PETROPHYSICAL AND SEISMICS ANALYSIS OF TUGA FIELD, NIGER DELTA BASIN NIGERIA

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Abstract: The evaluation of the seismic attributes of Tuga Field, Onshore Niger Delta, Southern Nigeria using 3D-seismic data was undertaken. Six shale and five reservoir sand units were identified. All of these units were penetrated by three wells. The results revealed that the rock properties are variable and are controlled by environments of deposition during Oligocene – late Miocene. The Shales had high acoustic impedances, high transmission coefficients and low reflection coefficients compared to sands. The Seismic attributes analysis also revealed rock properties in terms of fluid content and depositional environments with moderate - high amplitude and strong reflection strength with continuity being continuous to chaotic and truncated by faults. From seismic attributes and gamma log motif, depositional environments of fluvio-deltaic plain, deltaic front and open shelf margin are inferred. The oil and gas yield of the field is high and can be exploited at profit.

Key Words: Delta, Seismic data, Deposition, Environment.

1. INTRODUCTION:

The Field first discovery was made in 1975 by TUGA Well-01 which found some 264ft NGS and 307ft NOS in 11 intervals. A total of 5 wells have been drilled into the Tuga structure encountering 19 reservoirs between the depth of 7,000 and 12,000 feet. Thirteen of these reservoirs are oil bearing while 6 are gas bearing. Two of the oil bearing reservoirs are planned for further development. No hydrocarbon bearing reservoirs were logged in well-01. There are 7 completed drainage points in 4 wells, all producing under primary recovery technique.
The TUGA 3D seismic survey was carried out in 1996 after TUGA 2D seismic survey acquired in 1972. A total of 180km2 and 100km2 of 15 fold data with 25m x 25m bin spacing were acquired for the TUGA 3D survey.

2. LOCATION OF THE STUDY AREA:

The TUGA FIELD is located in the coastal swamp region of the western onshore Niger Delta, Nigeria. It lies between latitudes 5^0 52' 50" and 6^0 15' 00"N and longitudes 4^0 81' 25" and 4^0 92" 25"E.

Fig. 1: SHOWING MAP OF NIGER DELTA WITH PRODUCING OIL FIELDS.

