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STRUCTURAL INTERPRETATION OF SEISMIC REFLECTION DATA: A CASE STUDY OF AN X-FIELD, WESTERN NIGER DELTA

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ABSTRACT

A 2D seismic reflection data acquired over X-field, western Niger Delta is interpreted for its subsurface structural features that could be favorable for the accumulation and retention of hydrocarbon. Based on the interpretation of twenty seismic sections, four horizons (distinct reflectors) were mapped at two-way reflection time of 1.2 sec, 2.1 sec, 2.5 sec and 3.2 sec respectively and four faults were also identified. Two of the faults are recognized as major structural faults and the other two as minor synthetic faults.

From the analyses of the generated isochron maps, the features of the identified faults coincides with that of a growth fault which constitute an important trapping mechanism. And clearly defined on the isochron map of horizon B at the downthrown block of the faults is a closure that represents the crest of a rollover anticlinal structure.

Results of analysed geophysical logs from three exploratory wells in the field indicate the presence of hydrocarbon at the interpreted layers i.e. layer 2 and layer 3 which extends from 1400-2400 m and 2400-3100 m respectively and located within the Agbada Formation. Their isopach maps reveal the nature of the topography at the lower part of the layers. It was observed that two principal structural types of trapping mechanism i.e. rollover anticline and growth faults are responsible for the significant hydrocarbon accumulation in the X-field.

KEYWORD: Seismic sections, Growth faults, Horizons, Hydrocarbon and Isochron maps

INTRODUCTION

The X-Field covers an estimated area of 85 km^2 and is located in the on-shore western part of the Niger Delta. The Niger Delta is a known oil and gas rich province in the West African Continent, (Fig.1.0). The Niger Delta geologic structures and stratigraphic features are known to be favourable for the hydrocarbon accumulation.

The X-Field is adequately covered by several seismic lines, (Fig 2.0) with the dip and strike lines running almost in the north – south and east – west direction respectively, while the tie lines are oriented in different directions. Also marked in Figure 2.0 are the locations of the exploratory wells EE1, EE2 and EE3 whose logs indicate presence of hydrocarbon (Amigun, 1998).

The objective of the study is to analyse and interpret the 2-D seismic reflection data acquired over the X-Field with the aim of mapping subsurface structural information that could trap hydrocarbon.

