Geometric characterization of Point Bar Deposits in the lower River Niger, Niger Delta.

Akana, S. Tombra1,3\*, Adeigbe, O.C2,

1Department of Geology, Pan African University Life and Earth Science Institute, University of Ibadan, Ibadan, Nigeria.

2Department of Geology, University of Ibadan, Ibadan, Nigeria.

3 Department of Geology, Niger Delta University, Wilberforce Island, Bayelsa State Nigeria.

\*e-mail: brossatombra@gmail.com.

ABSTRACT

Remote sensing and GIS based results from the geometric characterization of point bar deposits in the Lower River Niger are presented in this work. In this study the geometry of 75- point bar deposits from Landsat images of 1985 and 2015 were documented and compared to determine the relationship that exist between geometric dimensions and the amount of change that has occurred on them. Point bars in 2015 are observed to be greater in length, width and area than those in 1985. The R² values indicate that no relationship exists between point bar length and width. However, a significant relationship is observed to exist between both length and area and width and area of the point bars within the study area. Thus, the utilization of width to predict the length and vice versa of point bars is unreliable. Information from this study provides useful information on specific shape and size ranges that can be utilized for the efficient characterization and development of hydrocarbon reservoirs.

**Keywords:** Lower River Niger, Remote sensing, GIS, Landsat, Point bar geometry,

Introduction

With fossil fuel in high demand worldwide, the focus of most oil producing countries and Exploration companies is on identifying new reserves and fully optimizing old ones. The modern Niger Delta is evolving daily, impacted by the increasing activity within, both naturally and anthropogenically. Therefore, an understanding of the characteristics of the modern surface reserves would greatly improve exploration programs, reduce exploration and production costs and manage downtime in industry. Fluvial channel bar deposits especially point bars are known to be one of the best reservoirs within the Niger Delta because of their high sand ratio and thickness [1]. Thus, it is necessary to understand the external geometry of such an important landform which would lead to the effective characterization and development of similar hydrocarbon reservoirs [2].

Meandering rivers are known to deposit sand and mud within well-defined meander belts [3]. Macro landforms found in meander belts include point bars, crevasse splays, and mud-rich channel plugs within a background of floodplain muds [4]. This paper focuses on the Point bar macro landform. Although on the surface point bars are considered macro landforms, after they have undergone burial and diagenetic processes they reduce somewhat in size and therefore can be missed on seismic data due to resolution. Exploration wells which can address resolution problems are usually expensive to drill and spaced far apart and thus can also miss these point bars. Remote sensing which is a low-cost technique is suitable for studying modern fluvial channels and their landforms which in turn provide valuable information on the geometry of point bar deposits. The findings of such study can be utilized in

ancient fluvial channel deposits as an input in characterization and development of hydrocarbon

bearing reservoirs.

Very few literatures are available where the spatial geometry of point bars are considered [5]; [6]. However, through the study and understanding of the geometry of outcropped fluvial deposits [7] suggests exploration and exploitation potentials of hydrocarbon reservoirs can be improved. [4] studied the geometry surface landforms in the Mississippi river with the use of remote sensing techniques and established that a correlative relationship exists between length and width channel bars. He also suggests that geometric landform surface studies provide information which can aid cost efficient exploration and characterization of ancient fluvial hydrocarbon reservoirs.

Study Area

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between latitudes 3°N and 6°N and longitudes 5°E and 8°E [8]. It is bound on the northwest by a subsurface continuation of the West African shield, the Benin Flank. The eastern edge of the basin coincides with the Calabar Flank to the south of the Oban Masif [9] on the south bound by the Atlantic Ocean (Figure 1). The proto delta developed in the northern part of the basin during the Campanian transgression and ended with the Paleocene transgression. Formation of the modern delta began during the Eocene, the three major depositional environments typical of most deltaic environments are the marine, transitional and continental represented in the Niger Delta basin by the Akata, Agbada and Benin Formations respectively. The delta has been fed by the Niger, Benue and Cross Rivers, which between them drain more than 106 km2 of continental lowland savannah, The Niger-Benue river system alone brings a sediment load of about 0.02 km3/yr. which is deposited mainly on top the delta [10].

