Asian Journal of Environment & Ecology

13(4): 52-57, 2020; Article no.AJEE.61424
ISSN: 2456-690X

Geometric Characterization of Fluvial Associated Braid Bar Deposits in the Niger Delta

Tombra Susan Akana[1*] and Oyinkuro Austin Oki[1]

[1]*Department of Geology, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.*

Authors' contributions

This work was carried out in collaboration between both authors. Authors TSA and OAO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author TSA managed the analyses of the study. Author OAO managed the literature searches. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJEE/2020/v13i430190
Editor(s):
(1) Prof. Daniele De Wrachien, University of Milan, Italy.
Reviewers:
(1) Hem Kant Jha, S. K. Murmu University, India.
(2) Dwi Astuti Wulandari, Mataram University, Indonesia.
Complete Peer review History: http://www.sdiarticle4.com/review-history/61424

Original Research Article

Received 03 August 2020
Accepted 09 October 2020
Published 28 October 2020

ABSTRACT

Remote sensing and GIS based results from the geometric characterization of braid bar deposits in the Niger Delta are presented in this work. In this study the geometry of 67- braid 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. The braid bars identified in this work are all associated with fluvial environment in the Niger Delta. Braid bars in 1985 are observed to be greater in length, width and area than those in 2015. R^2 values (0.6) indicate that a significant relationship exists between braid bar length and width. R^2 values also indicate a significant relationship exists between both length and area (0.7) and width and area (0.8) of the braid bars values within the study area. Thus, the utilization of width to predict the length and vice versa of braid bars is reasonable. Hence data from this study provides relevant information on size ranges that can be utilized for the efficient characterization, modelling and development of hydrocarbon reservoirs.

Keywords: Niger Delta; remote sensing; GIS; Landsat; braid bar deposits.

**Corresponding author: E-mail: brossatombra@gmail.com;*

1. INTRODUCTION

Braided rivers and their products are well preserved in the rock record and typically make excellent, very productive reservoirs with many ancient braid plain deposits forming important hydrocarbon reservoirs [1,2]. Their relatively coarse-grained gravel and sand lithologies make braid bars one of the best reservoirs [3]. Oil recovery factors can be very high in braided river reservoirs, commonly more than 50% [4]. However, heterogeneities present their architecture in form of sand-body connectivity, shale intercalations and depositional controls upon diagenesis can markedly reduce effective permeability [2]. Braid bars are common on many active meandering and braided river beds, but specific information on their geometry, scale of development and on the occurrence of bars is lacking [5]. Although, relations have been established between indices describing the mid-channel bars and the controlling variables, such as the channel width, the percentage silt-clay content in the channel boundary and the energy expenditure of flowing water [6]. Bank erosion provides space and materials for mid-channel bar formation especially braid bars thus, braid bar formation and size is directed related to the bank erosion rate.

2. STUDY AREA

The Niger Delta Basin is situated in the Gulf of Guinea in equatorial West Africa, between 3°N and 6°N latitude and 5°E and 8°E longitude [7,8]. It is bound on the northwest by the Benin Flank, a subsurface continuation of the West African shield. 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 (Fig. 1). It is an extensional rift basin surrounded by other basins in the area formed under similar conditions. It is positioned on the passive continental margin of Gulf of Guinea near the western coast of Nigeria. It is one of the largest sub-aerial basins in Africa with a sub-aerial area of about 75,000 km^2, a total area of 300,000 km^2 and sediment fill of 500,000 km^3 and depth of 9-12 km [10]. The proto delta developed in the northern part of the basin during the Campanian transgression and ended with the Paleocene transgression. It is bounded by Cameroon, Equatorial Guinea and São Tomé and Príncipe (Fig. 1). The basin which contains a very productive petroleum system is known for its complexity and high economic value. The Niger Delta basin lies in the south westernmost part of a larger tectonic structure, the Benue Trough. The onshore portion of the Niger Delta province