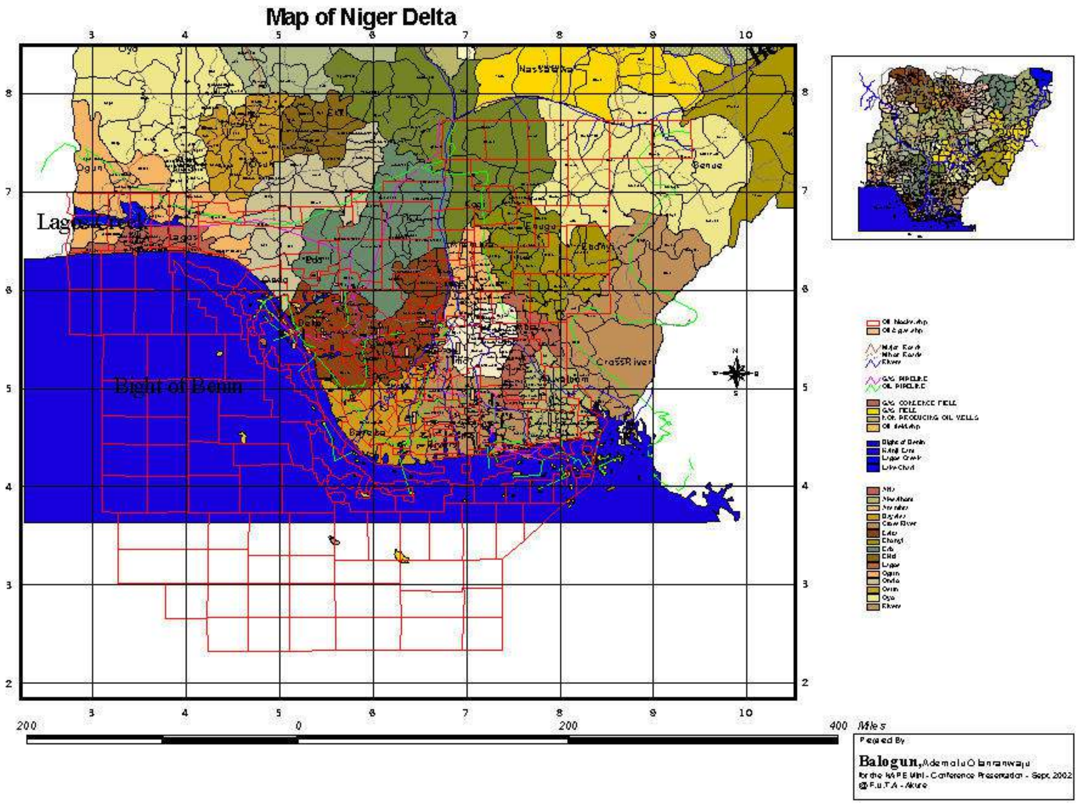

Fig. 2 Map of the Niger Delta

3. STRATIGRAPHY OF THE NIGER DELTA:

The stratigraphy of the Niger Delta is intimately related to its structure. The development of each being dependent on interplay between sediment supply and subsidence rate.

Short and Stauble (1967) recognized three subsurface stratigraphic units in the modern Niger Delta. The delta sequence is mainly a sequence of marine clays overlain by parallic sediments which were finally capped by continental sands.

BENIN FORMATION: - The formation comprising over 90% sandstone with shale intercalations extends from the west across the entire Niger Delta area and southward beyond the present coast line. The thickness though variable is estimated at about 6000fts. It is coarse grained, gravelly, poorly sorted, sub-angular to well rounded and bears lignite streaks and wood fragment.

The formation is characterized by structural units such as channel fills, point bars etc which indicate variability of the shallow water depositional medium. The Benin formation with very little hydrocarbon accumulation ranges in age from Oligocene to Recent.

AGBADA FORMATION: - The formation is a sequence of sandstones and shales with sandstone dorminant in the upper unit and thick shales in the lower unit. It is very rich in microfauna at the base decreasing upwards suggesting an increase in the rate of deposition at the delta front. The grains are coarse and poorly sorted indicating a fluvatile origin.

The Agbada Formation covers the entire subsurface of the delta and may be continuous with the Ogwashi-Asaba and Ameki formations of Eocene- Oligocene age. It is over 10,000ft thick and are the major hydrocarbon bearing unit in the delta.

AKATA FORMATION: - The formation underlies the entire delta and forms the lower most unit. It is a uniform shale development consisting of dark grey sandy, silty shale with plant remains at the top. The Akata formation is typically overpressured and believed to have formed during lowstands when terrestrial organic matter and clays were transported to deep water areas characterized by low energy conditions and oxygen deficiency (Statcher 1995). It is over 4000ft thick and ranges in age from Eocene to Recent and is believed to have been deposited in front of the advancing delta.