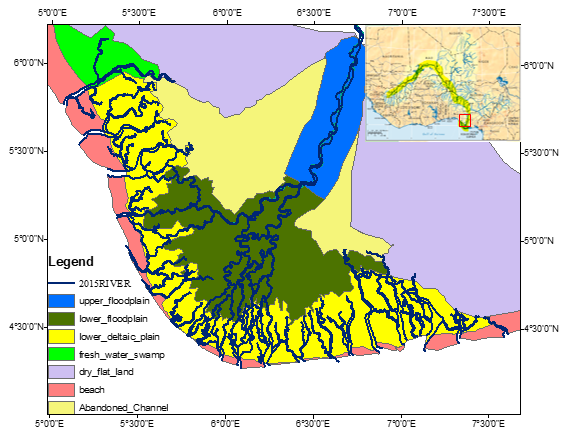
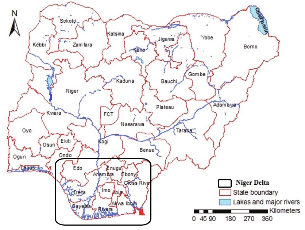


Figure 1: Geologic map of Niger Delta showing study location and major sedimentary environments as defined by the fluvial, tidal and wave-related processes.

Data and Methodology

Satellite images of 1985 and 2015 (Landsat TM—resolution 30 m) were used for assessing the geometric changes in channel bar (point bar) deposits over a 30-year period. All datasets were geometrically corrected and resampled to bring to the same scale [11]. Processing and interpretation of satellite imagery to delineate changes in point bar landforms and analysis of the dataset was achieved using ESRI ArcGIS 10.3 and ArcView 3.5 computer software. The procedures were tailored towards extracting quantitative parameters from the identified point bars using geoprocessing operations. The parameters estimated from the point bars include length, width and area. The length of the point bar is determined as the distance between the two terminal points along a bar. The width of a point bar is defined as the maximum length between the two end-to-endpoints across a bar. Length, width and area of the point bars have been measured within the Arc GIS software.

Results and Discussion

Point bar deposits and their geometry

Channel- belt deposits formed in bends of meandering rivers tend to provide a good proxy estimate of paleo-channel depth (e.g., [12]; [13]. Therefore, channel depth can be estimated by measuring a completely preserved channel-bar-deposit [14]; [15]; [16]; [17]. There are 38point bars mapped in the Niger Delta in 1985 and 37 in 2015. They are associated with the fluvial channels within the upper delta plain covering the upper and lower floodplains of the Niger Delta. The length of the point bars mapped varies between 476m and 9,305m in 1985 and 300m to 8,604m in 2015 whereas their width varied from 116m to 4896m in 1985 and 101m to 6490m in 2015 (Table 1). Area varied from 33171m² to 22499271m² in 1985 and 53286m² to 6103804m² in 2015. There is an average of 0.6% rate of change in the length of the point bars within the study period and a 2.6% of positive change affecting their width. An average of 8.6% rate of positive change affected the area of the point bars over the period of study (30 years) which lends to the high rates of erosion within the river Niger channel. The mode length of point bars increased from 1-4km in 1985 to 2.5- 4.7km in 2015 whereas the width increased from 0.1km-1km in 1985 to 0.1km- 1.6km in 2015. The mode area was also observed to increase from 0.1km- 5km in 1985 to 0.1km -6.5km in 2015. This invariably implies that although deposition on the point bars were observed, erosion was prevalent over the study period. The overall geometry of point bars is not only influenced by sediment erosion and deposition along the channel bank but also depends on the river hydrodynamics. Low energy rivers with high braiding can also affect the formation and geometry of the point bars; as areas with high braiding index has less and or smaller sized point bars. On the other hand, braiding can trigger accumulation of the sediment at the banks which can initiate point bar formation [18]. However, most point bars evaluated in this study were associated with channel portions with little or no braiding and lower energy levels. The length, width and area, associated with the point bar are plotted to validate the dependence of these parameters to one another (Table 2).

Studies of point bars and related fluvial bodies by [19]; [20]; [21]; [22]; [23] have shown that relationships exist between parameters such as thickness, length and width, volume, river sinuosity and bend tightness. The plots of point bar length against area and the point bar width against area show a significant relationship in this study. However, no significant relationship is observed to exist between point bar width and point bar length within the study period (Table 2).

