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Research Article

SEQUENCE STRATIGRAPHY AND RESEARVOIR CHARACTERISATION; CASE STUDY OF FIELD X, NIGER DELTA

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ABSTRACT

The study area has two recognized depositional sequences, bounded above and below by maximum flooding surfaces (MFS). The maximum flooding surfaces are Uvigerina 8, (9.5ma) and Dodo shale (11 .5ma) and the two sequence boundaries are l0.35ma and 10.6ma. Nonion 4, MFS (lO.4ma) was missing in the section, which could have been as a result of 1.6ma erosion as evidenced from the seismic section. Based on the above, systems tracts were interpreted; High stand systems tract (HST), Low stand system tract (LST) and Transgressive systems tract (TST).

INTRODUCTION

Sequence stratigraphy has evolved from an academic concept to va1uab1e tool for oil and gas exploration in the past two decades, but it is under-utilized. The predictions about reservoir potential based on sequence stratigraphy depend on the changes in global sea level, tectonic movements and how they affect lithologic facies and boundaries. The concept of Sequence stratigraphy (Sloss et. al., 1949, Sloss, 1963), developed through Seismic stratigraphy, as a recent methodology for stratigraphic interpretation was pioneered by Peter Vail, (Vail et al, 1977). It was gradually introduced into Nigeria since the early nineties. It was first applied in the Niger Delta where it has since refined the potential for prediction of hydrocarbon habitats by Durand, 1995; and Stacher 1995). Thereafter, it was tentatively introduced in the Anambra basin and in the carbonates on the Calabar flank by Reijers (1996).

AIM OF THE RESEARCH WORK

To determine the key sequence stratigraphic surfaces and systems tracts of the five wells in the study area within the coastal swamp depobelt in the Niger delta, using wire-line logs, seismic information and biostratigraphic data.

LOCATION OF STUDY AREA: The area of study lies within the coastal swamp depobelt in OML 13 of the eastern part of the Niger delta petroleum province . Five wells Xl, X2, X3, X4 and X5 were used for this study.

DATA AND METHOD OF STUDY

DATA USED FOR STUDY:

The following data were used for this study:

- Seismic base map of the field showing all the five wells at their exact positioned locations.
- Raw numerical data of wire-line logs made up of Gamma Ray log (OR), Spontaneous Potential log (SP), Compensated Bulk Density Log (CDL), Compensated Neutron Log (CNL), Borehole Compensated Sonic Log (BCSL) and Resistivity log.
- Available biofacies data of well X1 was used as a control to interprete the other wells, which provided information on fossil abundance and diversity. The indicated sample type used here are side wall cores and ditch cuttings.

WIRE-LINE LOGS:

The wire-line logs were retrieved from the Petrotek data base. It was transferred to the petrel software and plotted out for the building of the correlation panels. With the base map as a control, the logs were loaded in strike and dip directions. In strike direction, four of the wells (Xl, X5, X4 and X3) were displayed, while in dip direction, two wells (X3 and X2) were and displayed.

These logs were displayed at a consistent scale, chosen to enhance the log trend. The trends on the logs were observed for stacking patterns, viewing the parasequences and parasequenees sets which gave an insight on the nature of the depositional patterns.

BIOFACIES DATA:

The well Xl is the only well with biofacies data. The biofacies data were analysed based on abundance and diversity of pollen, foram and environment. SPDC zones P770, P800 and F9600 were derived from the data. The biofacies data were loaded in excel software chart wizard, which was used to prepare XY scatter charts showing foram/pollen population abundance, diversity and environment in relation to depth. (Wornardt, 1992; Wornardt et. aL, 1992).

The keys Stratigraphic Surface: Sequence boundaries and maximium flooding surfaces, and the parasequence stacking patterns were used as defining criteria to interpret the systems tracts.

SEISMIC SECTION DATA:

The seismic section covering the entire area were interpreted from the seis works workstation on every 16th seismic grid of line and trace.

The identification of faults were based on the discontinuities in reflection falling along an essentially linear pattern and on distortion or disappearance of reflections below suspected fault lines.