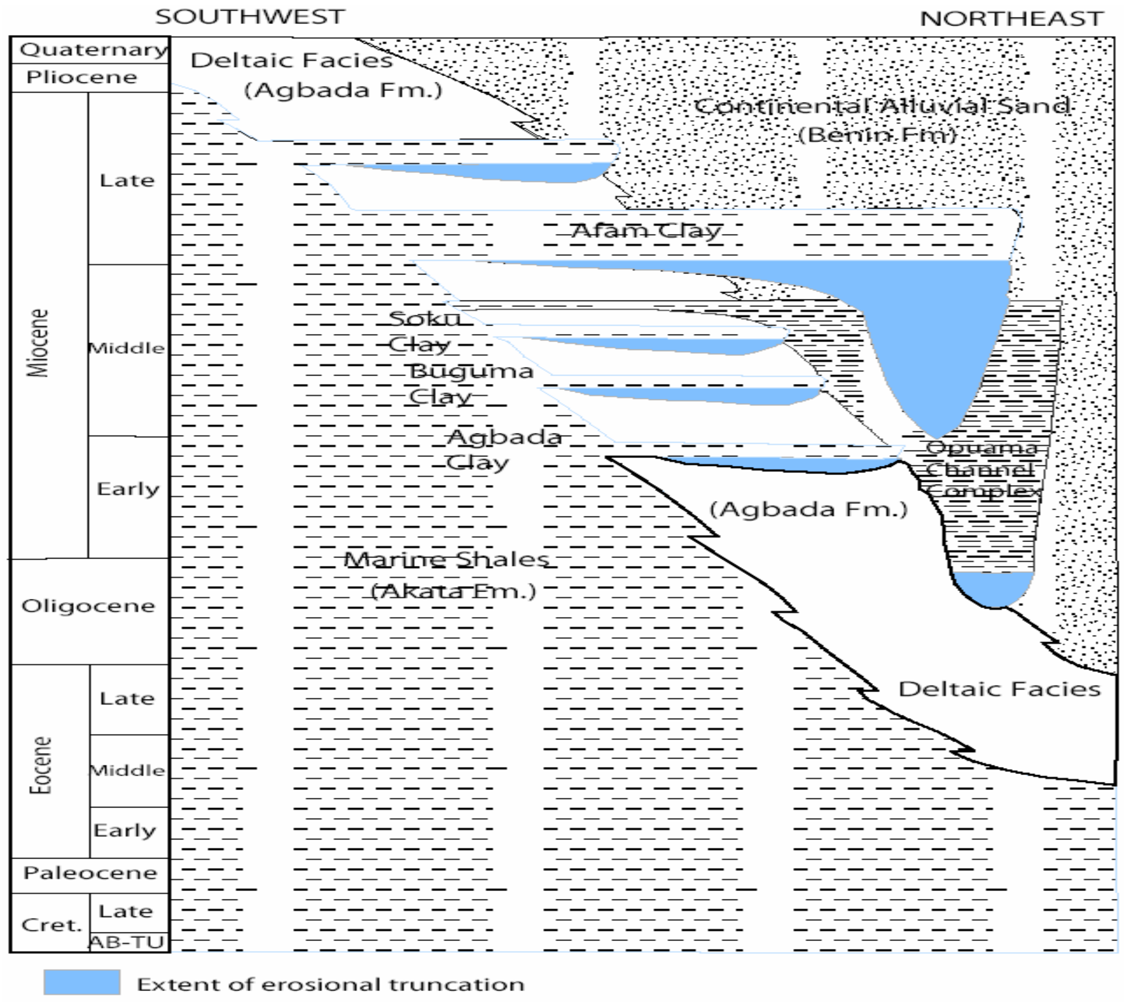

Fig. 3; Stratigraphic column showing the three formations of the Niger Delta (Modified from Doust and Omatsola, 1990).

4. METHODOLOGY:

Data Sets

The following data sets were obtained and used for this study:

- 3D Seismic sections
- Structure Contour Map
- Check shot data

Seismic Sections

For this study, 5-profile lines of a 3D-Seismic section of Tuga Field were obtained. The section included 1 X-line (Strike line) section and 4 In-line (Dip line) sections. The X-line section shows reflected events at time window of 1,500 – 3,300 msec and between T1000 and T1350 offsets, with well locations between T1160 and T1220 while the 4-Dip line sections (Traces 1153, 1169, 1185 and 1201 show the events between L5700 and L6440 offsets. Figure 2.4 shows the X-line seismic section while Figures 2.5 – 2.8 show the traces of the dip-line section.

The seismic section and the traces were used for:

- Overall sub-surface appraisal of structural features
- Tracking lateral variation and changes in lithofacies
- The analysis of the seismic attribute
- Evaluation of the field in combination with geophysical logs

