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Growth Fault Analysis in the Niger Delta, Nigeria

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Abstract

Growth fault is one of the characteristic features of the Niger Delta, a petroleum province. Growth fault analysis is very important because it is considered as a structural trap for hydrocarbons. The aim of the analysis is to detect the presence of the fault using geological tools like well tops, fault slips and beddings. The objectives are to correlate well tops and beds as well as determination of throws of the faults. Three basic steps were used in the analysis. The first step is well top determination at each well position, the second step is the fault throw determination and the last step is bed thickness analysis. Three well tops and three beds were used for the analysis. Between Well A-2 and A-1, the throw (dip slip) of Bed 1, 2 and 3 are 19ft (6m), 30ft (9m) and 15 ft (5m). Bed 1 is down-throw (footwall) in Well A-2 and up-throw (hanging wall) in Well A-1. The throw thicknesses respectively are 106ft (32m) and 100ft (30m). Bed 1 is thicker on the down- throw side. Bed 2 is down-throw in Well A-2 and up-throw in Well A-1. The throw thicknesses respectively are 35ft (11m) and 30ft (9m). Bed 2 is thicker on the down-throw. Bed 3 is down-throw in Well A-3 with a thickness of 1125ft (342m) and up-throw in Well A-5. The thickness of Bed 3 in Well A-5 is 130ft (40ft). Bed 3 is thicker in the down-throw.

Key Words: Petroleum, Growth-faults, Dip-slip, well-tops, Bed-thickness, Fault-throw

Introduction

The Niger Delta petroleum province can be related to the Gulf Coast deposits. They are characterized by normal faults and growth faults assemblages (Harding and Lowell 1979). Growth faults are gravity sliding structures. They decrease in dip with depth to a low angle fault, often becoming bedding planes (Tearpock and Bischke 1991). The purpose of this paper is to analyze growth fault in the Niger Delta. Four wells are used for the analysis. They are Wells A-2, A-1, A-3 and A-5. Three steps are adopted in the analysis. The first step is the analysis of formation tops, the second step is vertical separation of the formation tops analysis and the third step is bed thickness analysis. Two important conditions are used to confirm the presence of growth faults: The throw of the faults and bed thicknesses on the hanging walls and the footwalls. In growth fault regions, the beds are thicker on the down-throw sides.

Geological of the Niger Delta

The Niger delta is made up of three sequences: the Akata Formation at the base, the Agbada Formation at the middle and the Benin Formation at the Top Short and Stauble (1967), Amigun J. O., B. Olisa and O. O. Fadeyi (2012), Olisa B. A. and Aduloju B. B. (2020, and Olisa B. A. and C. Okafor (2014). The petroleum producing interval is the Agbada Formation (Figure 1). This interval contains the growth faults.

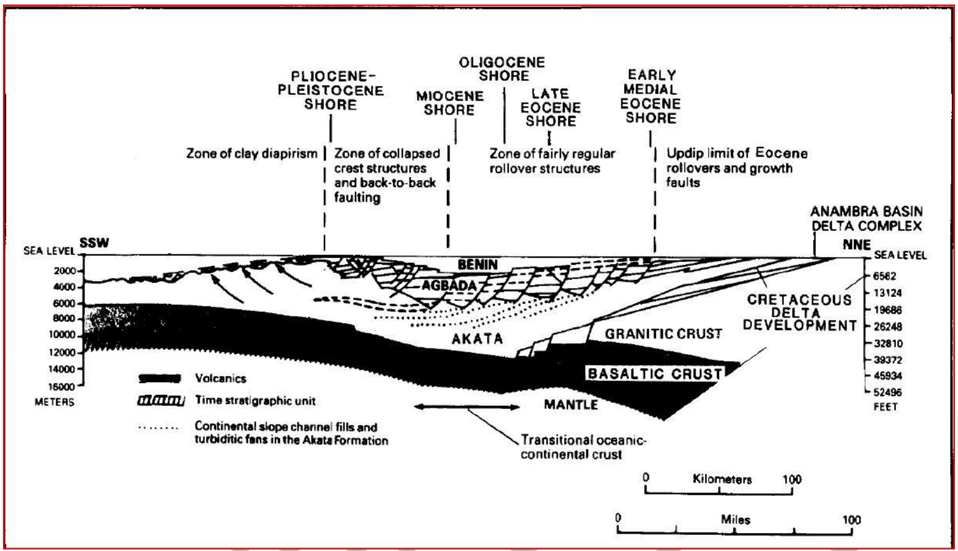

Figure 1: Growth Faults Location in the Niger Delta (After Ablewhite *et al.* 1985)

The Akata Formation

Type locality- Akata-1 well

Type locality/section and geographical coordinate: Lat. 4^0 41’50.5’’N; Long. $7^0$46’58.6’’E.

