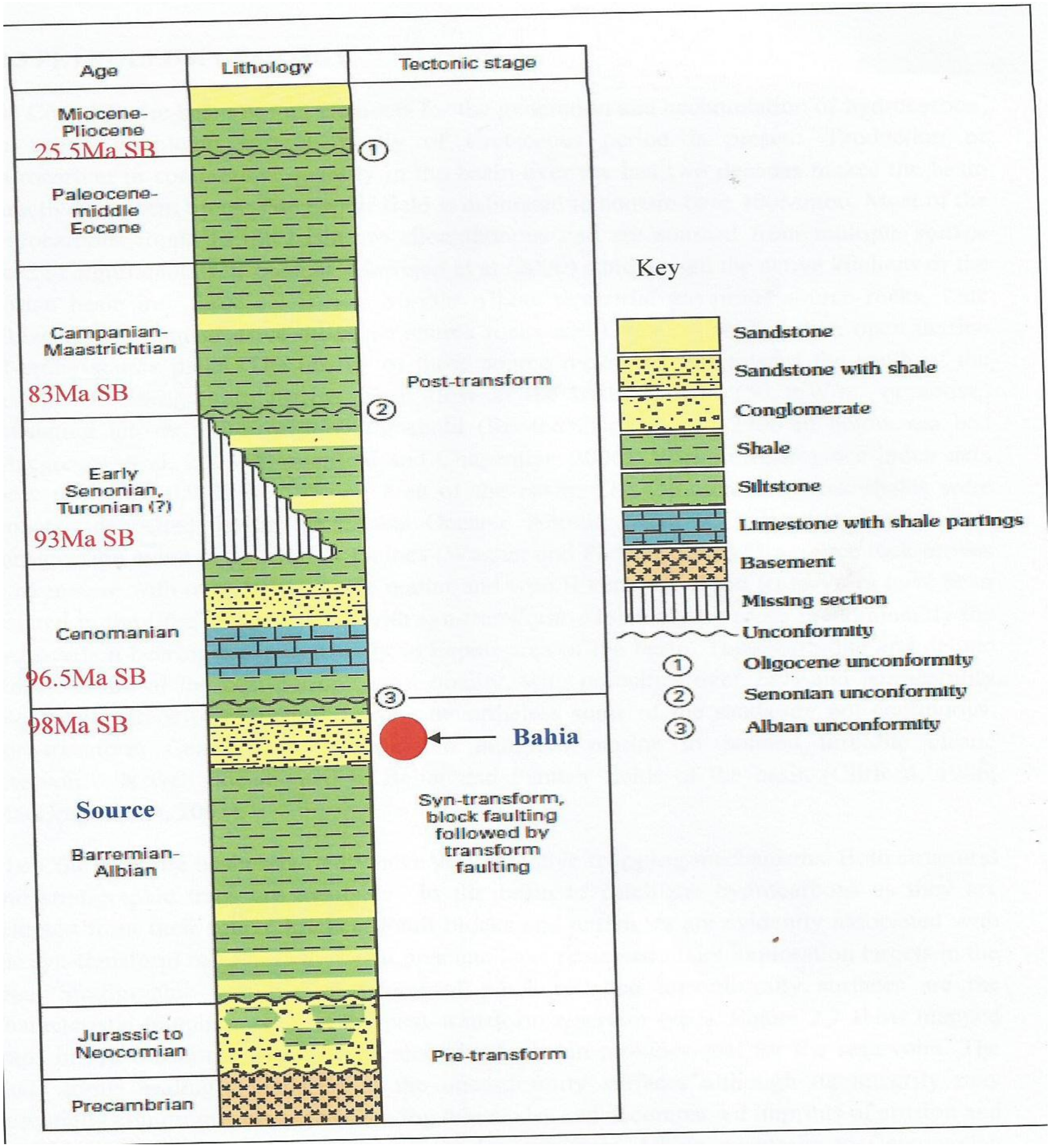


Figure 1: Generalized stratigraphy of the central and western parts of the Cote d' Ivoire basin

PETROLEUM GEOLOGY:

The Côte d'Ivoire basin has all elements for the generation and accumulation of hydrocarbon (See figure 2). An active petroleum system mostly of Cretaceous period is present. Production of hydrocarbon in commercial quantity in the basin over the last two decades makes the basin attractive in recent times. The Espoir field is estimated to contain over 400Mmbo.(Cameron, 1999)