The key stratigraphic surfaces of sequence boundaries were confirmed and interpreted as truncation surfaces, particularly eroding the topsets of older units, while the maximum flooding surface (MFS) as downlap backstepping display on underlying topsets.

A structural configuration of these key stratigraphic surfaces ,aimed at achieving their depths, were depicted by interpolation of the grid polygons and horizons. The Systematic Process involved zapping of the data. Zapping is a procedure aimed at filling interpretation gaps, since the interpretation was done at every 16th interval on line and strike time slices. The zapped horizons were then subsequently used for depth conversion. First, a polynomial relationship was achieved between depth and time, using available check shot survey of wells, X2, X4 and X5 This was imputed into the Excel computer software, and used to producea combined TZ curve The seismic facies analysis were interpreted based on three primary seismic facies categories; Convergence, Parallell Subparallel and Chaotic, which were in relation to the seismic reflectivity, geometry and event continuity. This was with the aid of gamma ray logs superimposed on the seismic by appropriate TZ conversions.

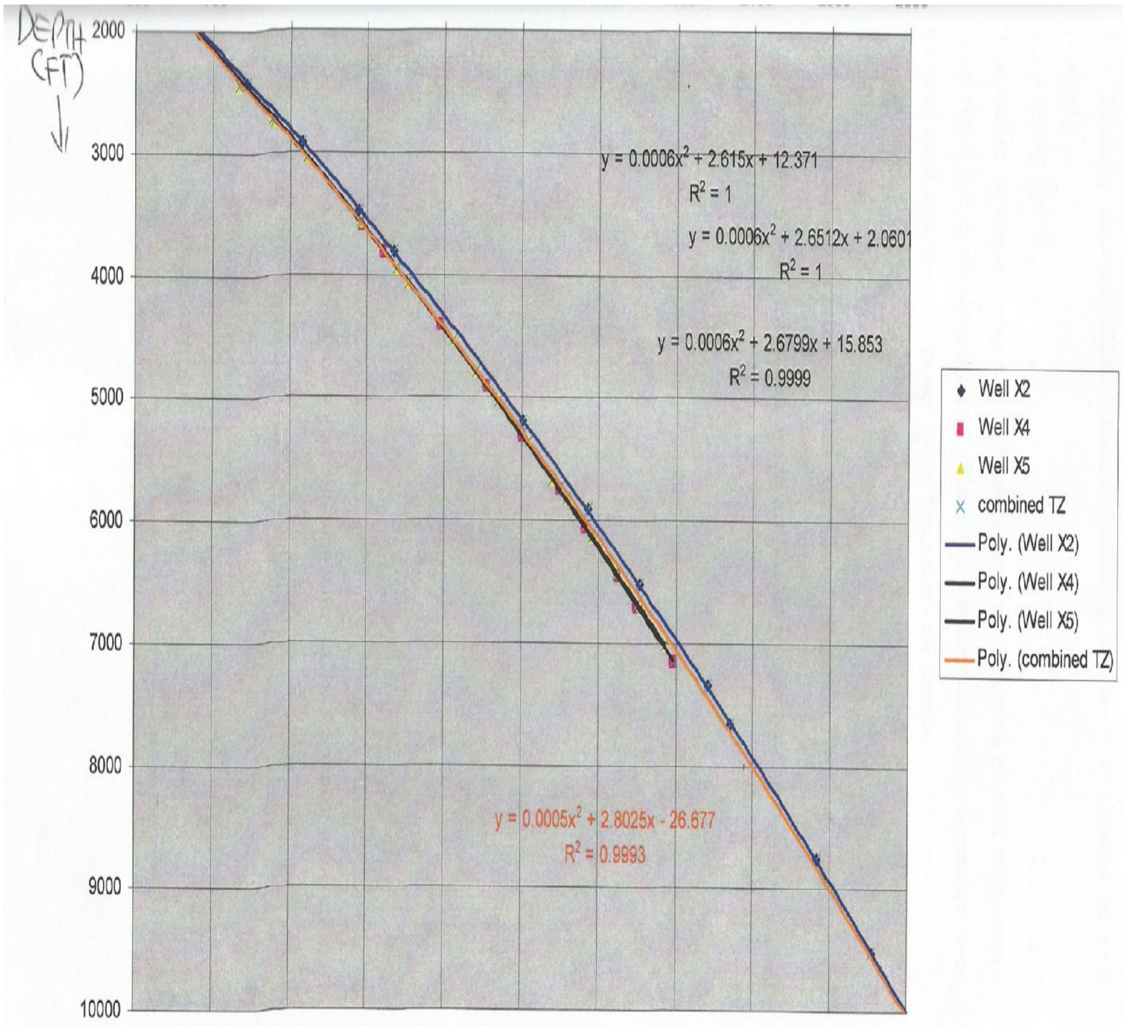

Figure 1: Conversion Plot using Polynomial equation Relationship

RESULTS PRESENTATION AND INTERPRETATION

WELL LOG SEQUENCE INTERPRETATION:

The 5th and 4th order parasequences and parasequence sets of depositional system were identified and marked out on the log panel, following different successive patterns of progradation, retrogradation and Aggradations.

