International Journal of
Science Inventions Today
www.ijsit.com
ISSN 2319-5436
Research Article

APPLICATION OF SEISMIC ATTRIBUTES TO RESERVOIR CHARACTERIZATION, JUWA FIELD, ONSHORE, NIGER DELTA, NIGERIA

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ABSTRACT

The evaluation of the seismic attributes of JUWA Field, Onshore Niger Delta, Southern Nigeria using 3D-seismic data was undertaken. Eight shale and six 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 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.

INTRODUCTION

The Field first discovery was made in 1980 by JUWA Wells which found some 304ft NGS and 457ft NOS in 11 intervals. A total of 7 wells have been drilled into the JUWA 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. There are 7 completed drainage points in 6 wells, all producing under primary recovery technique.

Location of the Study Area: The JUWA FIELD is located in the coastal swamp region of the western onshore Niger Delta, Nigeria,. It lies between latitudes 6^0 60' 50" and 6^0 20' 00"N and longitudes 4^0 60' " and 4^0 55 "E.

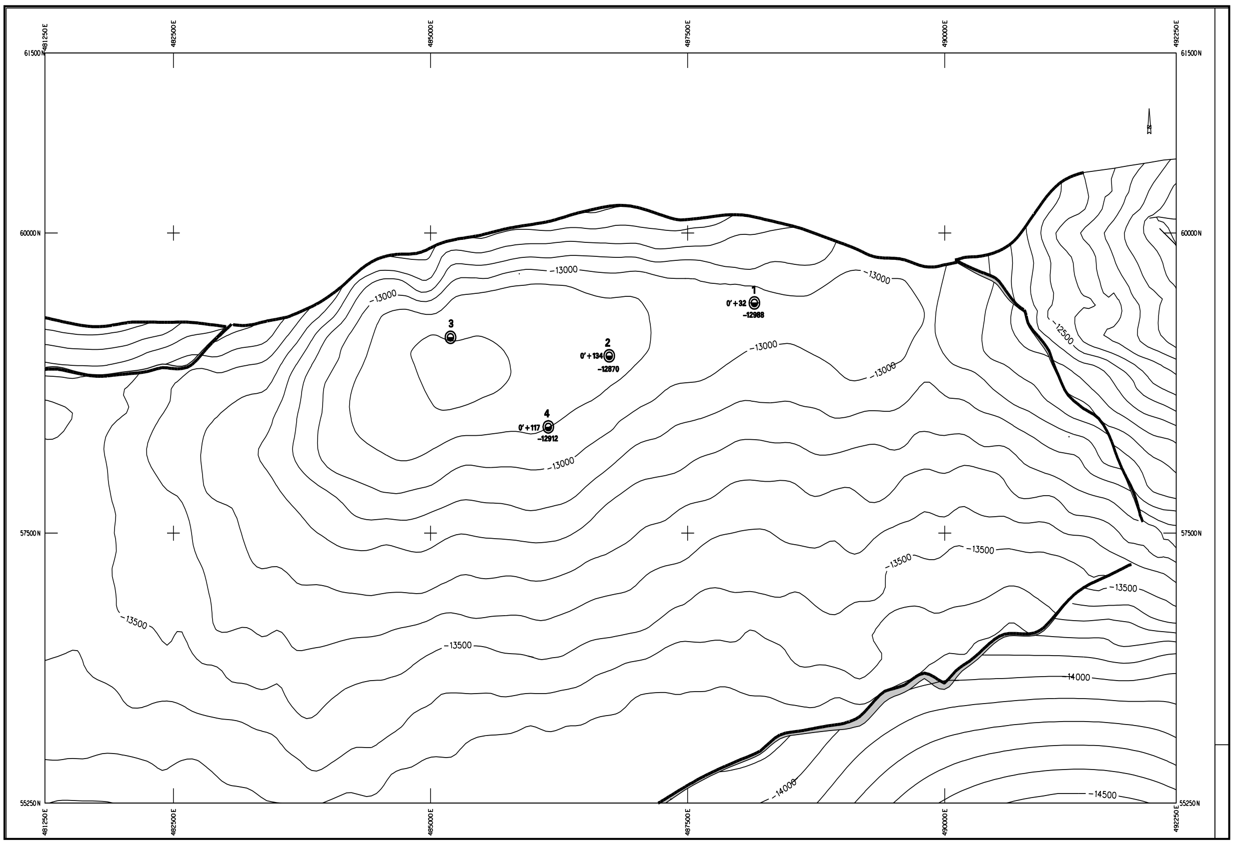

Figure 1: Contour Map of the Area

AIM OF THE STUDY

The Aim of this Study is to determine the seismic attributes of the JUWA Field

Niger Delta Geology: The early Niger Delta is interpreted as being a river dominated Delta, the post Oligocene delta is a typical wave dominated delta with well developed shore face sands, beach ridges, tidal channels, mangrove and fresh water swamps. It is one of the world's largest Deltas and shows overall upward transition from marine shales (Akata Formation) through a sand/shale paralic interval (Agbada Formation) to continental sands of the Benin Formation (Whiteman, 1982). Stratigraphic evolution of the Tertiary Niger Delta and underlying Cretaceous strata is described by Short and Stauble (1967). The three major lithostratigraphic units defined in the subsurface of the Niger Delta (Akata, Agbada and Benin Formations, (See Table 1 and Figure 2.)

The Akata Formation is the basal unit of the Tertiary delta complex. This lithofacies is composed of shales, clays, and silts at the base of the known delta sequence. They contain a few streaks of sand, possibly of turbiditic origin (Doust and Omatsola, 1989), and were deposited in holomarine (delta-front to deeper marine) environments. The thickness of this sequence is not known for certain but may reach 7000m in the central part of the delta. Marine shales form the base of the sequence in each depobelt and range from Paleocene to Holocene in age