Most of the hydrocarbons found in the basin are allochthonous and are sourced from multiple source rocks of significant TOC content. Morrison et al (2000) summarised the active kitchens of the Ivorian basin into three categories: Middle Albian terrestrial gas-prone source rocks, Late Albian marine transgressive oil-prone source rocks and Cenomanian-Turonian open marine oil-prone source rocks. The quality of these source rocks increase toward the south of the basin becoming more marine. Heat flow in the basin is high (50 mW/m2 or above) translating into an oil generation threshold (Ro'—43.6%) of around 2700 m below sea bed (Macgregor et al, 2003; Brownfield and Chapentier, 2006). Vitrinite reflectance index data show up to 0.7-0.9 % in Espoir area of the basin.(Smallwood, 2002)

The Cenomanian black shales were probably deposited during the Global Oceanic Anoxic Event (GOAE) that denotes first transgression event in the Gulf of Guinea (Wagner and Plestch, 1999).The source rock proves to be mature with over 10% organic matter and type II kerogen. Good Reservoirs have been isolated in the Côte d' Ivoire basin with syn-transform Albian elastic rocks predominantly the hydrocarbon bearing rocks especially in Espoir area of the basin. (Clifford, 1986).

These turbidite and deltaic sandstone are of the best petrophysical quality, with porosities over 22% and permeability into the hundreds of mD (millidarcies) nevertheless some of the sands are not continuous. Post-transform Cenomanian-Maastrichtian marginal marine to ponded turbidite clastic reservoir is well documented in Belier and Panther fields of the basin (Clifford, 1986; MacGregor et al, 2003).