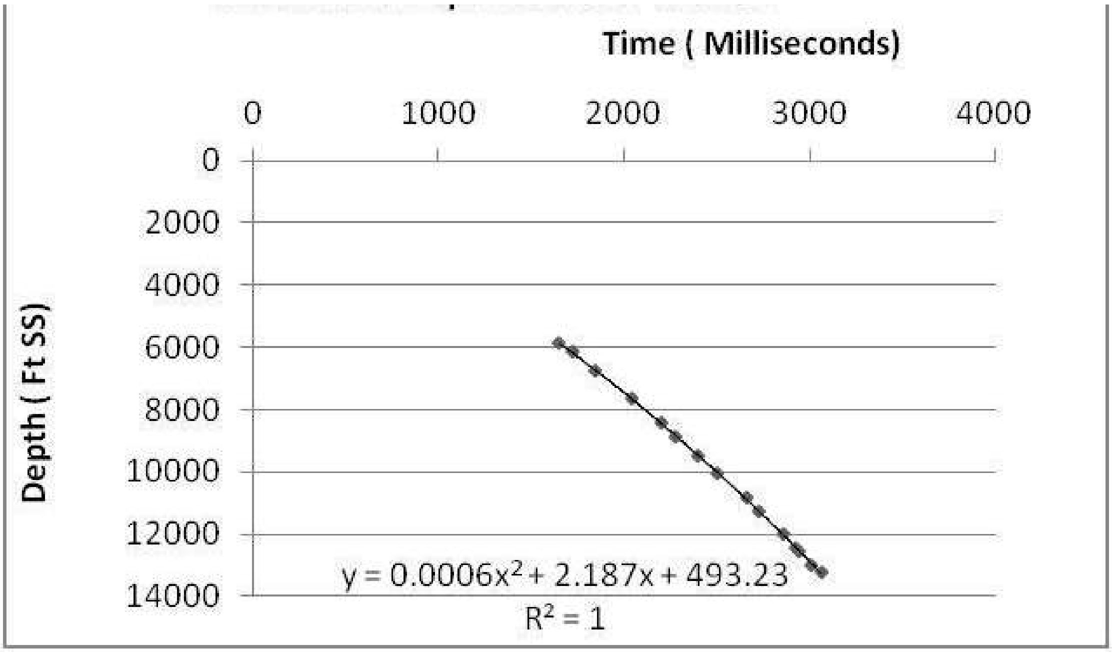

Figure 4: A plot of survey check shot travelling time against depth at Tuga 01. TD: 13343.0ft. Sampled depth range: 5878.0 - 13245.0ft. Time is 2-Way.

5. RESULTS AND INTERPRETATION:

Seismic Attribute Interpretation

a. X-Line Section

. The attribute of seismic reflection packages identified from X-line seismic section