. **The Agbada Formation** overlies the Akata Formation and forms the second of the three strongly diachronous Niger delta Complex formations. This forms the hydrocarbon-prospective sequence in the Niger Delta. As the principal reservoir of Niger Delta oil, the formation has been studied in some detail. The Agbada Formation is represented by an alternation of sands (fluviatile, coastal, fluviomarine), silts, clays, and marine shales (shale percentage increasing with depth) in various proportion and thicknesses, representing cyclic sequences of offlap units. These paralic clastics are the truly deltaic portion of the sequence and were deposited in a number of delta-front, delta-topset, and fluvio-deltaic environments and range in age from Eocene to Pleistocene

The Benin Formation is the topmost sequence of the Niger Delta clastic wedge, and has been described as the Coastal Plain Sands which outcrop in Benin, Onitsha and Owerri provinces and elsewhere in the delta area. It consists of massive continental (non-marine) sands and gravels considered to have been deposited in the alluvial or upper coastal plain environment. Very little oil has been found in the Benin Formation (mainly minor oil shows). The formation is generally water bearing, thus the main source of potable ground water in the Niger delta.

Subsurface			Surface Outcrops		
Youngest Known Age		Oldest Known Age	Youngest known Age		Oldest Known Age
Recent	Benin Formation (Afam clay member	Oligocene	Plio/Pleistocene	Benin Formation	
Recent	Agbada Formation	Eocene	Miocene Eocene	Ogwashi-Asaba Formation Ameki Formation	Oligocene Eocene
Recent	Akata Formation	Eocene	Lower Eocene	Imo shale Formation	Paleocene
Unknown			Paleocene	Nsukka Formation	Maestrichtian
			Maestrichtian	Ajali Formation	Maestrichtian
				Mamu	
			Campanian Campanian/Maestrichtian Coniacian/santonia	Formation Nkporo Shale Awgu Shale Eze Aku	Campanian Santonian Turonian
			Turonian	Shale	Turonian
				Asu River	
			Albian	Group	Albian

Table 1: Formation of the Niger Delta area, Nigeria (modified from Avbovbo, 1978; Short and Stauble, 1967)