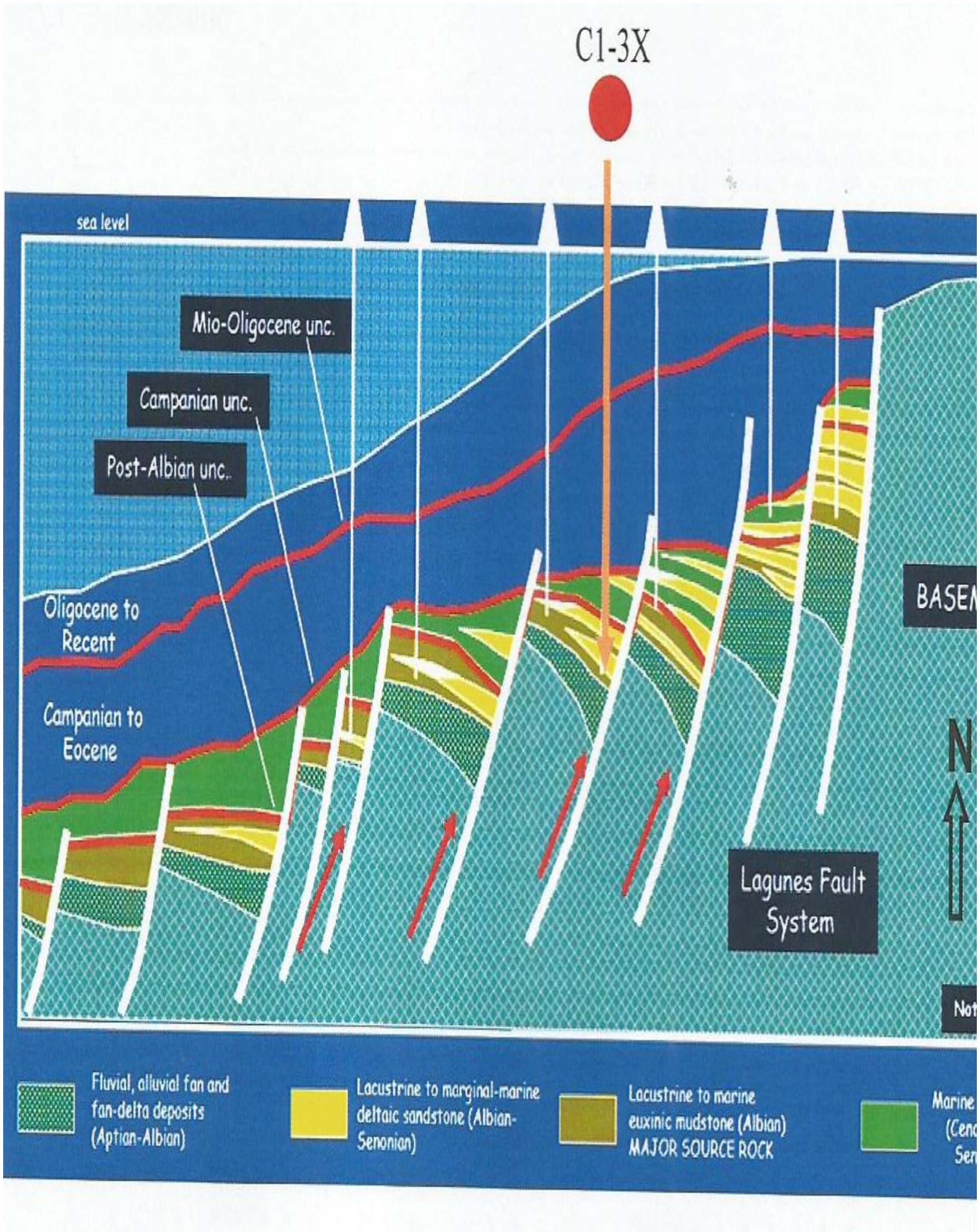


Figure 2: Migration paths in the Cote d Ivoire Basin

The Côte d 'Ivoire basin reportedly have very effective trapping mechanisms. Both structural and stratigraphic traps are available in the basin to catch the hydrocarbons as they are released from their source kitchen. Fault blocks and anticlines are evidently associated with the syn-transform reservoirs in Espoir area and have remained major exploration targets in the area. Stratigraphic traps in the form of pinch out and unconformity surfaces are the characteristic trapping styles of the post—transform reservoir types (De matos 2000).

Thick shale in the basin provides seal for the reservoirs. The shale forms sealing boundaries at the unconformity surfaces although its integrity may potentially compromised in areas having thin shales and accompanied imprints of erosion and could probably account for observed gas leakage from Albian reservoirs to Cenomanian reservoir in nearby fields in the basin. The migration of hydrocarbon in the basin is considered up-dip along faults from older source kitchen to younger reservoirs. Maturation and migration are known to occur in Early and Late Cretaceous times

AIM OF THE STUDY

The outcome of this project will increase understanding of the Bahia (field) discovery and influence future decision towards development of the Bahia field.

Key deliverables include:

Synthetic seismogram of well C1 -3X

Time to Top reservoir (structure) map

Depth to Top reservoir map

Hydrocarbon pool size (STOIIP and/or GIP)

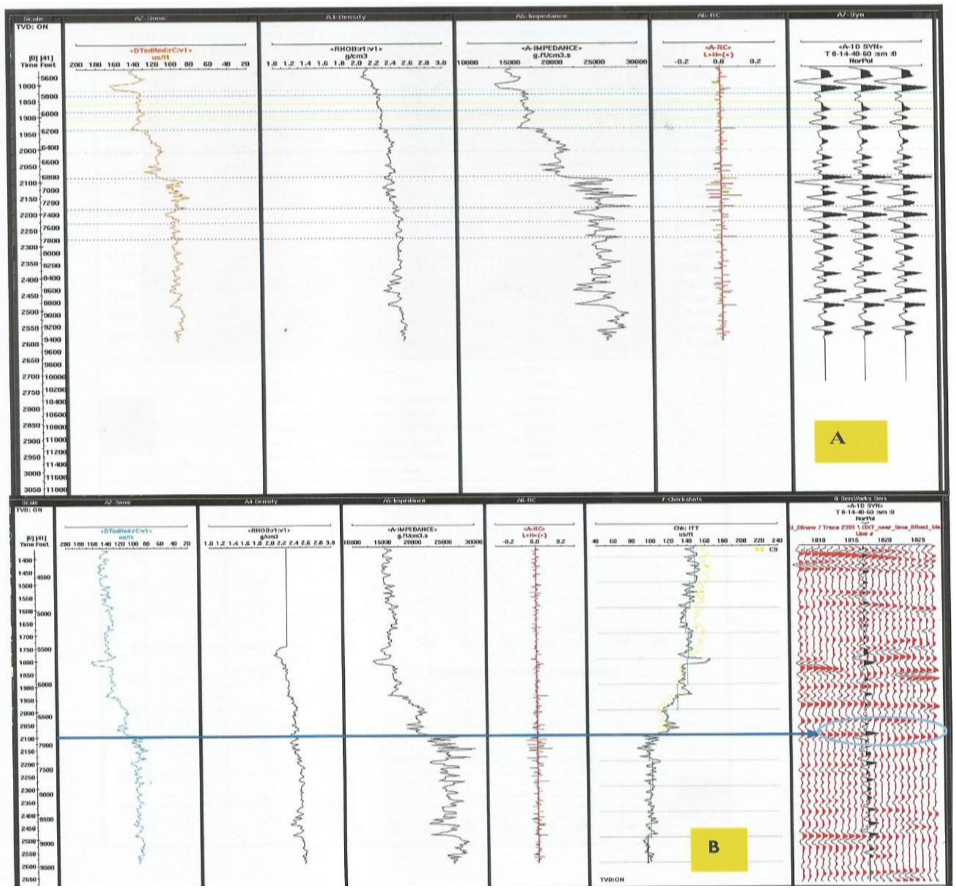
Hydrocarbon types (oil and/or gas) associated with the field.