The lithologic correlation showed that most sand bodies thin out towards the east, an explanation that the eastward part of the field is more proximal to the sea compared to the west. Also, some sand bodies were missing out, inferring an influence of faulting.

The point of convergence of the parasequence sets, suggested a candidate Maximum flooding surface, while the point of divergence suggested a candidate Sequence boundary. However, this was realistic with Biofacies interpretation for confirmation.

BIOFACIES INTERPRETATION:

From the biofacies data of well Xl, the F9600 was used to pick out the candidate sequence boundaries (SB) and candidate Maximum flooding surfaces (MFS), while P770 and P800 were used to confirm them.

The Dodo shale (11. 5ma) candidate MFS was picked at the depth of 6220ft, within the bathyal environment. It has a faunal diversity/population of 43 and 648, respectively, and a pollen diversity/population of 22 and 374, respectively.

The candidate sequence boundary 10.6ma was picked at a depth of 5404ft within Barren environment. It was barren of both fauna and pollen. A subsequent candidate sequence boundary 10.35ma, was picked at a depth 4400ft within Barren environment. It was clearly observed, especially from the biofacies XY scatter charts that the Nonion 4, (l0.4ma) candidate MFS was missing.

At a depth of 4350ft, the Uvigerina 8, (9.5ma) candidate MFS was picked within Outer Neritic to Bathyal environment. It has a faunal diversity\population of 19 and 189, respectively and a pollen diversity\population of 2 and 15, respectively.