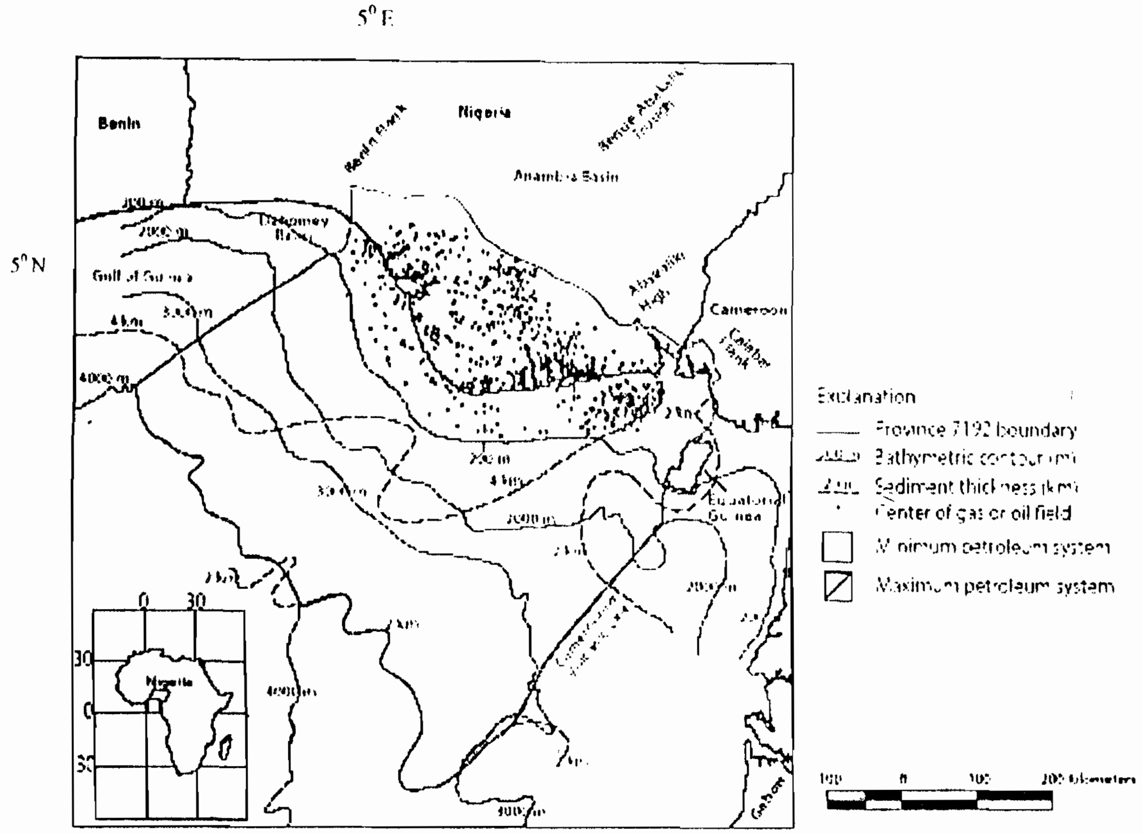

Fig.1.0 Map of the Niger Delta showing Province Outline, Petroleum System and Bounding Structural Features. (After Tuttle et. al, 1999)

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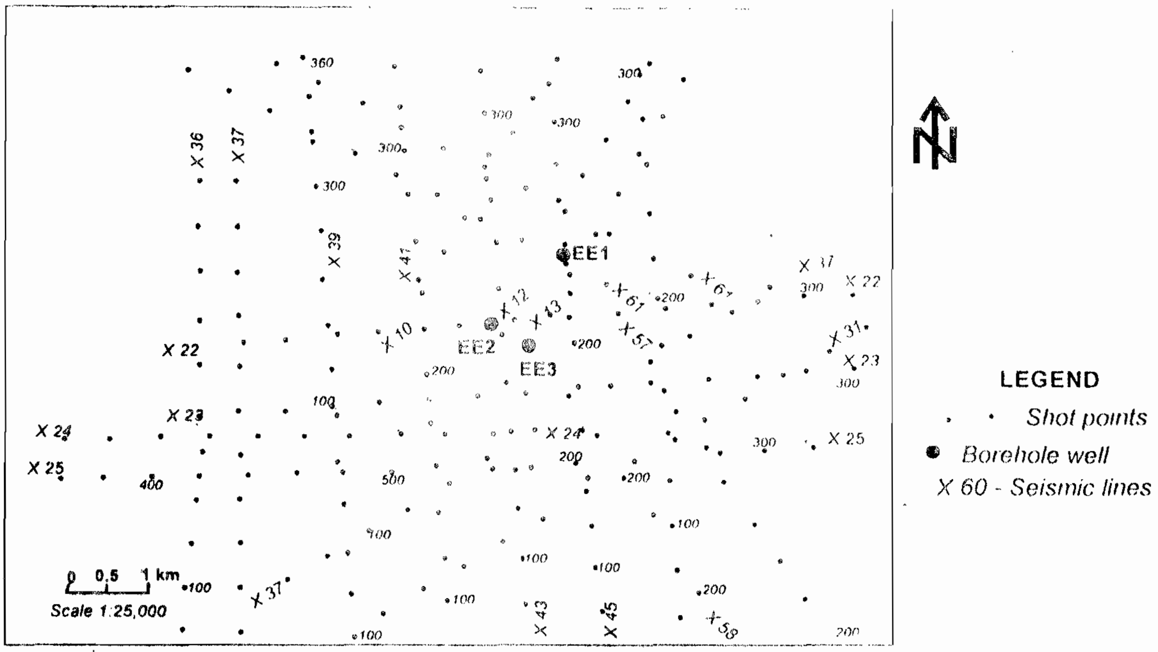

Fig. 2.0 : Seismic location map of the study area.

GEOLOGY OF THE NIGER DELTA.

The Niger Delta is a large acute delta, which extends between longitudes 3^0 and 9^0E and latitudes 4^030^1 and 5^020^1N. The tertiary deposits in the Niger Delta covers an area of about 75000 km^2 (Doust and Omatsola, 1990).

The stratigraphy of the Niger Delta has been described by Short and Stauble (1967) and Frankl and Cordry (1967) in some detail. They recognised three dichronous lithostratigraphic units. In ascending order, these are the Akata, Agbada and Benin Formation (Fig 3.0)

The Akata Formation is under compacted (i.e. over pressured) in much of the delta. The Agbada Formation is a paralic sequence characterized by the alteration of sand bodies and shale layers. This sequence is associated with synsedimentary growth faulting and contains the bulk of the known oil accumulation in the Niger Delta. The Benin Formation is the uppermost and youngest rock stratigraphic unit.