Reservoir quality information

(I) METHODS AND INTERPRETATION OF DATA

SEISMIC MARKERS:

The top Albian horizon is a regional unconformity surface in the entire Cote d' Ivoire basin. Biostratigraphic studies show the surface to be 96.5Ma. It produces a very strong positive black peak. Other seismic makers in the basin are the Senonian unconformity surface (83Ma) and the Miocene unconformity surface 25.5 Ma figure 3. These correlative surfaces (sequence boundary) are important surfaces for velocity analysis in the basin.



Fiugure 3: (a) Synthetic generated with 8-1440-60 wavelenght

(b) Synthetic seismogram generated with Synthetic generated with 8-1440-60 wavelength tied to seismic trace at well location

VELOCITY MODEL OVERVIEW:

The velocity model used for the depth conversion is the acceleration function method similar to CNR depth conversion method. This method is useful in strata that have several interval velocities and where a single average velocity is insufficient. This method is called the 'V0-k' method and is popular in the petroleum industry.(Smallwood 2002) documented that due to increasing pressure and overburden of the underlying strata with depth below sea bed, the porosity of the strata will decrease with depth and so the rock density increases in response which causes the instantaneous velocity increase with depth. A constant 'K' is used which is the rate at which velocities increases with depth within a given interval While VO is the velocity value at the datum level and is used as a reference value for the K value for each interval.V0 shows the discrepancies from a function which is related to velocity uncertainties. The depth conversion is carried out using equation 2 and 3 considering changing velocities within each interval.

Vint = Thickness *2000 equation(2)

4STWT

Where; Vint = Interval Velocity at depth Z

Thickness = Thickness of interval(Isopach)

4TWT = TWT difference of top and base interval (isochron)

2000 = Constant to convert TWT milliseconds to OWT seconds

Vint = VO + KZ equation (3)

Where; Z = Mid point depth below datum

VO = Velocity at reference datum (intercept of slope with interval velocity Y- axis)

K Gradient of slope (an acceleration constant which accounts for the rate at which velocity increases with depth due to compaction) and Vint = Interval velocity at depth Z.

The input needed for VO —K depth conversion is derived from well data. The interval velocity, Vint is calculated for each interval by using the thickness of the interval (Isopach) and the time thickness (isochronous) from top to base of the interval (equation2).The mid-point interval velocity is plotted against the mid-point well depth .The slope of the graph represent the 'K' value, while the intercept with the interval velocity axis is taken as the 'VO' value.

RESULTS AND INTERPRETATION

HORIZON INTERPRETATION:

Two- way- time horizon interpretation of the 3D seismic data was carried out in SeisWork module of OpenWorks. The Mid offset cube was mostly used for the interpretation especially in areas of poor data quality as it show the top reservoir better and has less dipping noise but has low frequency content and the positioning may be less accurate (figure 4 and 5).

The other reason behind using the mid offset cube is to show interpretation uncertainty over the structure in relation to the near offset cube previously picked by CNR. Prior to interpretation a multiple prediction volume was created in the Poststack Pal to help predict possible peg-leg multiples that could lead to wrong interpretation.