Interval- 7,180 -11,121 feet.

Desciption- The top of Akata Formation is the deepest occurrence of deltaic sandstone beds at 7180 feet. The base was not reached at the depth of 11,121 feet.

Lithology- The Akata Formation is characterized by a uniform development. The shale in general is dark gray, in some places sandy or silty, and contains, especially in the upper part of the Formation, plant remains and some mica. Toward the top of the formation where it grades into the overlying Agbada Formation, some thin sandstone lenses may occur. The fauna generally is very rich. Planktonic Foraminefera may make up more than 50 per cent of the microfauna. The bentonic foramineferal assemblages indicate deposition of the shale on a shallow-marine shelf.

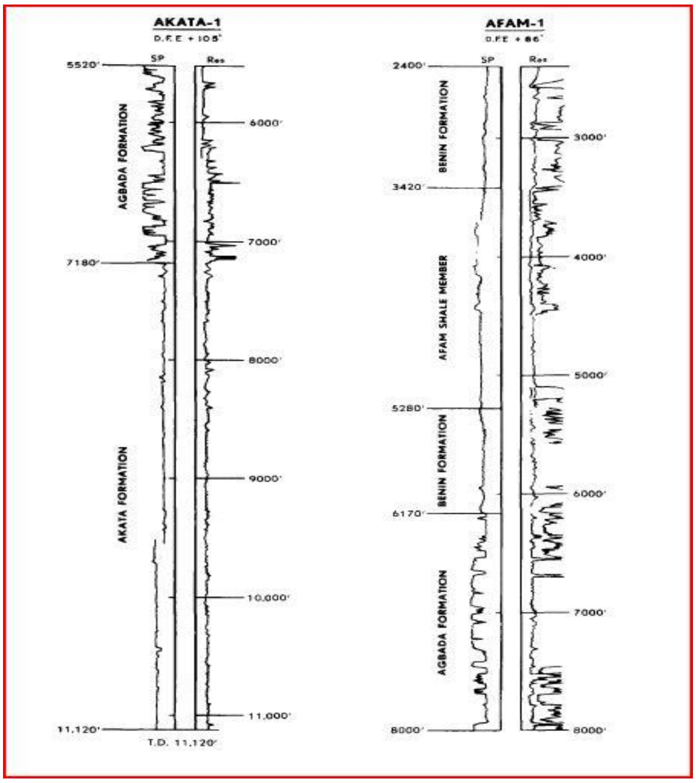

Figure 2: The Akata Formation

The Agbada Formation

Type section – Agbada 2

Interval – 5760-9500 feet below derrick floor

Location – geographical coordinates: Lat. 4^{0}55’ 39.94’’N; Long. 7^{0}i’50.92’’E

Total depth – 9,500 feet.

Description of type section- the top is the highest occurrence of a shale with a brackish-water to marine fauna. The base is not reached at a depth of 9500 feet.