Structurally the Niger Delta is characterized by synsedimentary faults called growth fault and folds (Schlumberger, 1974). The growth faults according to Weber, 1987 are considered to be the major migration conduit and leading factor controlling the hydrocarbon distribution pattern in the Niger Delta.

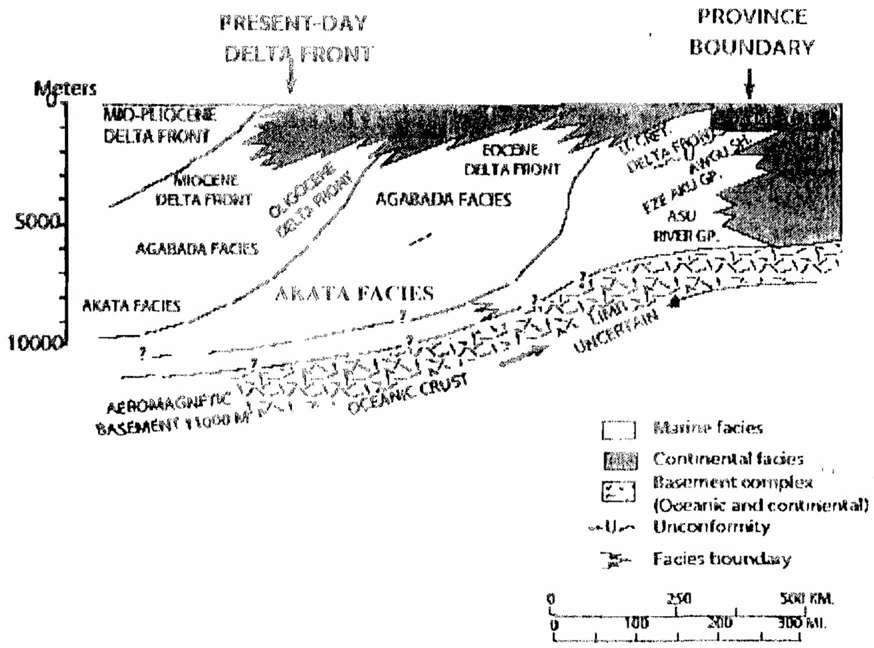

Fig.3.0 Map Showing the Niger Delta Stratigraphic Units.
(After Tuttle et. al, 1999)

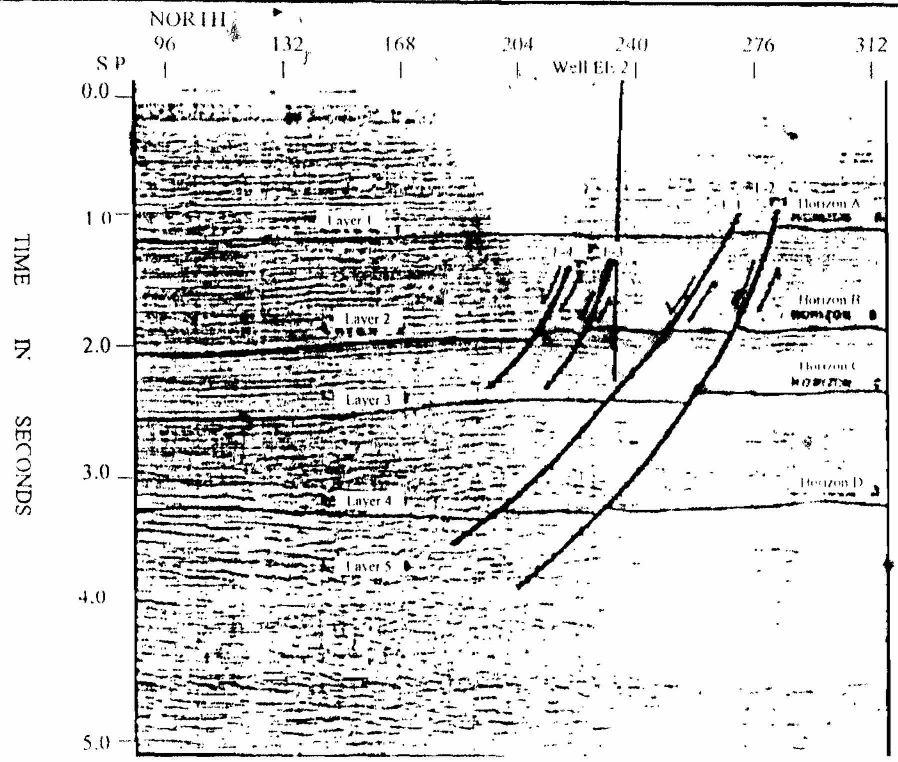

Fig. 4.0a Seismic Line of X41 Showing Mapped Faults in the Study Area.