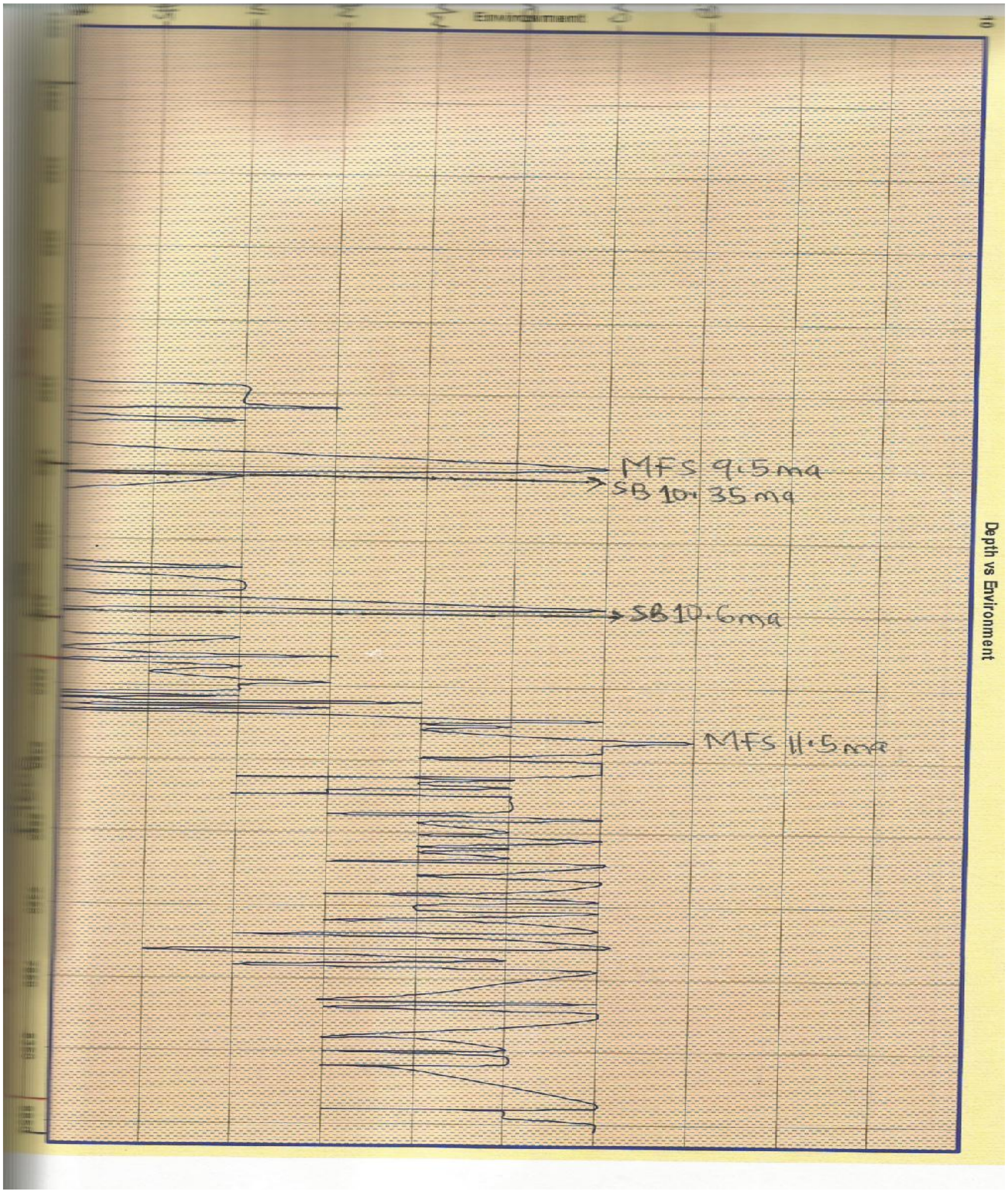

Figure 2: Depth Vs Enviroment Biofacies Chart

SEQUENCE STRATIGRAPHIC INTERPRETATION:

Following Galloway (1989), two depositional sequences were observed in this interpretation . The first sequence (depositional sequence 1) is bounded below by Dodo shale, 11 .Sma MFS, and above by a supposed Nonion 4, 10.4ma which was missing in the section. In an ideal situation, the Nonion 4, (10.4ma)

MFS would be seen within the transgressive system tract lying above the lowstand stemsy tract on sequence boundary lO.6ma. This missing Nonion 4, lO.4ma is attributed most likely to erosion as evidenced also from the seismic section.. The depositional sequence 2 is bounded below by this supposed Nonion 4, 10.4ma MFS, and above by Uvigerina 8, 9.5ma MFS. The Uvigerina 8, 9.5ma is observed within the Afam Clay member.

There is one sequence boundary within each of these depositional sequences. In depositional sequence 1 is the sequence boundary 10.6ma, while in the depositional sequence 2 is the sequence boundary 10.35ma. The sequence boundary 10.3 5ma was picked and confirmed based on the SPDC Sand tops/bases report data , which marked out the depth for top of Afam Clay formation (TAF) and Base of Afam formation (BAF). The SPDC standard has it that the base of Afam clay formation, is the sequence boundary l0.35ma. This was also confirmed and picked out on the log. It marks the boundary between the Benin and Agbada formation.

The interpreted Key stratigraphic surfaces were marked out across the field at different varying True Vertical Depth Subsea (TVDSS),. The maximum flooding surfaces were labeled as 3rd order depositional sequences. The observed depth differences across the field is as a result of sea level changes and faulting. The sea level changes across the field was observed from the trends of parasequence stacking pattern while the faulting evidence was seen from the missing sections of correlated sand bodies.