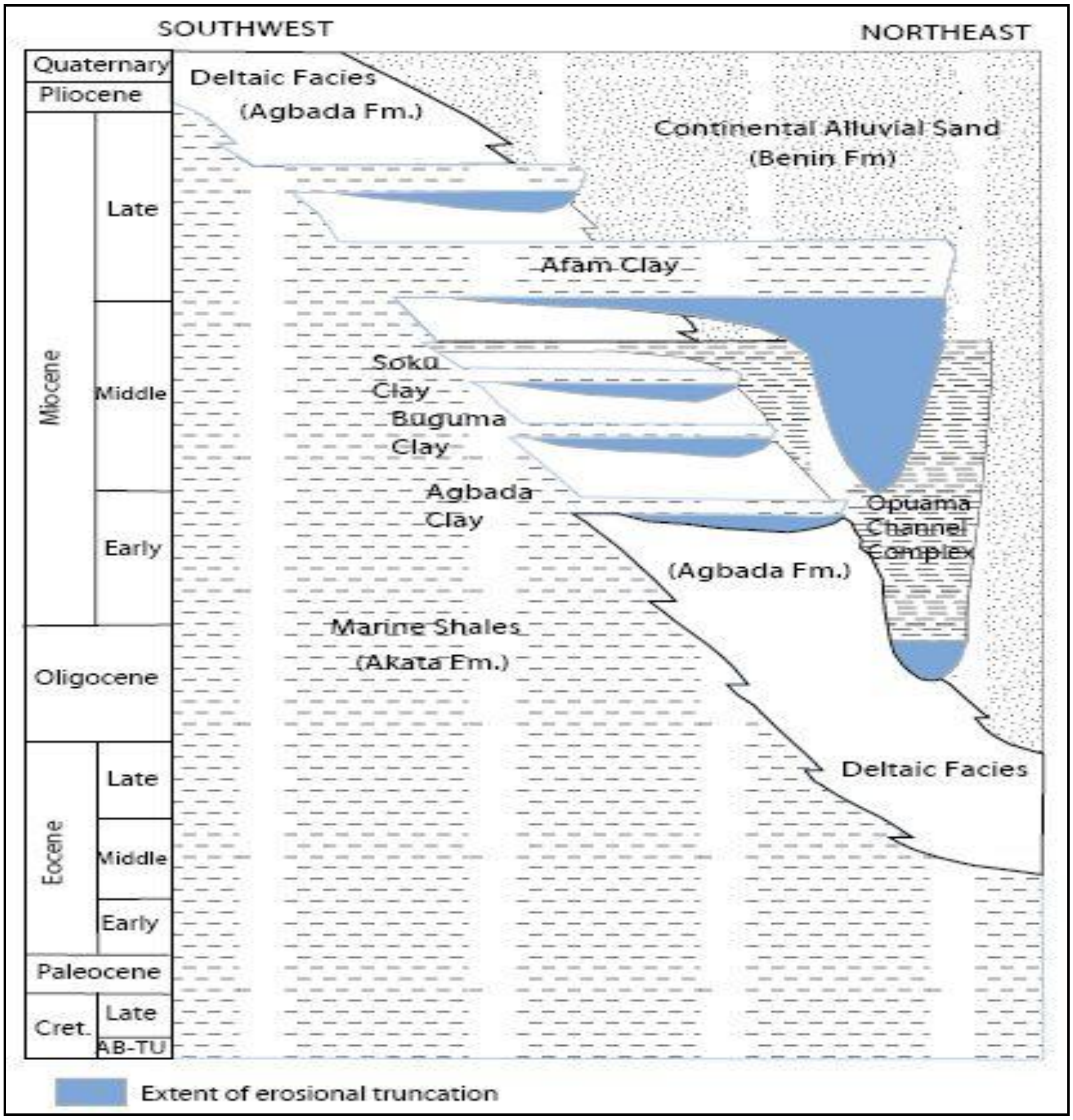

Figure 2: Stratigraphic column showing the three formations of the Niger Delta (Tuttle et al.1999). Modified from Doust and Omatsola (1990)