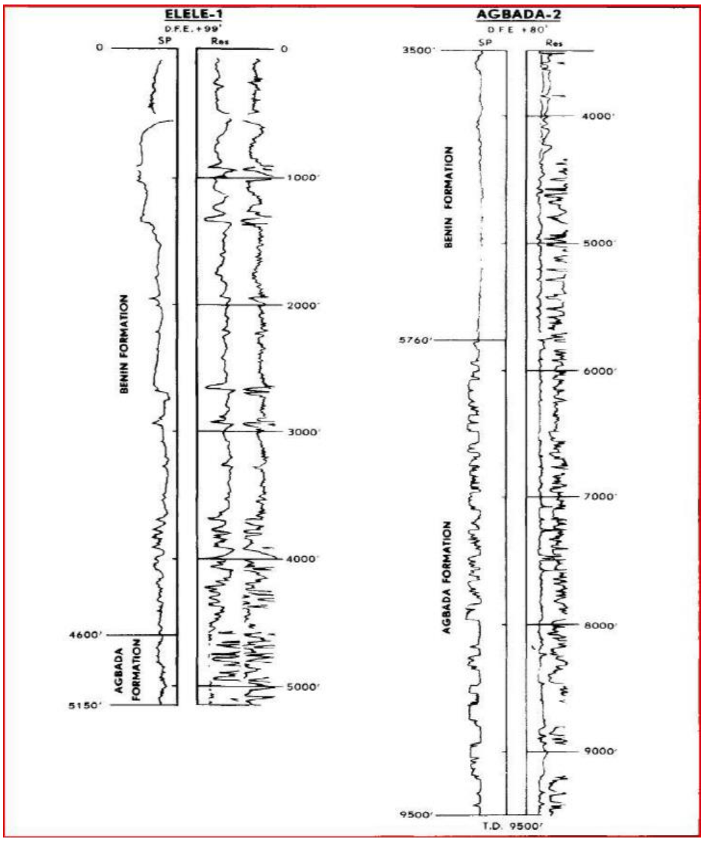

Figure 3: The Agbada Formation and Benin Formations at the type locality.

Lithology – the Agbada formation is characterized by the alternation of sandstone and sand bodies with shale layers. The sequence penetrated in Agbada-2 may be divided into two units: an upper one in which sandstone-shale alterations are abundant and shale intercalations relatively thin; and a lower unit in which the shale units become more prominent and in some places are thicker than the intercalated sandstone o sand bodies. The sandstone percentage ranges from 75 in the upper unit to 50 in the lower unit.

The shale beds are grey and dense at the base; they become markedly sandy and silty upward and grade into the overlying sand and sand bodies. Commonly they contain a microfauna which is best developed at the base of the shale units and becomes sparse or absent in the upper part. This indicates an increase in the rate of deposition in the front of the approaching delta.

The Benin Formation

The type locality is Elele-1. The interval studied is 0-4,600 feet below derrick floor. Total depth is 10,635 feet.

Description: the top of the type section is at the surface; the base of the type section is at a depth of 4,600 feet, and is the top of the highest shale bearing a marine fauna. On the log of type section figure.. , a more pronounce break appears at 3,700 feet but this was found to have only local significance. Of greater importance is the highest appearance within the shale of the first fully marine Foraminefera.

Lithology: The sequence penetrated by Elele-1 is predominantly (more than 90 %) sandy with few shale intercalation; these become more abundant toward the base. The sand and sandstone are coarse-grained, commonly very angular and pebbly to very fine-grained. In general they appear to be very poorly sorted. The grains are sub-angular to well-rounded. The sand and sandstone are white or, because of a limonite coating, yellowish brown. Lignite occurs in thin streaks or finely dispersed fragments; hematite grains and feldspars are common. The shale is grayish brown, sandy to silty, and contains some plant remains and dispersed lignite. Composition, structure, and grain size of the sequence indicate deposition in a continental, probably upper deltaic environment. The sand and sandstone may represent point-bar deposits, channel fills, or natural levees, whereas the shales may be interpreted as backswamp deposits and oxbow fills. The age of Benin Formation indicates an early Miocene to recent.

Methodology

To analyse the growth faults, formation tops 1, 2 and 3 are used respectively at the shallow, the middle and the deepest depths. Well top positions in two adjacent wells were determined. The up-throw side is subtracted from the downthrown side to determine the separation between the tops (deep slip) in each well, A', A'' and A''' (Figure 3). Three beds Bed 1, Bed 2 and Bed 3 are correlated across the wells. The thicknesses were determined on the up-throw and the down-throw sides.

Results and Discussions

Fault throw

Figure 2 and Tables 1, 2 and 3 show the growth fault analyses. The formation tops are A', A'' and A''' at their respective positions (Table 2). In-between Well A-2 and A-1, well tops A' and A'' have throws of 19ft (6m) and 30ft (9m) respectively and well top A''' is 15ft (5m). The fault throws between Wells A-2 and A-1 did not have a corresponding increase with depth.