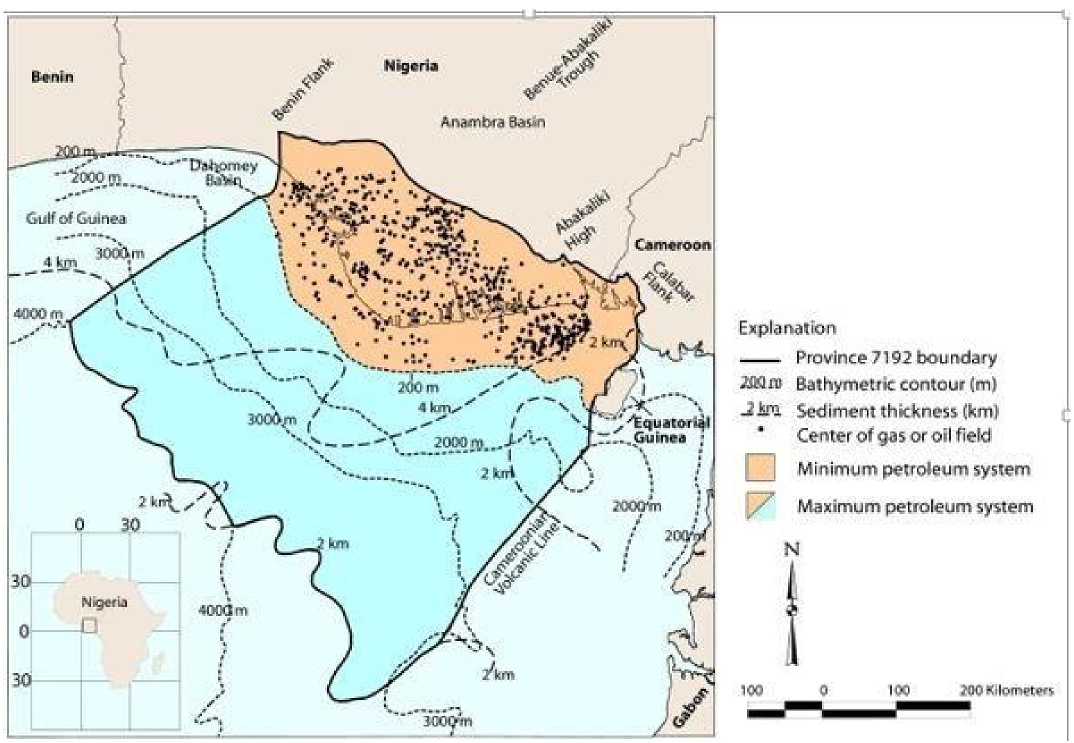


Fig. 1. Index map of Nigeria and Cameroun [11]

is delineated by the geology of southern Nigeria and south-western Cameroon (Fig. 1). It is bounded to the north by the Benin Flank, an east-northeast trending hinge line at the south of the West Africa basement massif. Outcrops of the Cretaceous Abakiliki high demarcate the province to the Northeast and the Calabar Flank (a hinge line bordering the adjacent Precambrian) to the east-south-east [10]. The province is bounded offshore by the Cameroon volcanic line to the east. To the west it is bounded to the west by the easternmost West African transform-fault passive margin, the Dahomey Basin. Also, in this direction is a two-kilometer sediment thickness contour to the south and southwest. Part of the province is the geologic extent of the Akata-Agbada Formation in the Tertiary Niger Delta Petroleum System [10].

3. RESEARCH METHODOLOGY

Satellite images of 1985 and 2015 (Landsat TM—resolution 30m) were used for assessing the geometric changes in channel bar (braid bar) deposits over a 30-year period. All datasets were geometrically corrected and resampled to bring to the same scale [12]. 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 braid bar is determined as the distance between the two terminal points along a bar. The width of a braid bar is defined as the maximum length between the two end-to-endpoints across a bar. Length, width and area of the braid bars have been measured within the Arc GIS software.