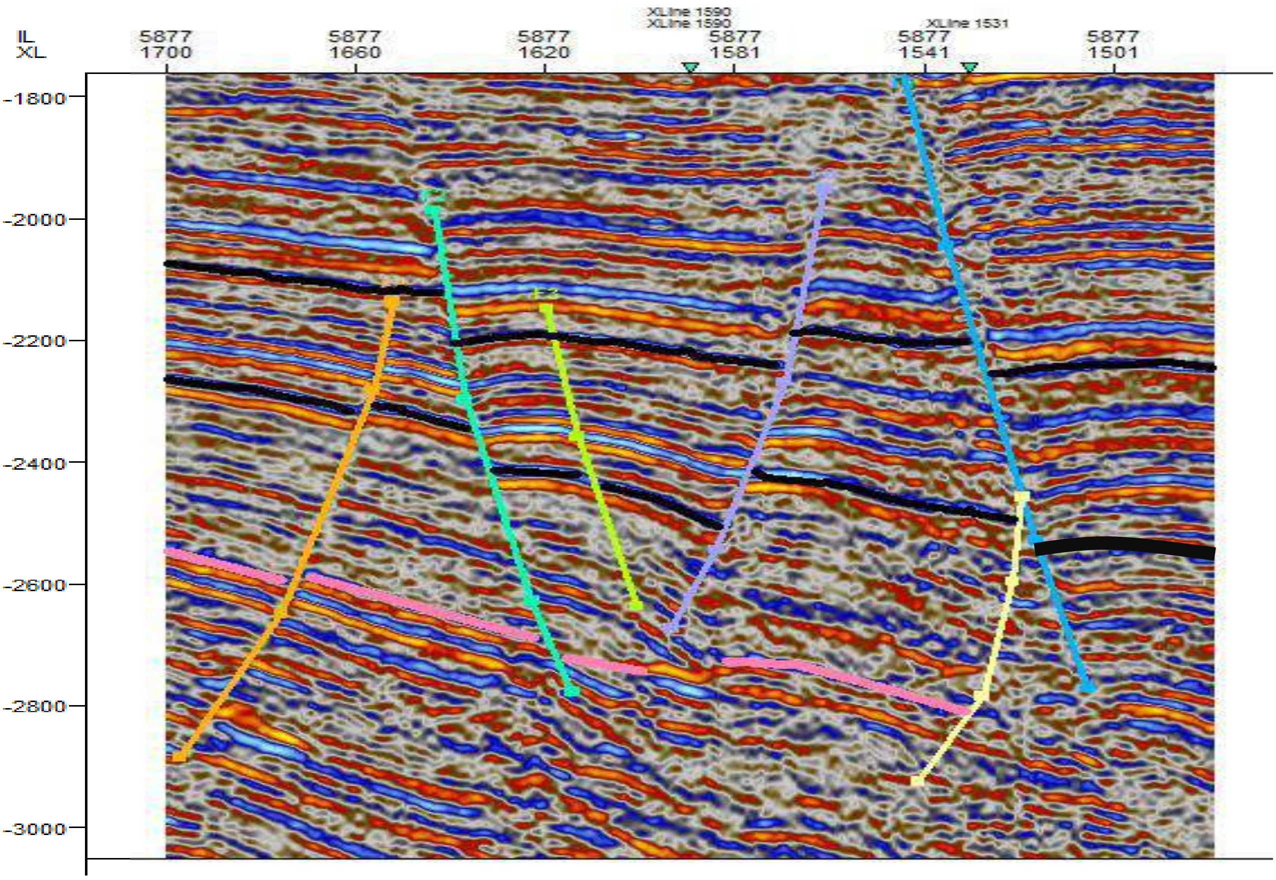

Figure 5: Faults (F), seismic packages / facies (A, B and C) and diapiric structure (S) mapped on X-line section. Bold upward arrow indicates direction of diapiric intrusion.

From Figure 5, three (3) seismic reflection packages labeled A, B, and C, from top to bottom, was identified based on their reflection patterns. Between shot points T1000 and T1350 and between the time windows of 1500msec to about 2500msec, the beds in Unit A tend to be continuous with parallel – sub-parallel, strong reflection strength, uniform frequency and high amplitude. This unit is interpreted as massive sand body with shale intercalations deposited in a low energy deltaic plain / platform and shelf margin shoreface.

Six faults identified were designated F1, F2, F3, F1, F2, and F3. Fault F1, F2, and F3 are synthetic (growth) faults that dip in the basinward direction while faults F1, F2, and F3 are antithetic faults dipping in landward direction.

Unit B, just below Unit A, is characterized by sub- parallel (variable parallel to divergent) reflection pattern, poor to moderate continuity and low-medium amplitude. This Unit also displays weak to moderate reflection strength and downlap on yet another package. It extends from time window of about 2200msec to about 3150msec.\

This unit is interpreted as thick sand body with inter-bedding shales deposited in a low – medium energy deltaic front; inner - middle neritic shelf margin. Well-logged intervals are within this Unit. That is, within the time slice of about 2650 - 3150msec.

The seismic reflection package labeled Unit C displays hummocky to chaotic configuration, with weak reflection and low amplitude. Reflection continuity is poor to very poor. This unit might have been formed by gravity mass transport in a high energy basin slope, submarine canyon, lower