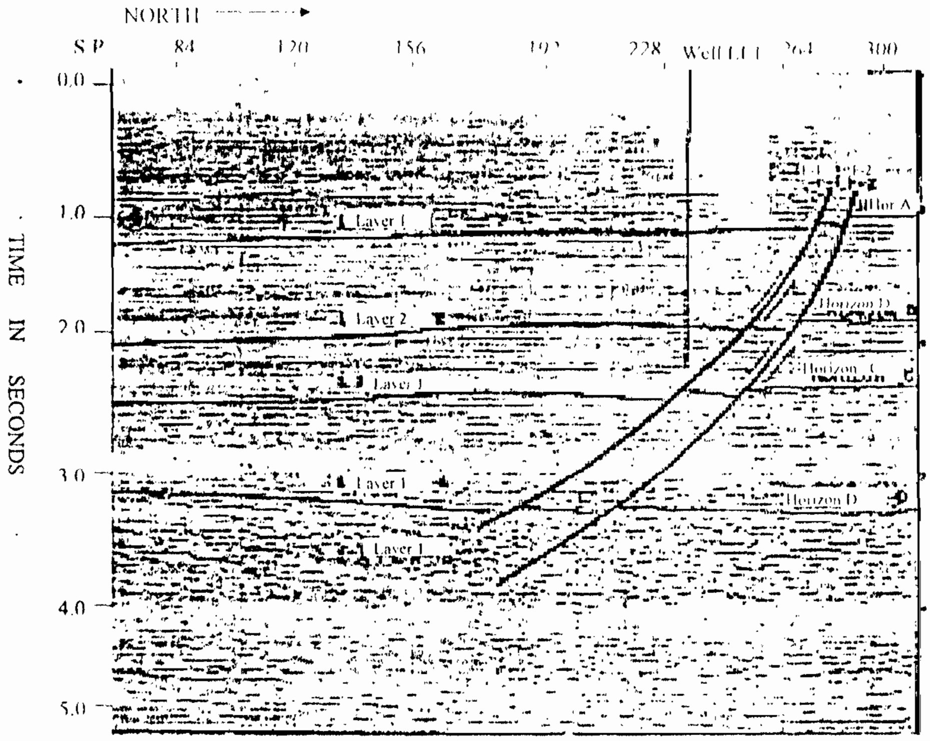

Fig. 4.0b Seismic Line of X45 Showing Mapped Faults in the Study Area.

METHODOLOGY

The seismic reflection method is used in this study to mapped the subsurface structural features and infer other geologic information of the X-Field. This method is known to provide a structural picture of the subsurface which is comparable to what could be obtained from a number of boreholes in close proximity (Dobrin and Savit, 1988). According to Sheriff and Geldart, 1995, the coherent events seen on seismic sections (Fig 4.0) are reflections from acoustic impedance contrast in the earth, and the arrival times of the coherent events are related to geologic structure.

The contouring principles employed in this study for constructing the various structural maps (Figs 5.0 and 6.0) are that proposed by Tearpock and Bischke (1991). The maps are used to develop an interpretation of the subsurface for the purpose of exploring hydrocarbon reserves.

DATA ANALYSIS.

Following the initial procedure of mapping the fault structures recognized on the seismic sections and the picking of the coherent reflection events, the two-way times to the picked events were measured. Table 1.0 shows the two-way reflection time in millisecond for some seismic lines for horizon