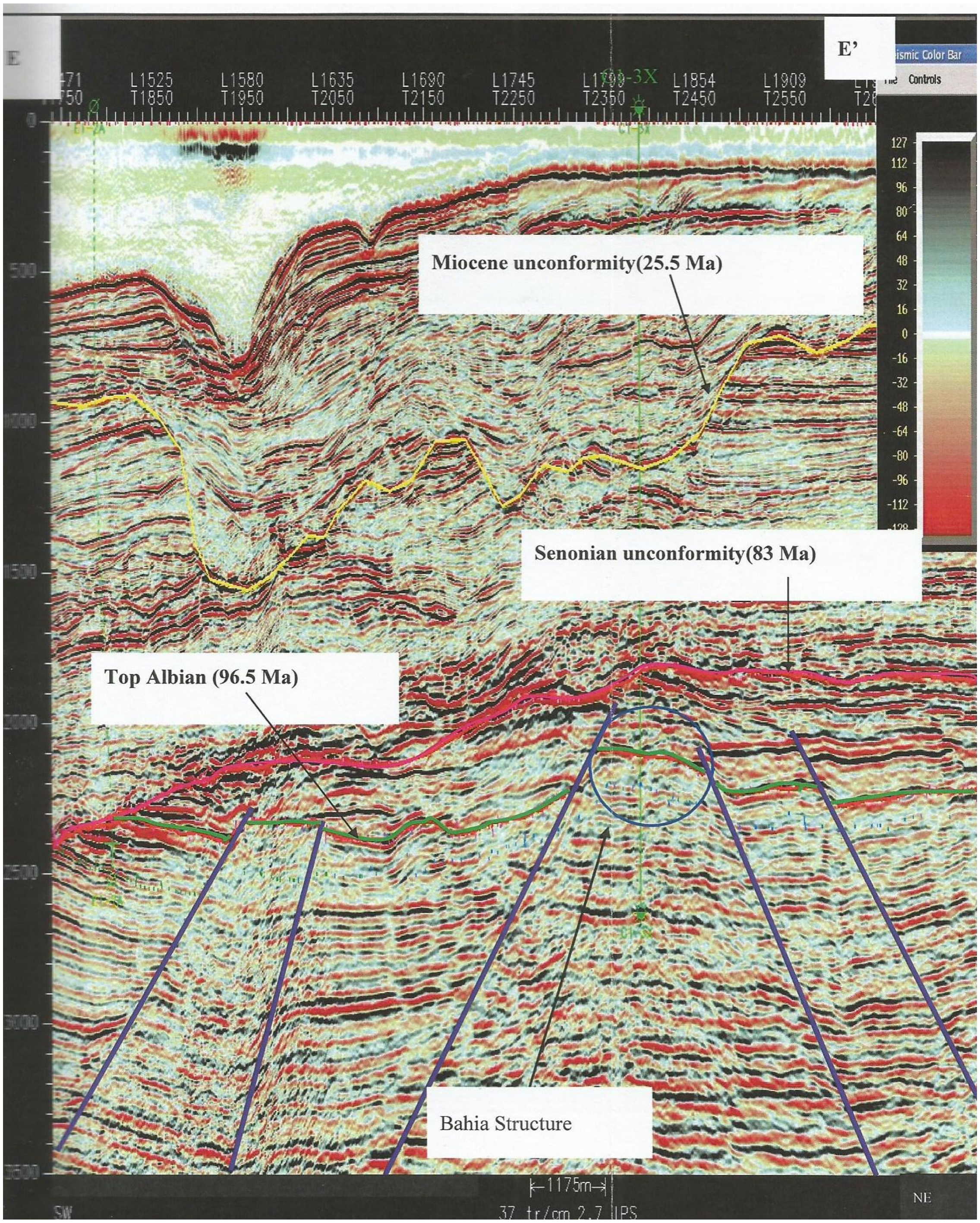


Figure 4: Seismic analysis of the study Area

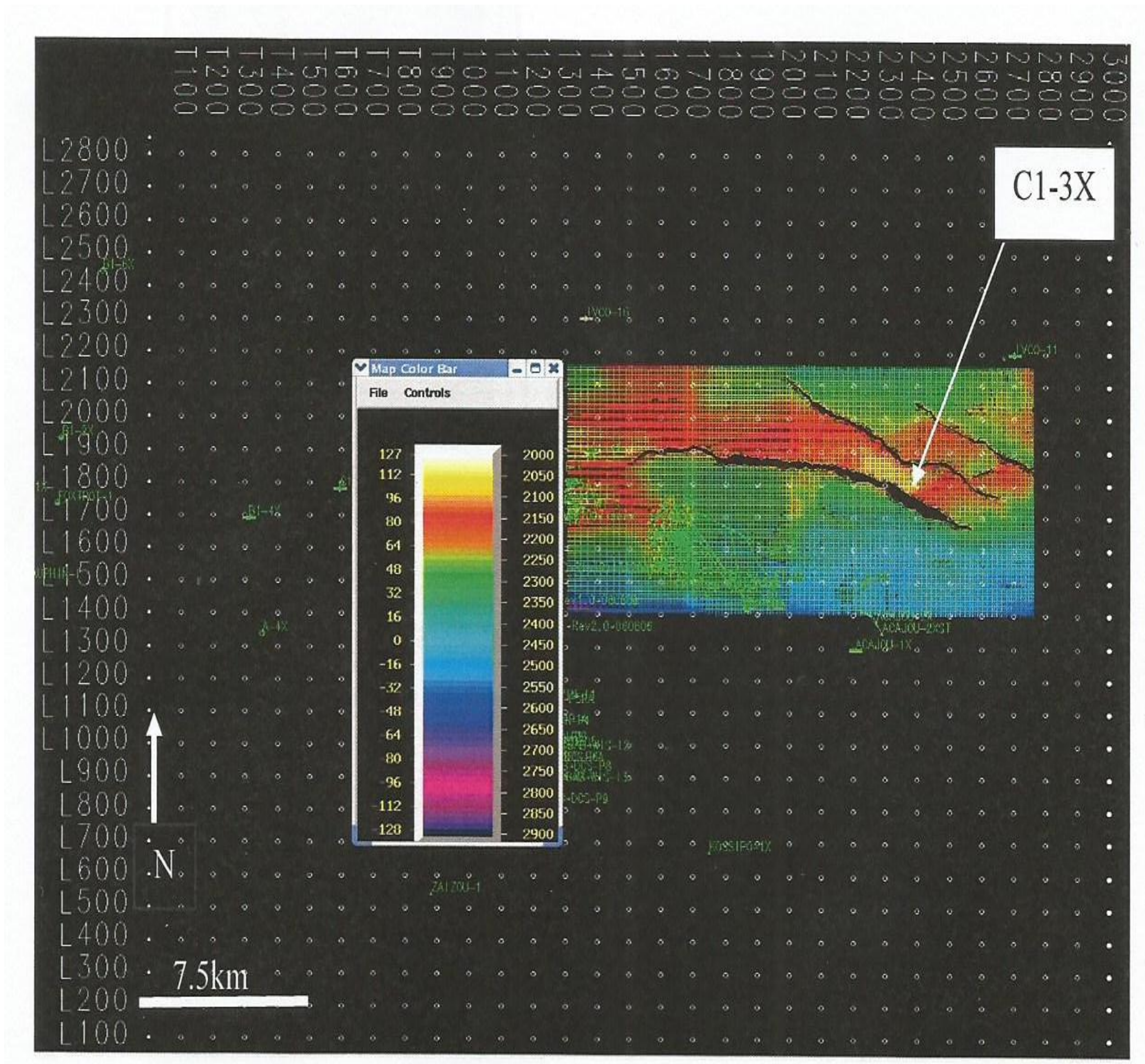


Figure 5: Top Albian TWT Interpreted grid

This multiple prediction volume was used (as overlays) on the section for the interpretations. Picks were carried out in a 1.0 xl 0 grid and 5x5 grids in some areas, on strike and dip lines. The top Albian horizon is marked to be the positive black peak on the seismic data.. Several attempts made to map the base horizon could not yield positive results due to poor data quality.

Reflection discontinuities on the E-W (strike) line suggest minor faults that could form reservoir barriers that were not evident in the dip lines. Amplitude attenuation at some points on the reservoir horizon is probably related to gas effects. About three cases of possibilities were created based on the TWT resultant maps using the mid offset cube picks as the low case, the CNR near offset cube picks as the high case and average of the two picks served as base case for the TWT interpretation of the Bahia Structure (See figure 6).

The three cases are presented in TWT structure maps.