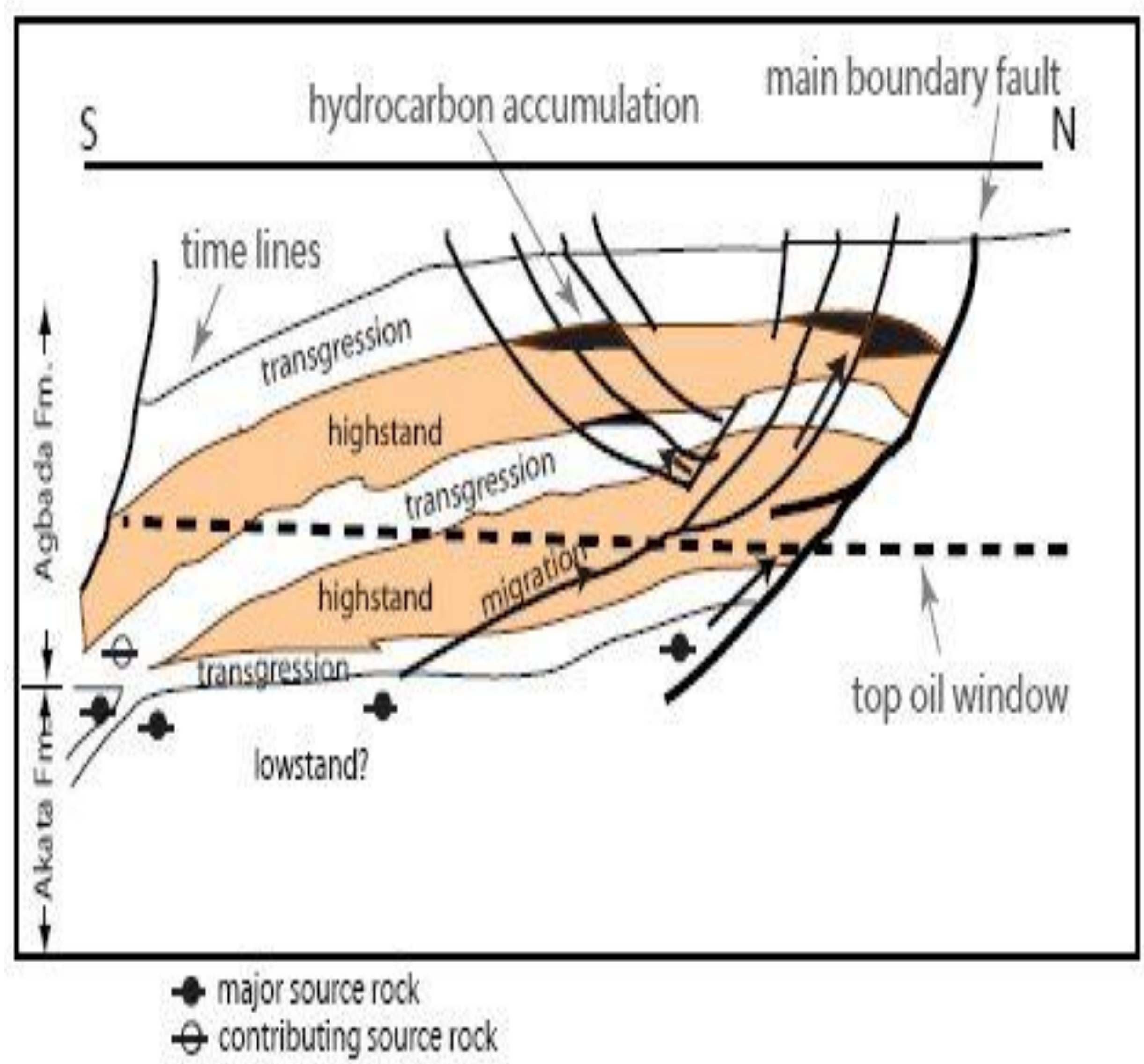

Figure 3: Generalized sequence stratigraphic model for the Niger Delta showing the relation of source rock, migration pathways, and hydrocarbon traps related to growth faults.

METHODOLOGY

The following data sets were obtained and used for this study: 3D Seismic Sections , Structure Contour Map, Check shot data and Seismic Section .For this study, 5-profile lines of a 3D-Seismic section of JUWA 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 1,600 – 3,500 msec and between T1100 and T1450 offsets, with well locations between T1350 and T1330 while the 4-Dip line sections (Traces 1152, 1169, 1187 and 1204 show the events between L5800 and L6540 offsets. shows the X-line seismic section while show the traces of the dip-line section.