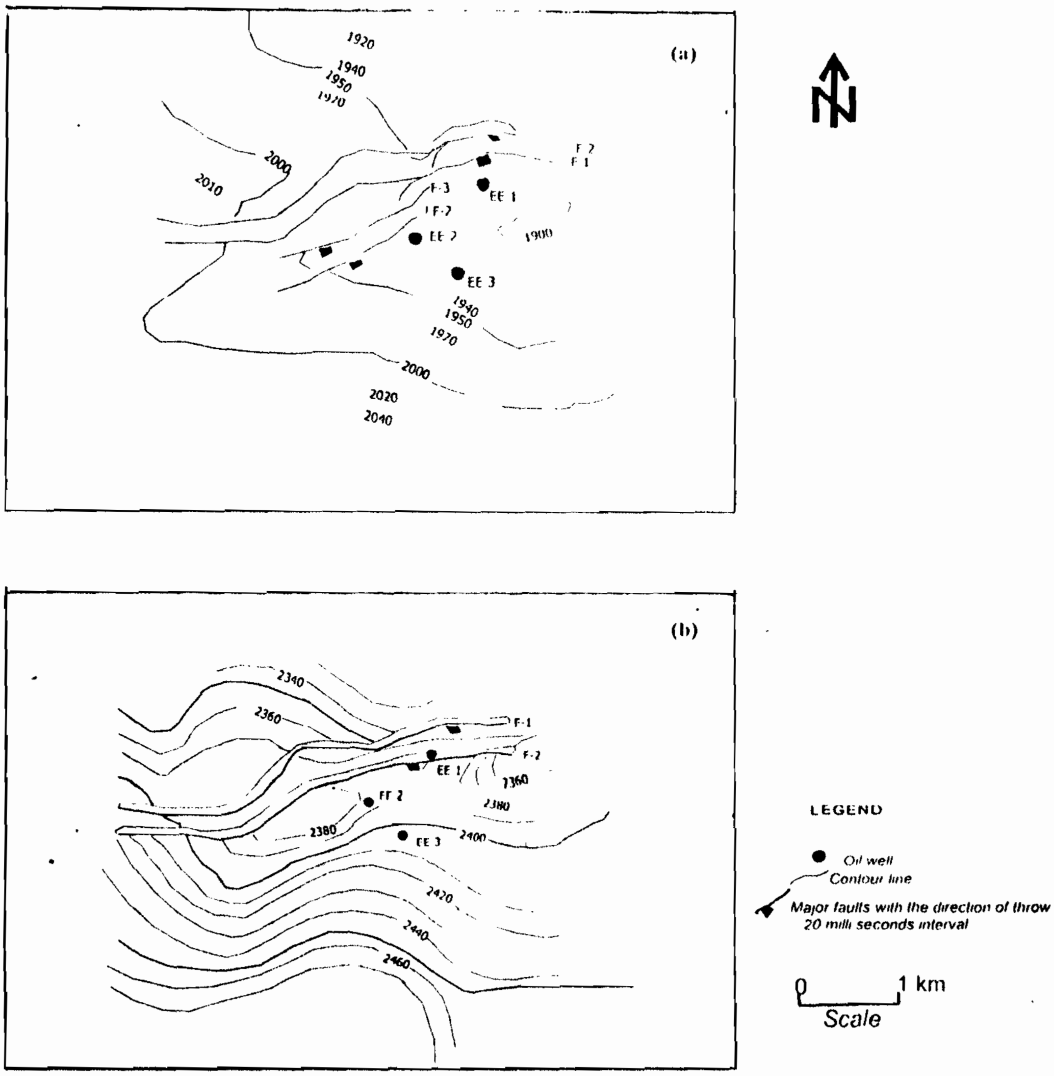

Fig.5.0 shows the Isochron maps of two Horizons of the X – field: (a) Horizon B and (b) Horizon C.