In-between well A-1 and A-3, well tops A' and A'' have throws of 18ft (5m) and 35ft (11m) respectively and well top A''' is 33ft (10m). The fault throws between Wells A-1 and A-3 did not have a corresponding increase with depth.

Between A-3 and A-5, well tops A' and A'' have throws of 45ft (14m) and 40ft (12m) respectively and well top A''' is 42ft (13m). The fault throws between Wells A-3 and A-5 did not have a corresponding increase with depth.

In the analyses using fault throw, growth fault was not detected because the throw did not increase with depth.

Bed thickness

Figure 2 and Table 3 show thickness variation of three beds 1, 2 and 3. Bed 1 is down-throw in Well A-2 and it is 106ft (32m) thick. In Well A-1 (the up-throw side), Bed 1 is 100ft (30m) thick. Bed 1 is thicker in the down- throw side. Bed 1 is down-throw in Well A-1 and up-throw in Well A-3. In Well A-3, the thickness is 110ft (34m). Bed 1 is thinner in the down-throw. Bed 1 is down-throw in Well A-3 and up-throw in Well A-5. The thickness of Bed 1 in Well A-5 is 115ft (35m). Bed 1 is thinner in the down-throw.

Bed 2 is down-throw in Well A-2 and it is 35ft (11m) thick. In Well A-1 (the up-throw side), Bed 2 is 30ft (9m). Bed is thicker in the down-throw (A- 2). Bed 2 is down-throw in Well A-1 and up-thrown in Well A-3. In Well A-3, the thickness is 25ft (8m). Bed 2 is thicker in the down-throw (A-1). Bed 1 is down-throw in Well A-3 and up-throw in Well A-5. The thickness of Bed 2 in A-5 is 35ft (11ft). Bed 2 is thinner in the down-throw.

Beds 3 is down-throw in Well A-2 and it is 115ft (35m) (Table 2). In Well A-1 (the up-thrown side), Bed 3 is 105ft (32m). Bed is thicker in the down-throw (A-2). Bed 3 is down-throw in Well A-1 and up-throw in Well A-3. In Well A-3, the thickness is 1125ft (342m). Bed 3 is thinner in the down-throw (A-1). Bed 3 is downthrown in Well A-3 and up-throw in Well A-5. The thickness of Bed 3 in Well A-5 is 130ft (40ft). Bed 3 is thicker in the down-throw (A-3).

Table 1 Formation Tops in Wells

	Well A-2		Well A-1		Well A-3		Well A-5	
	Ft (TVDSS)	m	ft (TVDSS)	m	ft (TVDSS)	m	ft (TVDSS)	m
Well Top 1 position	4689	1429	4670	1423	4625	1410	4580	1396

Well Top 2 position	4910	1497	4880	1487	4845	1476	4805	1465
Well Top 3 position	5030	1533	5015	1528	4982	1518	4940	1506