The key stratigraphic surfaces aided in marking out the systems tracts. The transgressive systems tract had a characteristic finning and thinning of facies upwards, for the Lowstand systems tract, the facies thickened and coarsened upward while within the Highstand system tract, the facies coarsened upward and subsequently maintained a uniform trend. The system tracts within the study area were in the order of Highstand system tract (HST), Transgressive system tract (TST), another HST/Lowstand system tract (LST), and then finally HST and TST. We observed a situation of an HST seating directly on an LST, and two sequence boundaries lO.35ma and lO.6ma succeeding each other. This is the effect of the missing Nonion 4, lO.4ma MFS while the faulting evidence was seen from the missing sections of correlated sand bodies.

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Wells	Xl	X5	X4	X3	X2
Key Stratigraphic Surfaces					
Uvigerina9.5ma Ift)	3886	3730	3780	3650	3752
Sequence Boundary l0.35ma (ft)	3946	3875	3886	3770	3805
Sequence Boundary 1O.6ma(ft)	5488	5380	5565	5230	5200
Dodo—Shale l1.5ma (ft)	6889	6779	7080	6780	6580

Table 1: Key Stratigraphic Interpreted Log Depths of the Study Area.

SEISMIC FACIES ANALYSES:

Apart from picking out the maximum flooding surfaces and sequence boundaries on the seismic section, the facies were also analysed based on the reflections and amplitudes.

Three pronounced seismic facies were picked out, parallel-subparallel, chaotic, and high/low amplitude convergent . The well logs were superimposed on the seismic section for proper analysis of this facies. The parallel-subparallel high reflection amplitude continuity were picked across the section and these were interpreted as suggesting sharp sand/shale altemations of high and low energy environments. The chaotic facies were seen mostly close to sequence boundaries and in this case, they are suggestive of strata deposited in a variable, relatively high energy setting (channels), while the High/low amplitude convergent facies were interpreted as suggestive of amalgamated channel complexes and amalgamated layered sheets.

The porosity and permeability values within the system tracts were observed to decrease with depth . This decrease of porosity and permeability with depth, is thought to be diagenetical, including compaction, (considering growth faults), cementation and dissolution, which is a function of time, temperature, pressure and fluids.

The studied area was conclusively observed to have low permeability values. Permeability of a rock body can be affected by certain mineralogical changes, arising from the modifications of pore size and shape without necessarily being accompanied by appreciable changes in porosity. Example of such, is in cases where the clay has undergone less dissolution, remaining as grain rims and still blocks pore throats. This significantly reduces permeability, although the porosity may remain high (Gaughan, 1989).

The Gas prone nature of the sand bodies could be associated with the low permeability. The pore systems (Pore topology, geometry, pore throat and size distribution) are fundamental building blocks of reservoir architecture. Pore systems affect not only hydrocarbon storage and flow, but also reservoir producibility, flow-unit quality and comparative rank in the field. Pore throat size distribution is one of the important factors determining permeability because the smallest pore throats are the bottlenecks that determine the rate at which fluid can pass through a rock, (Earnest et. al., 2004).

The likely source rock (possibly MFS) constituent is of a significant importance in this regard. When combining hydrocarbon distribution with Sequence stratigraphy, it becomes obvious that the MFS(s) also control that particular petroleum system that contains most hydrocarbons (Ganz et. al., 2006). The temperature maturation period also counts. In most of the Western Delta and narrow belt within the Eastern Delta, the hydrocarbon generation at temperatures of 140 — 186°C suggest a predominance of gas source (Ejedawe et. al., 1983,).

Also observed, are very low average water saturation values of 0.01 — 0.04, to no saturation within the gas bearing reservoirs, compared to the oil zones which average values varies between 0.07 — 0.2. This is in agreement with Law and Dickerson (1985) and Law (2002), who noted that water production is relatively uncommon in many low-permeability accumulations and suggested that vast areas of gas-saturated rocks are at irreducible water saturation, reflecting active gas generation and expulsion of formation water.