Table 1: Variation in geometric dimensions (length, width and area) of point bars (PB) within the Niger Delta between year 1985 and year 2015

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| PB NAME | LENGTH (M) | | | WIDTH (M) | | | AREA (M²) | | |
| YEAR 1985 | YEAR 2015 | % RC | YEAR 1985 | YEAR 2015 | % RC | YEAR 1985 | YEAR 2015 | % RC |
| 1 | 3655 | 2857 | -0.7 | 1231 | 1613 | 1.0 | 2873570 | 2262264 | -0.7 |
| 2 | 8154 | 2042 | -2.5 | 2060 | 805 | -2.0 | 8872040 | 907228 | -3.0 |
| 3 | 3874 | 2558 | -1.1 | 643 | 860 | 1.1 | 1877913 | 1371097 | -0.9 |
| 4 | 3218 | 3755 | 0.6 | 881 | 1277 | 1.5 | 1692639 | 2185746 | 1.0 |
| 5 | 3653 | 5199 | 1.4 | 1302 | 2471 | 3.0 | 2834949 | 10749460 | 9.3 |
| 6 | 3068 | 3243 | 0.2 | 1431 | 2093 | 1.5 | 2951935 | 4339841 | 1.6 |
| 7 | 2486 | 5140 | 3.6 | 679 | 2846 | 10.6 | 1368884 | 10630383 | 22.6 |
| 8 | 6098 | 3147 | -1.6 | 2862 | 2216 | -0.8 | 8952148 | 3092528 | -2.2 |
| 9 | 5008 | 6933 | 1.3 | 2149 | 2743 | 0.9 | 7614191 | 10811505 | 1.4 |
| 10 | 5668 | 1950 | -2.2 | 3228 | 287 | -3.0 | 11283454 | 394892 | -3.2 |
| 11 | 6434 | 7981 | 0.8 | 729 | 3406 | 12.2 | 2744708 | 16899259 | 17.2 |
| 12 | 5831 | 7091 | 0.7 | 1687 | 5255 | 7.0 | 7158460 | 21819150 | 6.8 |
| 13 | 1997 | 6566 | 7.6 | 795 | 4048 | 13.6 | 915618 | 15664665 | 53.7 |
| 14 | 7481 | 8604 | 0.5 | 4659 | 3216 | -1.0 | 21499273 | 15647302 | -0.9 |
| 15 | 7694 | 6485 | -0.5 | 4896 | 6490 | 1.1 | 5582275 | 19598271 | 8.4 |
| 16 | 6175 | 3445 | -1.5 | 3384 | 3437 | 0.1 | 1493120 | 11508165 | 22.4 |
| 17 | 9305 | 5543 | -1.3 | 2142 | 3181 | 1.6 | 9938875 | 11212784 | 0.4 |
| 18 | 1638 | 5982 | 8.8 | 738 | 1309 | 2.6 | 743941 | 8173841 | 33.3 |
| 19 | 2492 | 5832 | 4.5 | 305 | 1935 | 17.8 | 410735 | 8408931 | 64.9 |
| 20 | 3139 | 2547 | -0.6 | 694 | 680 | -0.1 | 1546816 | 1160386 | -0.8 |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| PB NAME | LENGTH (M) | | | WIDTH (M) | | | AREA (M²) | | |
| YEAR 1985 | YEAR 2015 | % RC | YEAR 1985 | YEAR 2015 | % RC | YEAR 1985 | YEAR 2015 | % RC |
| 21 | 5249 | 3304 | -1.2 | 1450 | 703 | -1.7 | 7151553 | 1436439 | -2.7 |
| 22 | 6162 | 3448 | -1.5 | 1760 | 880 | -1.7 | 8278769 | 1677171 | -2.7 |
| 23 | 5643 | 2396 | -1.9 | 1921 | 434 | -2.6 | 8157500 | 1101159 | -2.9 |
| 24 | 4570 | 1339 | -2.4 | 1216 | 448 | -2.1 | 2880185 | 386001 | -2.9 |
| 25 | 3278 | 300 | -3.0 | 882 | 109 | -2.9 | 1669338 | 190737 | -3.0 |
| 26 | 2578 | 2426 | -0.2 | 565 | 1502 | 5.5 | 847896 | 2768175 | 7.5 |
| 27 | 2536 | 5064 | 3.3 | 1484 | 1411 | -0.2 | 3058628 | 4036041 | 1.1 |
| 28 | 3128 | 2462 | -0.7 | 718 | 2534 | 8.4 | 1235404 | 4452652 | 8.7 |
| 29 | 3557 | 5823 | 2.1 | 3118 | 885 | -2.4 | 8765554 | 4277302 | -1.7 |
| 30 | 1440 | 3162 | 4.0 | 350 | 1875 | 14.5 | 340083 | 4173703 | 37.6 |
| 31 | 1926 | 3533 | 2.8 | 1936 | 1334 | -1.0 | 3165994 | 5985016 | 3.0 |
| 32 | 3404 | 2570 | -0.8 | 1576 | 1828 | 0.5 | 3552385 | 4330978 | 0.7 |
| 33 | 3485 | 3454 | 0.0 | 1376 | 2473 | 2.7 | 5711433 | 6058858 | 0.2 |
| 34 | 2286 | 1954 | -0.5 | 1801 | 2363 | 1.0 | 4077233 | 4040931 | 0.0 |
| 35 | 1976 | 1135 | -1.4 | 4031 | 2219 | -1.5 | 4855496 | 3207949 | -1.1 |
| 36 | 2210 | 2136 | -0.1 | 1808 | 433 | -2.5 | 3883059 | 826667 | -2.6 |
| 37 | 476 | 561 | 0.6 | 116 | 101 | -0.4 | 33172 | 53286 | 2.0 |
| 38 | 579 | nil |  | 134 | nil |  | 56964 | nil |  |
| T-Min | 476 | 300 | -3.0 | 116 | 101 | -3.0 | 33172 | 53286 | -3.2 |
| T-Max | 9305 | 8604 | 8.8 | 4896 | 6490 | 17.8 | 22499273 | 21819150 | 64.9 |
| T-Ave | 3988 | 3837 | 0.6 | 1651 | 1938 | 2.5 | 4475689 | 6103804 | 8.6 |