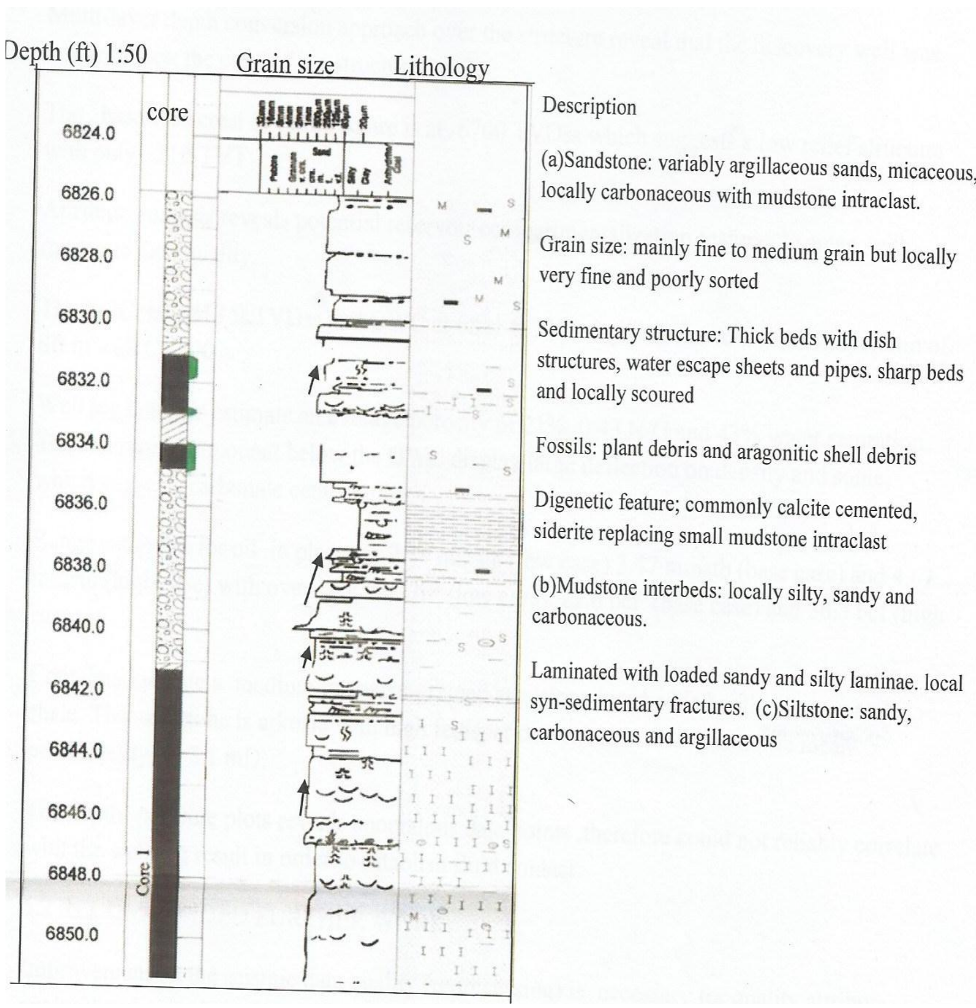


Figure 6: Sedimentary core log of well C1-3X

PETROPHYSICAL ANALYSIS:

The well log data was analyzed using the Eclogic software to generate petrophysical parameters used in reservoir volume calculation.. The sand are quite distinct on gamma logs with their logs spiking to the left (See figure 7).

The cleanest sand has an average gamma log value of 29 API. Vshale values were calculated from both the sonic, gamma, and Neutron-Density logs with Vshale cut off of 50% .Reservoir porosity calculation using the density, sonic and neutron porosities resulted in an average porosity of 21% . The resistivity log signatures show clear separation between the deep and shallow resistivity log signatures within the zone interpreted as hydrocarbon bearing sand. The Sw is calculated using the Archie's equation. The result is presented on Pickett plot

The gas leg GOC interpreted at -6813 ft TVDss and the OWC at - 6821 ft TVDss. The analysis shows about 8ft of oil column in the well. Series of spikes with the neutron- density logs resting on each other show carbonate cements that are present in the sand packages below the interpreted OWC