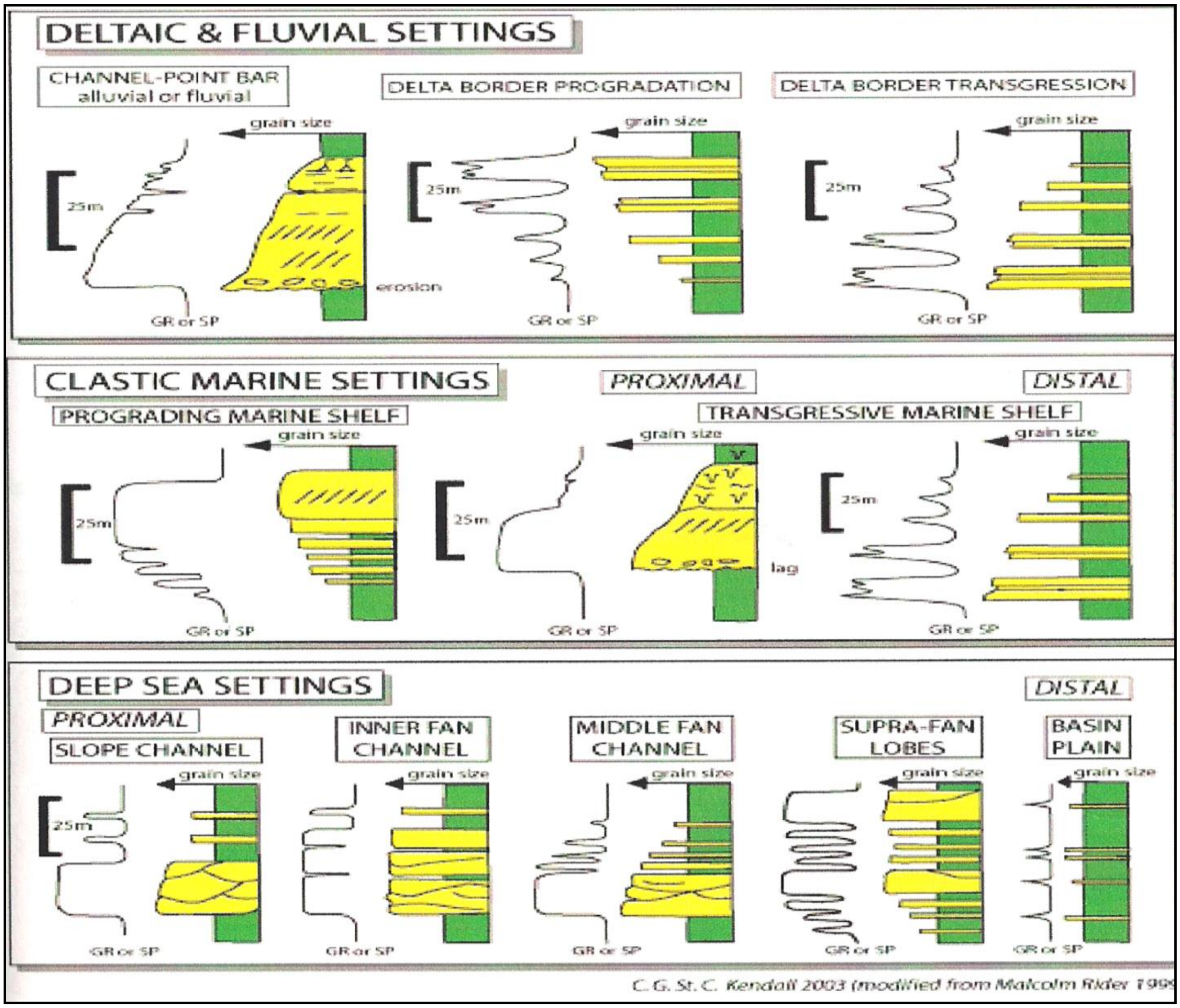

Figure 4: Gamma ray response and depositional setting (Modified from Malcolm Rider, 1999)

RESULTS AND INTERPRETATION

Seismic Attribute Interpretation:

Figure 5 shows structural features and seismic packages/facies (A, B and C) mapped on X-line section of JUWA Field. The attribute of seismic reflection packages identified from X-line seismic section.