\*PB- Point bars, T-Max- Total Maximum, T-Min- Total Minimum, T-Ave- Total Average, RC- Rate of change, Negative (-) values refer to erosion, Nil- not present in that year.

Table 2: Summary table for plots of point bar geometric dimensions dependence of a parameter against another.

|  |  |  |  |
| --- | --- | --- | --- |
| Plots for point bar geometric dimensions | | | |
| Year | PLOT | R² | Comment |
| 1985 | Point bar Length against Point bar Width | 0.3 | No significant relationship |
| 2015 | Point bar Length against Point bar Width | 0.4 | No significant relationship |
| 1985 | Point bar Width against Point bar Area | 0.6 | Significant relationship |
| 2015 | Point bar Width against Point bar Area | 0.8 | Significant relationship |
| 1985 | Point bar Length against Point bar Area | 0.6 | Significant relationship |
| 2015 | Point bar Length against Point bar Area | 0.7 | Significant relationship |

Conclusions

A total of 75point bars were analyzed, 38 in 1985 and 37 in 2015. Averagely the point bars identified in 2015 are greater in geometric dimensions than those identified in 1985. The average percentage rate of change in the length and width of the point bars were identified to be 0.6% 2.6% respectively and average of 8.6% rate of positive change affected the area of the point bars over the period of study (30 years). The coefficient of determination result suggests that there are no relationships between the width and length of point bar deposits within the River Niger channel. It is therefore unreliable to utilize width to predict the length of a point bar deposit or vice versa unless more data is incorporated. Remote sensed studies provide valuable information on the geometry of point bar deposits, in modern fluvial systems, which can serve as analogs, for the efficient characterization and development of hydrocarbon reservoirs in ancient fluvial channel bar deposits.

REFERENCES

1. J.D. Edwards, and P.A Santogrossi, “Summary and conclusions”, in, Edwards, J.D., and Santogrossi, P.A., eds., Divergent/passive Margin Basins, AAPG Memoir 48: Tulsa, American Association of Petroleum Geologists, (1990), p. 239-248.

2. T.H.D. Payenberg, S.C. Lang, S.C. and B. Wibowo, “Discriminating fluvial from deltaic channels examples from Indonesia”, Proc. 29th Ann. Conv. Indonesian Petroleum Association, 1, (2003), p. 1-16.

3. M. Shepherd, “Meandering fluvial reservoirs”, in M. Shepherd, Oil field production geology. AAPG, 2016.

4. V.K. Sahay, “Spatial Geometry of Channel Bar Deposits of Mississippi River, United States of America” International Basic and Applied Research Journal, Volume 2, Issue 9, (2016) p. 1-7.

5. A.D Miall, “Architectural-element analysis: A new method of facies analysis applied to fluvial deposits”, Earth-Science Reviews. 22. (1985), p. 261-308. 10.1016/0012-8252(85)90001-7.

6. G.E. Tucker, “Drainage basin sensitivity to tectonic and climatic forcing: Implications of a stochastic model for the role of entrainment and erosion thresholds”, Earth Surf. Processes and Landforms, 86, (2003), p. 76-88.