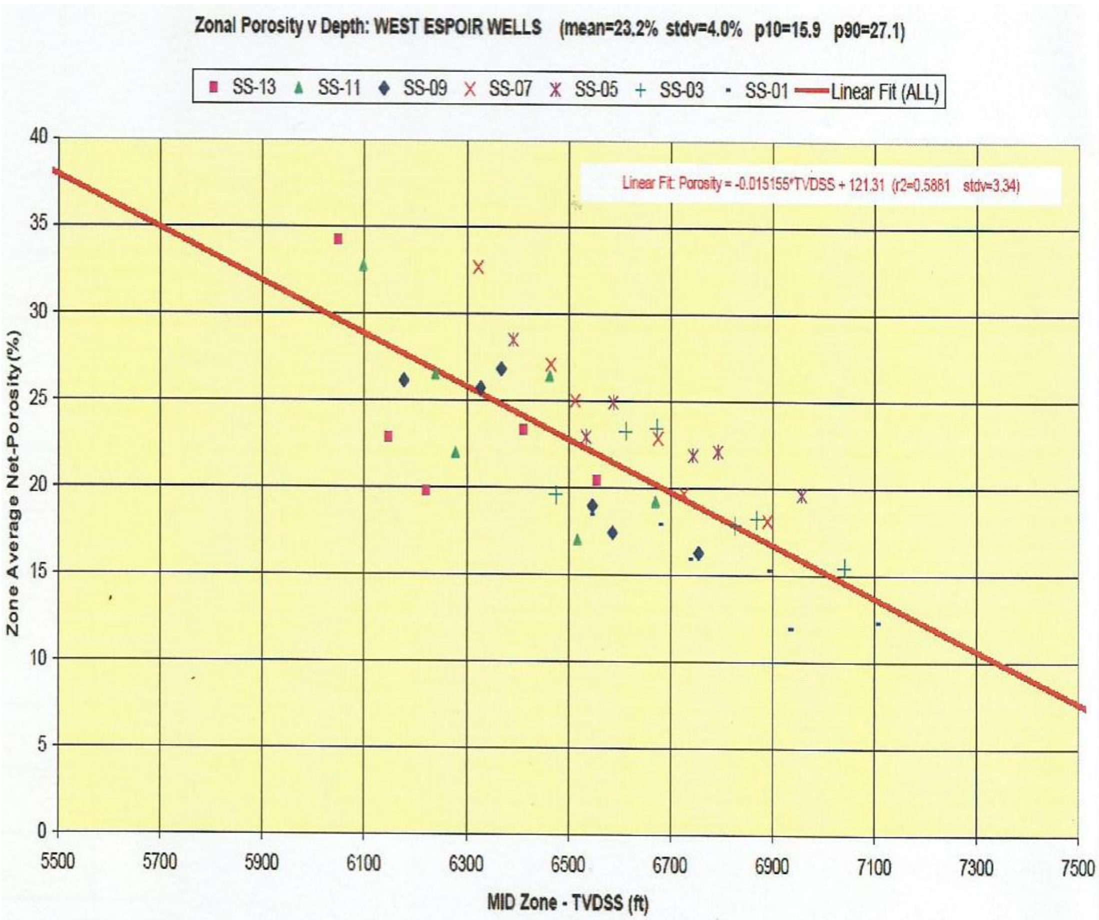


Figure 7: Regional Porosity plot West Espoir

DEPTH CONVERSION:

Depth conversion is one of the cardinal objectives of this project, so a thorough depth conversion approach was adopted in order to tie the existing wells and accurately predict horizon depth using the other wells in the nearby fields.

Depth conversion of Bahia Area:

The depth conversion was carried out using macros in the Z-map module of OpenWorks. The first approach was to crosscheck and edit well data provided from the CNR database.

Series of errors were corrected on the data by comparing the check shot data in Seiswork with the values on the CNR well data table as quality control measure. Exportation of the data to Z-Map in art ASCII format followed.

The four seismic intervals recognised in the region were adopted to split the overburden into four packages. They are:

(a) Sea water-Vint = 485OftJsec

(b) Sea bed to Miocene unconformity (25.5 Ma)

Vint=5203 +(0.533xZ)

(c) Miocene unconformity (25.5 Ma) to Senonian unconformity (83 Ma)

Vint=5040 + (0.4638 x Z)

(d) Senonian unconformity (83 Ma) to Late Albian unconformity (96.5 Ma)

Vint = 5494 + (0.39389 x Z) -Vint and Z retain their meanings

All these explanation of these intervals were shown on seismic. The only well in the field is well C1-3X located in the south —east of the field and therefore represents poor well control. The VO values for each of the intervals were gridded and contoured to generate velocity maps of the intervals to be the base case for the velocity models.

To predict possible velocities towards the north-west of the field, control points (pseudo velocities) were added to see how the velocity could vary in this area without wells. The lower case scenario involved increasing the velocity towards the north-west and the high case scenario involved decreasing the velocity in the same north-west area. These three probabilistic cases were used to depth convert the three cases of TWT picks accordingly i.e. base case VO with base case TWT (P50), high case VO with high case TWT(PlO) and low case VO with low case TWT(P90).

Depth conversion Result:

The velocity models show significant anomalies in some wells. The main VO trend involved faster velocities towards the North. This could be attributed to probable increase in sand materials towards the land while the decrease to the south (basin ward) may be connected to the increase in finer siliciclastics. Increase in finer sediments towards the southern part of the basin has been reported by McGregor et al 2003. Well log correlations do not show meaningful trend but depict the complexity of the entire region.(See Table 1& 2) for input data for STOIIP calculation and results

Velocity anomaly in sediments is controlled by various factors such as sand-shale ratio, overburden change, mineralogy, and fluid variation. Post depositional behaviour such as cementation also influence velocity

The result of the depth conversion is presented as maps on for the low case, base case and high case respectively.

Variables	Unit	shape	mm	mid	max
GRV	Acre-Ft	triangle	3907	4991	9191
N/G	%	triangle	35	43	70
0	%	triangle	18	18	22
SW	%	triangle	34	34	50
FVF (l/Bg)	Scf/cf	triangle	1.29	1.29	1.29

Table 1: Input data for STOIIP calculation

Ranges	**GIIP (bcf)**
P90	2.44
P50	3.40
P10	4.67
Mean	3.47

Table 2: Result of STOIIP

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