4. RESULTS AND DISCUSSION

Deposits formed in braided and meandering rivers tend to provide a good substitute estimate of paleo-channel depth [13,14,15] and thus, channel depth can be derived by measuring a completely preserved channel-bar-deposit [16,15,17]. 34 braid bars were mapped in the Niger Delta in 1985 and 33 in 2015. They are associated with the fluvial channels within the upper delta plain of the Niger Delta. In 1985, the area of the braid bars mapped ranged from 0.06 km^2 to 17.8 km^2, the length ranged from 697 m to 7,978 m and width from 105 m to 3,536 m. The length to width ratio ranged 1.66 m to 18.40 m (Table 1). By 2015, the area of braid bars ranged from 0.08 km^2 to 18.5 km^2, the length ranged from 685 m to 7,640 m and the width from 122 m to 3,146 m. The length to width ratio ranges from 1.27 to 16.33 and averages at 4 (Table 2).

Braid bars in 1985 are averagely larger in area than those mapped in 2015 (Fig. 2). There is a 3.7% reduction in area and a change rate of 3.29 m^2 /year. This indicates erosional processes rather than depositional processes are prevalent during the study period. Thus, the overall geometry of bars is not only affected by sediment erosion and deposition along the channel but also depends on the river hydrodynamics as the energy of river also determines the location and amount of sediment deposited along the river channel [18]. The coefficient of regression plots of braid bar length against width and area and width against area in 1985 falls between 0.6 and 0.8 whereas, in 2015 the coefficient of regression of these same plots falls between 0.6 and 0.9 (Fig. 3). In general, mid channel bar dimension (length and width) correlates positively with their area. Thus, with the determined regression coefficient values being favourably high, length and width values can be predicted from each other and there are scale invariant [19,20,21,22]. This implies that, knowledge of either the width or the length of the bar enables accurate reconstructions of the other dimensions. Although, braid bar dimensions are likely to be modified by erosion before preservation in the rock record, as fluvial bar-forms effectively represent the principal preserved depositional element of fluvial channel systems in the rock record, a quantitative understanding of likely braid bar dimensions will be particularly useful when attempting subsurface modelling.

Table 1. 1985 mid channel geometric dimension summary in the Niger Delta inclusive of Niger, Forcados and Nun Rivers

Braid bar function	Length of Braid bar (m) Lbb	Width of Braid bar (m) Wbb	Area of Braid bar (m^2) Abb	Lbb/Wbb
Average	3146	896	2675992	4.09
Maximum	7978	3536	17804492	18.41
Minimum	697	105	59210	1.67