7. A.D. Miall, “Architectural elements and bounding surfaces in fluvial deposits: Anatomy of the Kayenta Formation (Lower Jurassic), southwest Colorado”, Sedimentary Geology, v. 55, (1988), p. 233-262.

8. T.J.A. Reijers, S.W. Petters, C.S. Nwajide, “The Niger Delta basin” in Reijers TJA (ed.), selected chapters on Geology: SPDC corporate reprographic services, Warri, Nigeria. (1996), p. 103 – 114.

9. R.C. Murat, “Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria”, African Geology, DEssauvagie TFJ and Whiteman AJ (Eds), University of Ibadan Press. Pp. 251 – 266, 1972.

10. K. Burke, “Longshore drift, submarine canyons and submarine fans in the development of the Niger Delta” AAPG Bulletin. Vol. 50, (1972), pp. 1975 – 1983.

11. T.M. Lillesand and R.W. Kiefer, “Remote Sensing and Image Interpretation”. John Wiley and Sons, New York, 2000.

12. F.G Ethridge and S.A. Schumm, “Fluvial seismic geomorphology: a view from the surface”, in Davies R.J., Posamentier H.W., Wood L.J., Cartwright J.A. eds., Seismic Geomorphology: Applications to Hydrocarbon Exploration and Production: Geological Society of London, Special Publication 277, (2007) p. 205–222.

13. B.J. Willis, “Palaeochannel reconstructions from point bar deposits: a three‐dimensional perspective”, Sedimentology, vol 36, 5, (1989), p. 757-766.

14. J.S. Bridge, R.S. Tye, “Interpreting the dimensions of ancient fluvial channel bars, channels, and channel belts from wireline-logs and cores”, Am. Assoc. Petrol. Geol. Bull., 84, (2000), p. 1205–1228.

15. J.P. Bhattacharya and R.S Tye, “Searching for modern Ferron analogs and applications to subsurface interpretation”, in Chidsey, T.C., JR., Adams, R.D., and Morris, T.H., eds., Regional to Wellbore Analog for Fluvial–Deltaic Reservoir Modeling: the Ferron Sandstone of Utah: American Association of Petroleum Geologists, Studies in Geology 50, (2004), p. 39–57.

16. A.D. Miall, “How do we identify big rivers? And how big is big?”, Sedimentary Geology, 186(1), (2006), p.39-50.

17. J. Holbrook and H. Wanas, “A Fulcrum Approach to Assessing Source-To-Sink Mass Balance Using Channel Paleohydrologic Paramaters Derivable from Common Fluvial Data Sets with An example from the Cretaceous of Egypt”, Journal of Sedimentary Research ; 84 (5) (2014) p. 349–372. doi: <https://doi.org/10.2110/jsr.2014.29>.

18. L.B. Leopold, G.M. Wolman, J.P. Miller, “Fluvial processes in geomorphology”. W. H. Freeman, California, (1964), p. 453–468.

19. J.C. Lorenz, D. M. Heinze, J. A. Clark, and C. A. Searls, “Determination of widths of meander-belt sandstone reservoirs from vertical downhole data, Mesaverde Group, Piceance Creek basin”, Colorado: AAPG Bulletin, v. 69, (1985), p. 710–721.

20. C.R Fielding and R.C. Crane, “An application of statistical modelling to the prediction of hydrocarbon recovery factors in fluvial reservoir sequences” In: Recent Developments in Fluvial Sedimentology, (1987), p. 321–327 (eds Ethridge, F.G., Flores, R.M. and Harvey, M.D.). SEPM Special Publication 39, Tulsa, OK.

21. I.D. Bryant and S.S Flint, “Quantitative clastic reservoir geological modelling: Problems and perspectives” In: The Geological Modelling of Hydrocarbon Reservoirs and Outcrop Analogues, pp. 3–20 (eds Flint, S. and Bryant, I.D.). International Association of Sedimentologists Special Publication 15, Blackwell Scientific Publications, Oxford, 1993.

22. C.P. North, “The prediction and modelling of subsurface fluvial stratigraphy” In P. A. Carling and M. R. Dawson (eds), Advance in Fluvial Dynamics and stratigraphy. New York: John Wiley and Sons Ltd, p. 396-508, 1996.

23. M. De Rooij, P.W. Corbett, L. Barens, “Point bar geometry, connectivity and well test. first break”, (2002), 20(12).