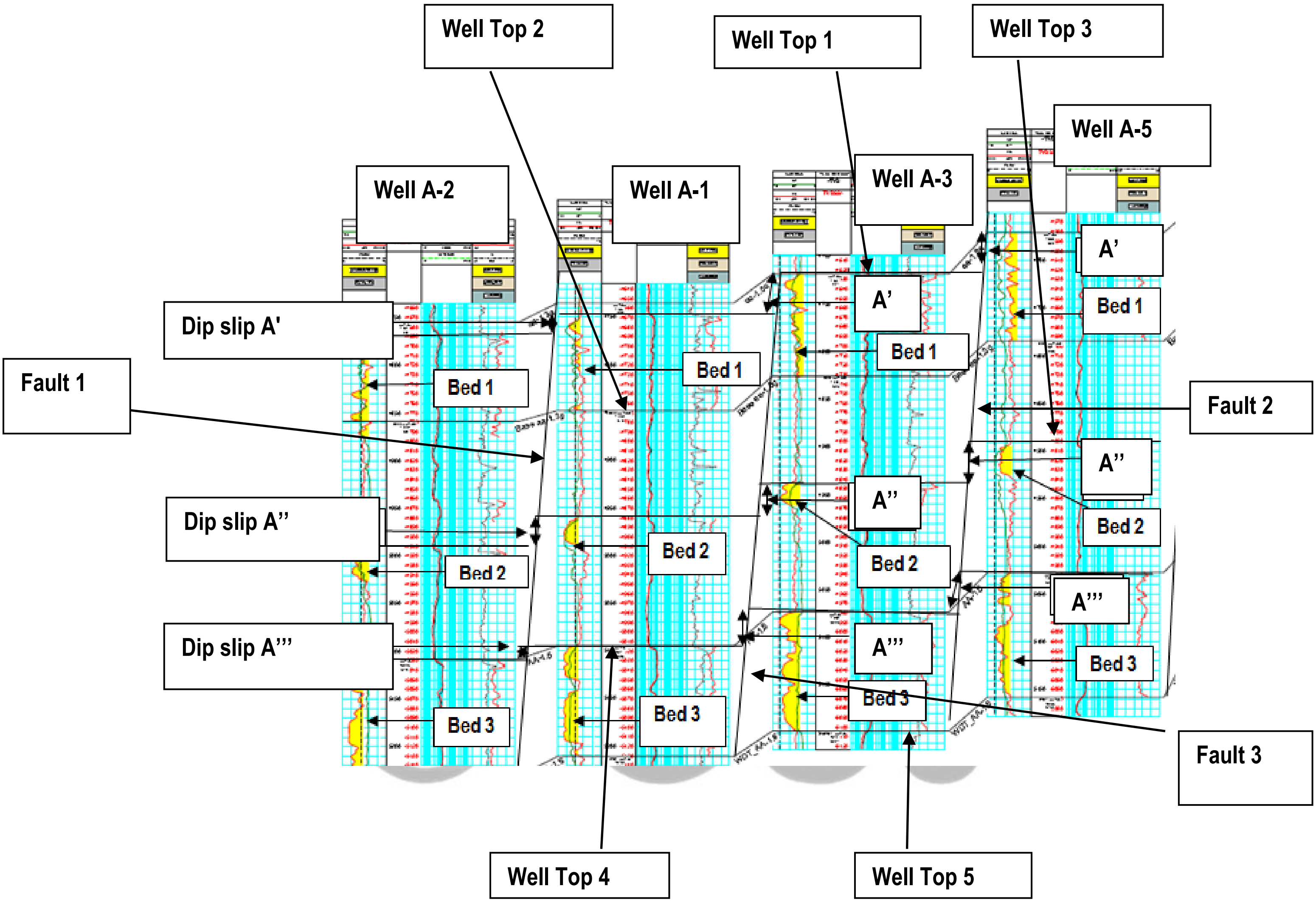

Figure 2 Analyses of Growth Faults

Table 2 Dip slip of Well Tops

	Well A-2/A-1		Well A-1/A-3		Well A-3/A-5	
	ft	m	ft	m	ft	m
A’	19	6	18	5	45	14
A’’	30	9	35	11	40	12
A’’’	15	5	33	10	42	13

Table 3 Thicknesses of the Footwalls and Hanging Walls

Well A-2					**Well A-1**				**Well A-3**			
	Top (ft)	Base (ft)	Thick. (ft)	Thick. (m)	Top (ft)	Base (ft)	Thick. (ft)	Thick. (m)	Top (ft)	Base (ft)	Thick. (ft)	Thick. (m)

Bed 1	4689	4795	106	32	4670	4770	100	30	4625	4735	110	34
Bed 2	4910	4945	35	11	4880	4910	30	9	4845	4870	25	8
Bed 3	5030	5145	115	35	5015	5120	105	32	4982	6108	1126	342

Well A-5				
	Top (ft)	Base(ft)	Thick. (ft)	Thick. (m)
Bed 1	4580	4695	115	35
Bed 2	4800	4835	35	11
Bed 3	4940	5070	130	40

Conclusion

Three faults 1, 2 and 3 had been analysed. There are variations of fault throws (dip slip) on the faults which characterises the Niger Delta growth fault environments. There is thickness variation on the up-throw and down-throw of the faults. Most often the thickness on the down-throw (footwall) is greater than up-throw (hanging wall) side.

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