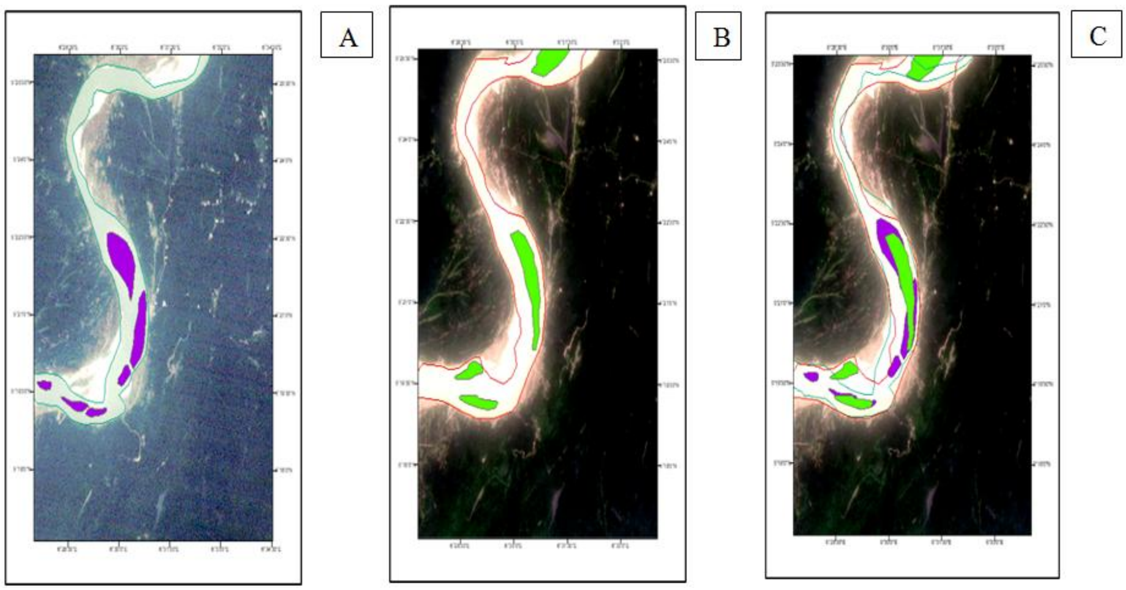
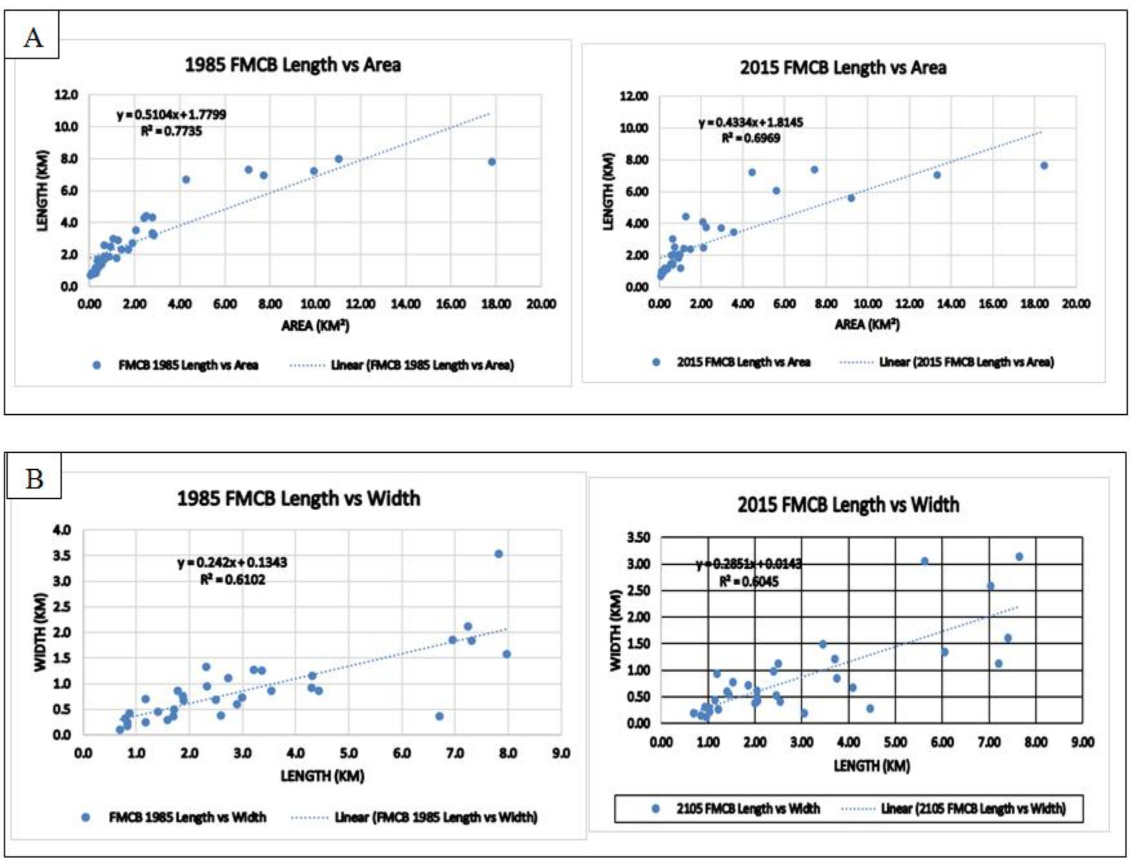