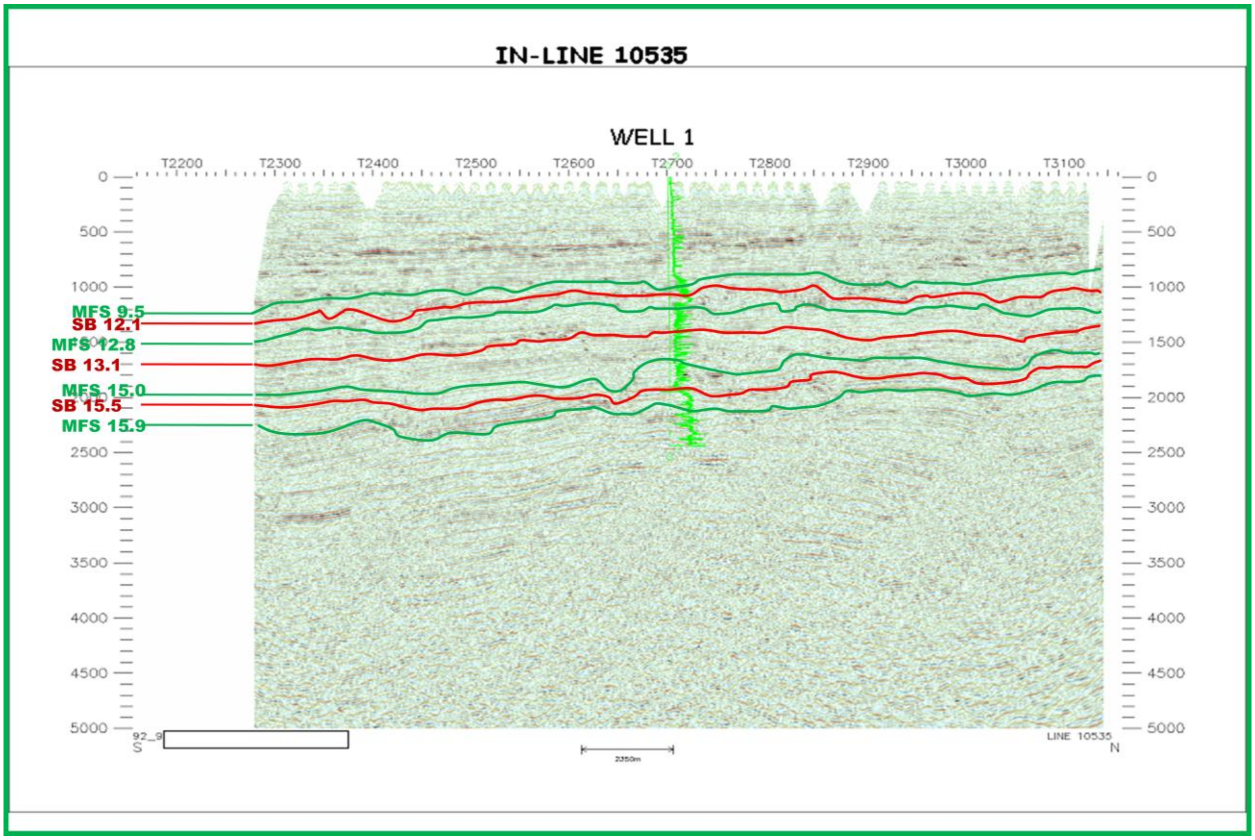

Figure 5: Show the seismic attributes on In-line section for Well 1

Seismic reflection packages from top to bottom, was identified based on their reflection patterns. Between shot points T1100 and T1450 and between the time windows of 1600msec to about 3500msec, 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. folding and faulting. Six faults identified were designated A1, A2, A3, A4, A5, and A6. Fault A1, A2, and A3 are synthetic (growth) faults that dip in the basinward direction while faults A1, A2, and A3 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 slope and deep water environments.

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 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.