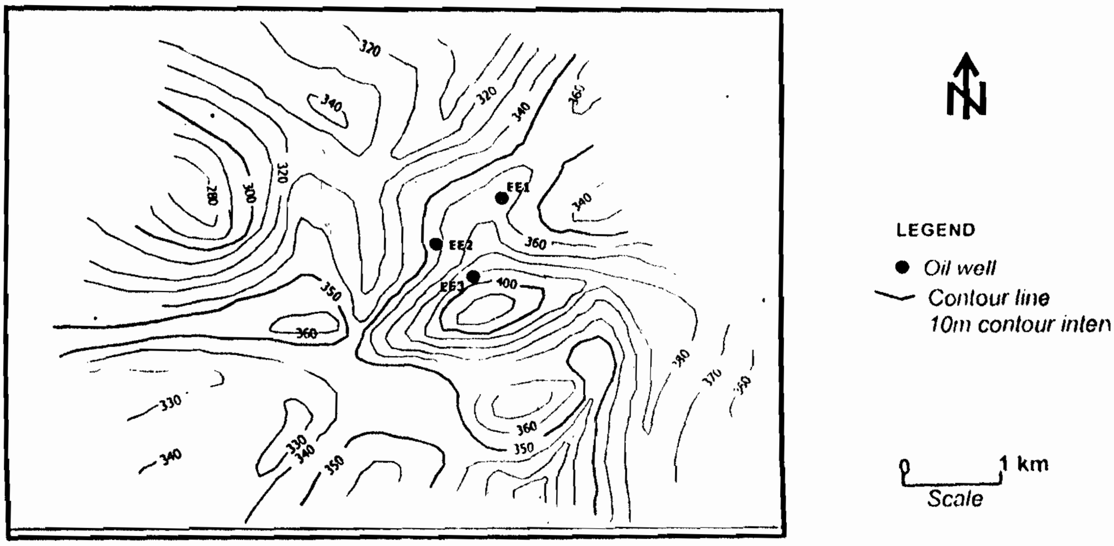

Fig. 6.0 : Isopach map of layer 3.

Table1.0 Two way reflection time values of part of horizon C.

Short point	LINE X10	X 23	X36	X39	X41	X43
108	2260	2490	2490	2570	2520	2480
120	2280	2490	2470	2480	2510	2470
132	2290	2500	2450	2480	2500	2450
144	2310	2500	2430	2470	2490	2240
156	2310	2510	2420	2450	2470	2430
168	2310	2510	2430	2440	2440	2320
180	2320	2490	2440	2420	2430	2400
192	2310	2480	2430	2400	2410	2400
204	2300	2490	2410	2390	2380	2390
216	2300	2480	2430	2490	2370	2390
228	2300	2470	2380	2380	2380	2380

Table 2.0 Measured layer thicknesses in meters.

	Shot point	Layer 1	Layer2	Layer3	Layer4
Line X10	188	630	470	310	760
	167.2	618	486	304	756
Line X23	115 2	656	484	364	708
	184.8	664	470	422	614
	244.8	670	470	416	614
	290	630	482	428	604
Line X41	114.4	712	494	402	530
	164	676	480	308	730
	211.2	656	456	326	726
	265.2	650	506	274	734

The Dix (1955) technique of depth inversion was used to compute the layer thickness between the picked horizons of the X- Field The equation is of the form

$$Z_{in} = V_{in} \frac{T_n - T_{n-1}}{2}$$

Where Z_{in} = the interval thickness of the nth layer
V_{in} = the interval velocity of the nth layer
T_n = Two-way travel time for nth reflector
T_{n-1} = Two-way travel time for (n-1)th reflector

Table 2 0 shows the computed layer thickness for some of the seismic lines.

RESULTS AND DISCUSSION.

On the seismic section (Fig 4 0a), four horizons were mapped and four faults identified The four horizons were mapped at two-way reflection time of 1.2sec, 2 0sec, 2.5sec and 3.2sec respectively. The horizons divide the study area into five layers. Observed also, is a rollover anticline whose crest is more clearly defined between the two-way time of 2.0 – 3.0 seconds. Figure 5.0a shows the isochron maps of horizon B produced from the measurement of two-way travel time. On the contour map, fault F-1 and F-2 are structural building faults for they appeared on all the mapped seismic sections Faults F-3 and F-4 are minor synthetic faults, the reason these faults did not appeared in Figure 4 0b The four faults are trending approximately in the east – west direction

At the downthrown block of the faults in Figure 5 0a is a contour closure, which represents the crest of a rollover anticlinal structure associated with listric growth faults. The contours are found to be near parallel to the fault surface, a pattern typical of a syn-depositional growth fault (Tearpock and Bischke, 1991). The isochron map to the top of layer 4 shown in Figure 5.0b indicates an east – west regional trend and a contour closure against the faults that indicate a good characteristic of a trap for possible hydrocarbon accumulation

The isopach map of layer 3 (Fig 6.0) shows the distribution of sediment of this layer It ranges in thickness from 280 - 410 m and there is a generally high sedimentary thickness in the eastern part of the X-Field, extending westward at the central portion

CONCLUSION.

From the interpretation of the seismic reflection data, the X-Field is found to have simple rollover anticline and growth faults as its main principal structural traps These structures are known to constitute an important hydrocarbon trapping mechanism (Downey, 1990).

The analyses of the composite logs from exploratory wells in the field indicate large quantity of hydrocarbon at the intervals where these structures were mapped.

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