Fig. 2. (A) 1985 Section of River Niger just before Asamabiri showing braided bars (B) 2015 Section of the same location showing braid bars. (C) Composite image of braid bars mapped along River Niger in 1985 and 2015 (Fluvial midchannel bars FMCB)



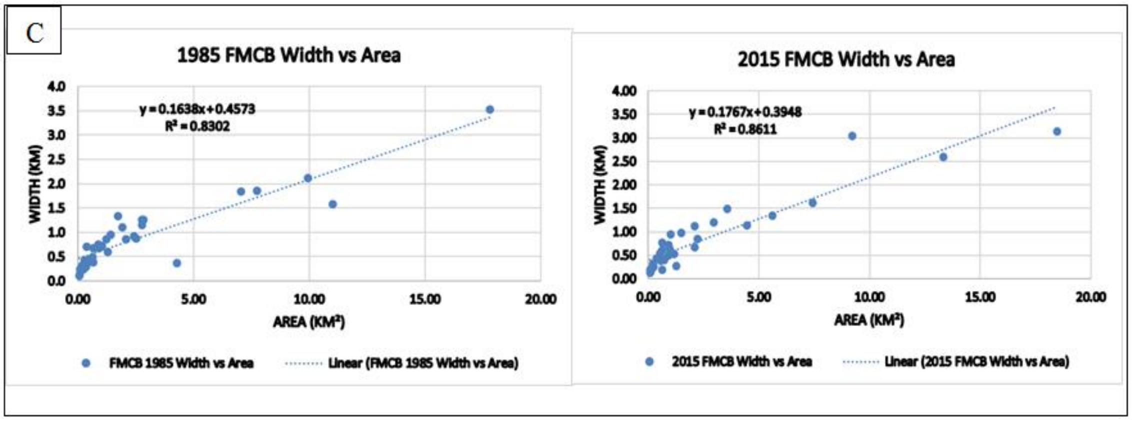


Fig. 3. Plots showing geometric relationships of braid bars within study area. A) Length against Area 1985 and 2015 B) Width against Length 1985 and 2015 C) Width against Area 1985 and 2015

Table 2. 2015 mid channel geometric dimension summary in the Niger Delta inclusive of Niger, Forcados and Nun Rivers

Braid bar function	Length of Braid bar (m) Lbb	Width of Braid bar (m) Wbb	Area of Braid bar (m^2) Abb	Lbb/Wbb
Average	2932	850	2577436	4.56
Maximum	7640	3146	18455194	16.33
Minimum	685	122	78763	1.27

5. CONCLUSION

In total 67 braid bars were analyzed; 34 in 1985 and 33 in 2015. On an average the braid bars identified in 2015 were greater in geometric dimensions than those identified in 1985 with length to width ratio of 4 in 1985 and 4.5 in 2015. The braid bars experienced averagely 3.7% of negative change during the 30-year study period and an erosional rate of 3.29 m per year. The coefficient of determination results suggests that there is a direct relationship between the width and length of fluvial associated braid bar deposits within the River Niger channel. It is therefore reliable to utilize width to predict the length of a braid bar deposit if either dimension is unavailable. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ferguson RI. Understanding braiding processes in gravel-bed Rivers: Progress and unsolved problems. Geological Society, London, Special Publications. 1993;75(1):73-87.
2. Jones JA, Hartley AJ. Reservoir characteristics of a braid-plain depositional system: The upper carboniferous pennant sandstone of South Wales. Geological Society, London, Special Publications. 1993;73(1):143-156.
3. Slatt RM. Stratigraphic reservoir characterization for Petroleum Geologists, Geophysicists and Engineers. Elsevier Publ. Co. 2006;492.
4. Martin JH. A review of braided fluvial hydrocarbon reservoirs: The petroleum engineer's perspective. In J. L. Best and C. S. Bristow, Eds., Braided Rivers: Geological Society. Special Publication. 1993;75:333–367.
5. Hooke JM. The significance of mid-channel bars in an active meandering river. Sedimentology. 1986;33(6):839–850.
6. Jiongxin X. Evolution of mid-channel bars in a braided river and complex response to