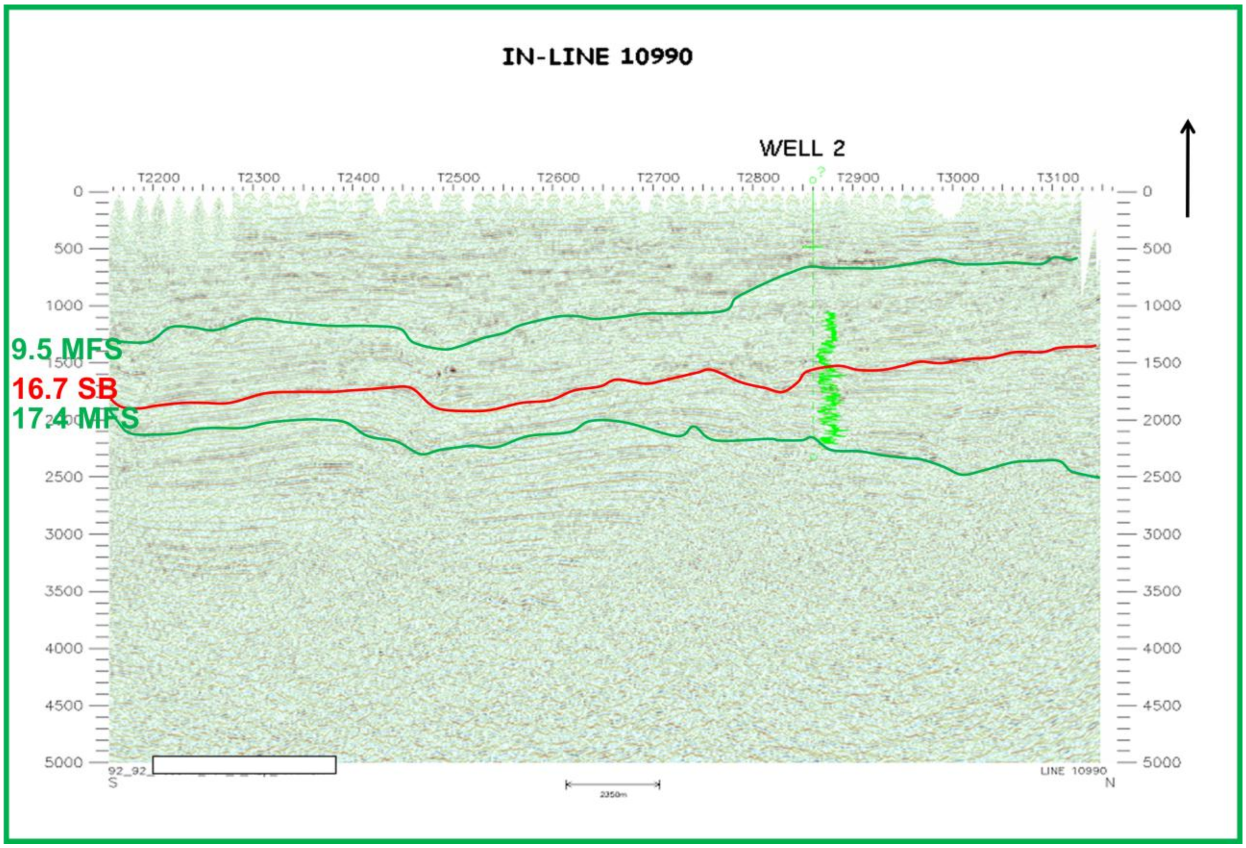

Figure 5: Show the seismic attributes on In-line section for well 2

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.

Between 2700-3700msec (Unit C), though continuity was high, the amplitude variation is rather low to moderately high, with reflection strength being weak to moderate. High continuity implies widespread and uniform deposition whereas the weak-moderate reflection and low-moderately high amplitude could indicate sharp sand-shale boundaries and their alternating successions. However, the reflection is much stronger within the anticlines than in the synclinal part of the folded / wavy sequence. The amplitude is higher within this zone as well than in the synclinal zone and it gradually reduces towards the West. Thus, low-moderately high amplitude is interpreted as indication of alternating thick and thin lithologic units of low and high energy environment and/or relatively high fluid content. The weak – moderate reflection implies low and moderately high acoustic impedance contrasts of the lithologic units and variable hydrocarbon content within the reservoirs. The high reflection strength of the anticlines possibly indicates hydrocarbon accumulation within the structure.

The Unit D, lying below Unit C and between time windows of 2850 – 3900msec across the four seismic traces of the In-line section show a relatively very high amplitude, very strong reflection strength, and high continuity of seismic facies which are truncated against diapiric structure (Unit E). Unit D seems to have the strongest reflection strength and the highest amplitude. The diapirc structure (Unit E) has low amplitude and variable weak reflection strength. It is characterized with hummocky-chaotic internal configuration pattern typical of plastic materials such as clay which flowed into the overlying structure upon gravitational loading. This unit also shows both vertical and lateral variation in size across the Field. Unit E could have resulted from deformation and flowage of initially continuous strata possibly the clay materials within the designated Unit E.

DISCUSSION AND CONCLUSION

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 sandstones along the fault planes (Bouvier et al, 1989). Clay or shale smears along the fault planes 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.

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