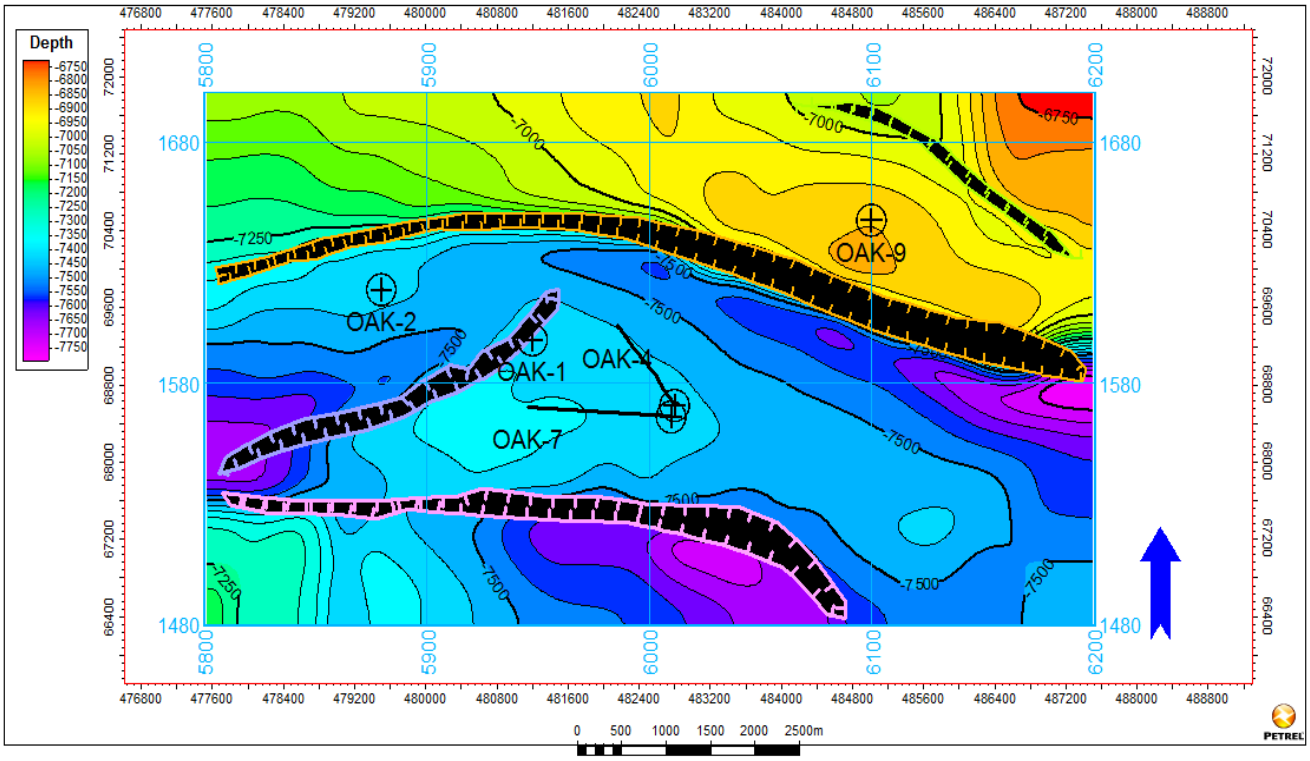

Figure 6 : Depth Structure map of Reservoirs

b. In-Line section (Traces 1153, 1169, 1185 and 1201) shows the seismic attributes on In-line section (traces 1153, 1169, 1185 and 1201). 2500-2600msec , the reflection are very continuous with moderate reflection strength and medium amplitude. The high continuity suggests widespread and uniform deposition along the strike direction. High amplitude suggests that the beds are relatively thick. Moderate reflection strength implies a relatively moderate variation in acoustic impedance contrast in lithofacies of the unit A.

From the In-line sections (traces 1153, 1169, 1185 and 1201), five (5) seismic reflection packages / units labeled A, B, C, D and E, from top to bottom, were identified. An overall view of these sections / traces reveals a parallel and wavy reflection patterns which become discontinuous, discordant and weakly chaotic with variable reflection strength easterly from about shot point L6350. The parallel and wavy reflection patterns suggest a uniform condition of deposition on uniformly subsiding substratum.

Unit A shows both the vertical and lateral facies variation and shift in time windows. Between