reservoir construction: An example from the middle Hanjiang River, China. Earth Surface Processes and Landforms. 1997;22(10):953–965.
7. Reijers TJA, Petters SW, Nwajide CS. The Niger Delta basin. In Reijers TJA (Ed.), Selected Chapters on Geology: SPDC Corporate Reprographic Services, Warri, Nigeria. 1996;103-114.
8. Adegoke J, Mofoluso F, James G, Agbaje G, Ologunorisa T. An assessment of recent changes in the Niger Delta coastline using satellite imagery. Journal of Sustainable Development. 2010;3:277-296.
9. Murat RC. Stratigraphy and paleogeography of the cretaceous and lower tertiary in Southern Nigeria. African Geology, Dessauvagie TFJ and Whiteman AJ (Eds), University of Ibadan Press. 1972;251-266.
10. Adegoke OS, Oyebamiji AS, Edet JJ, Osterloff PL, Ulu OK. Cenozoic foraminifera and calcareous nannofossil biostratigraphy of the Niger Delta. Elsevier. 2017;1-5.
11. Doust H, Omatsola E. Niger Delta: In J. D. Edwards and P. A. Santogrossi, Eds., Divergent/Passive Margin Basins: AAPG Memoir. 1990;48:239-248.
12. Lillesand TM, Kiefer RW. Remote sensing and image interpretation. John Wiley and Sons, New York; 2000.
13. Ethridge FG, Schumm SA. 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. 2007;277:205–222.
14. Willis BJ. Palaeochannel reconstructions from point bar deposits: A 3-Dimensional perspective. Sedimentology. 1989;36(5):757-766.
15. Bridge JS, Tye RS. Interpreting the dimensions of ancient fluvial channel bars, channels and channel belts from wireline-logs and cores. AAPG Bulletin. 2000;84:1205–1228.
16. Bhattacharya JP, Tye RS. 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: AAPG, Studies in Geology. 2004;50:39–57.
17. Holbrook J, Wanas H. 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. 2014;84(5):349–372.
DOI: https://doi.org/10.2110/jsr.2014.29
18. Akana ST, Adeigbe OC. Geometric characterization of point bar deposits in the lower river Niger, Niger Delta. Journal of Earth Sciences and Geotechnical Engineering. 2019;9(2):13-21.
19. Holzweber BI, Hartley AJ, Weissmann GS. Scale invariance in fluvial barforms: Implications for interpretation of fluvial systems in the rock record. Petroleum Geoscience. 2014;20(2):211-223.
DOI: https://doi.org/10.1144/petgeo2011-056
20. Kelly S. Scaling and hierarchy in braided rivers and their deposits: Examples and implications for reservoir modelling. In: Braided Rivers: Process, Deposits, Ecology and Management (Eds G.H. Sambrook Smith, J.L. Best, C.S. Bristow and G.E. Petts), IAS Spec. Publ. 2006;36:75–106.
21. Sambrook-Smith GH, Ashworth PJ, Best JL, Woodward J, Simpson CJ. The morphology and facies of sandy braided rivers: Some considerations of scale invariance. Spec. Publ. Int. Ass. Sediment. 2005;35:145-158.
22. Komar PD. The Lemniscate Loopacomparisons with the shapes of streamlined landforms. J. Geol. 1984;92:133–145.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/61424