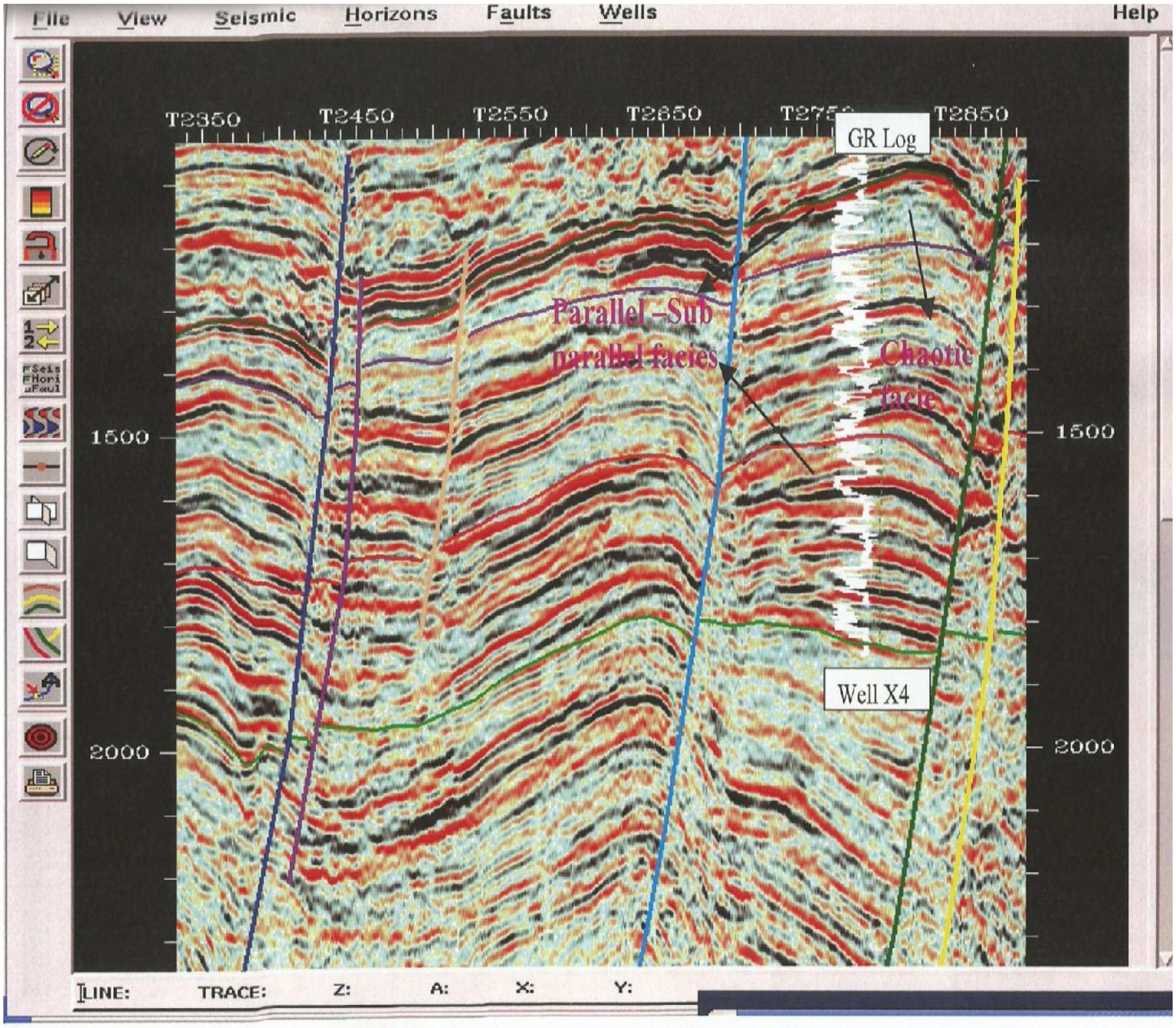

Figure 3: Seismic Section showing Parallel-Sub paralle and chaotic facies

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