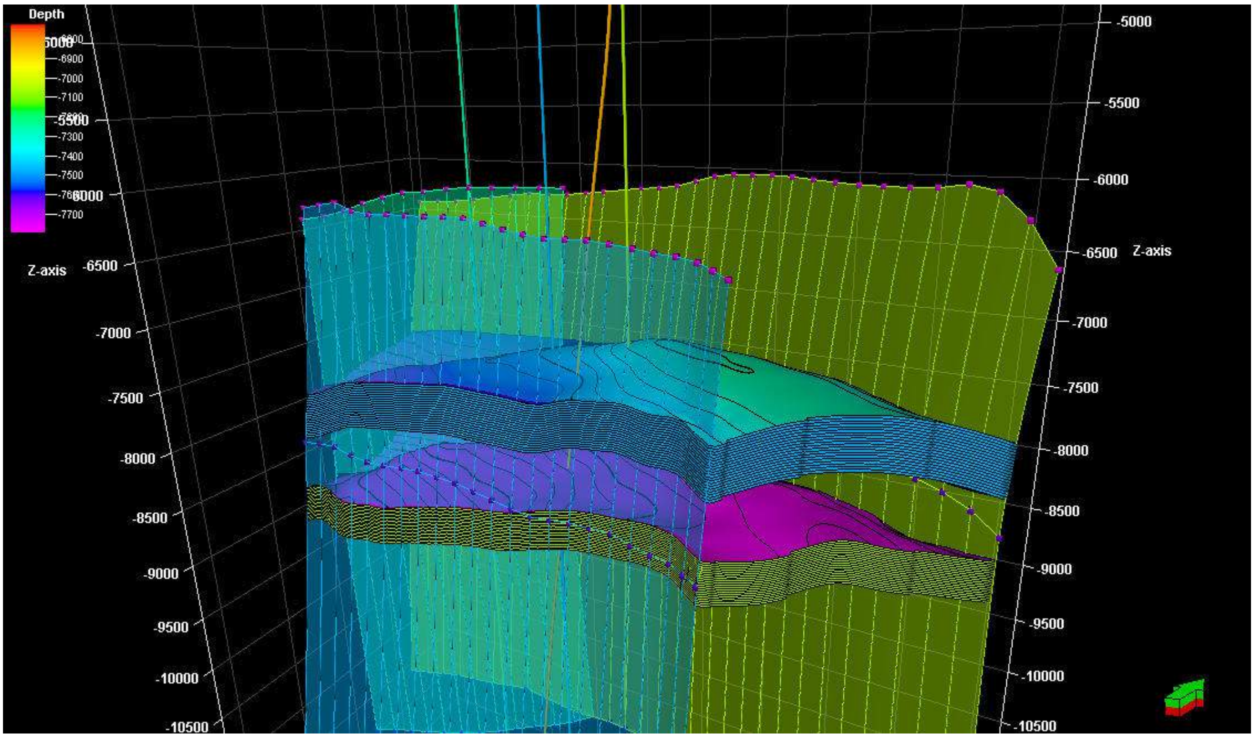

Figure 7: Reservoir Architecture showing Fault Model and reservoirs.

The Unit B which lies between the time windows of 2600 – 2840msec (trace 1153); 2550 -2800msec (trace 1169); 2500-2700msec (1185); and about 2500-2700msec (trace 1201) shows high continuity but weak reflection strength and low amplitude. The high continuity again suggests widespread deposition of various lithologic units while low amplitude suggests thin beds and/or gradational contacts between the lithologic units. Weak reflection is an indication of low acoustic impedance contrast between the various lithologic units.

6. DISCUSSION:

The structural section through the field reveals the anticlinal structure with fault that is hydrocarbon and water bearing. The high amplitude contrast on top of this anticlinal structure implies it is overlaid by shale which serves as seal or cap rock. High amplitude and strong reflection strength along the margin of the faults are indication of the smearing of the faults and sealing of the reservoirs by clays or shales, thus trapping the hydrocarbons migration within the closures. The top seals are provided by field-wide marine and continental clays/shales whereas lateral seals are provided by juxtaposition of impermeable units of shales/clays against the hydrocarbon-bearing

during faulting provided a seal to migrating gas and oil. The abundance of hydrocarbon distribution within the field could possibly be associated with lateral spill-points at the termination of discontinuous faults and seals, or lack of seals along fault planes (Bouvier et al, 1989).

Shales have higher interval velocities than the sands. Their velocities increase down the depth while those of the sands decrease with increasing depth. This boundary marks the limit beyond which the sandstone units begin to display marked reduction in porosity and permeability due to high volume of shale content.

The low velocity values for sand intervals indicate presence of oil and gas. Intervals with lowest velocity values would produce more gas than oil. This is also indicated by sand bodies having extremely high, positive reflection coefficients; low transmission coefficient and low acoustic impedance in contrast to shales with low, negative reflection coefficient; high transmission coefficient and high acoustic impedance. Good structures that favour hydrocarbon entrapment abound in the field. Oil and gas accumulation is high and widespread throughout the field.

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