Chapter 2
Geologic Framework

2.1 Regional Tectonic Setting

The Niger Delta basin is located at the southernmost extremity of the elongated intracontinental Benue Trough. To the west, it is separated from the Dahomey (or Benin) basin by the Okitipupa basement high, and to the east it is bounded by the Cameroun volcanic line. Its northern margin transects several older (Cretaceous) tectonic elements—the Anambra basin, Abakaliki basin, Afikpo syncline, and the Calabar Flank (Fig. 2.1a).

The evolution of the Niger delta is controlled by pre- and synsedimentary tectonics described by Evamy et al. (1978), Ejedawe (1981), Knox and Omatsola (1989) and Stacher (1995). The tectonic framework of the continental margin along the West Coast of equatorial Africa is controlled by Cretaceous fracture zones expressed as trenches and ridges in the deep Atlantic. The fracture zone ridges (Fig. 2.1b) subdivide the margin into individual basins, and, in Nigeria, form the boundary faults of the Cretaceous Benue-Abakaliki trough, which cuts far into the West African shield. The trough represents a failed arm of a rift triple junction associated with the opening of the South Atlantic. Rifting started in the Late Jurassic and persisted into the Middle Cretaceous (Lehner and De Ruiter 1977). In the Niger Delta region, rifting diminished altogether in the Late Cretaceous. Figure 2.2a, b show the gross paleogeography of the region as well as the relative position of the African and South American plates since rifting began.

After rifting ceased, gravity tectonics became the primary deformational process. For any given depobelt, gravity tectonics were completed before deposition of the Benin Formation and are expressed in complex structures, including shale diapirs, roll-over anticlines, collapsed growth fault crests, back-to-back features, and steeply dipping, closely spaced flank faults (Evamy et al. 1978; Xiao and Suppe 1992). These faults mostly offset different parts of the Agbada Formation and flatten into detachment planes near the top of the Akata Formation.

© The Author(s) 2017

C.I.P. Dim, *Hydrocarbon Prospectivity in the Eastern Coastal Swamp Depo-belt of the Niger Delta Basin*, SpringerBriefs in Earth Sciences,
DOI 10.1007/978-3-319-44627-1_2

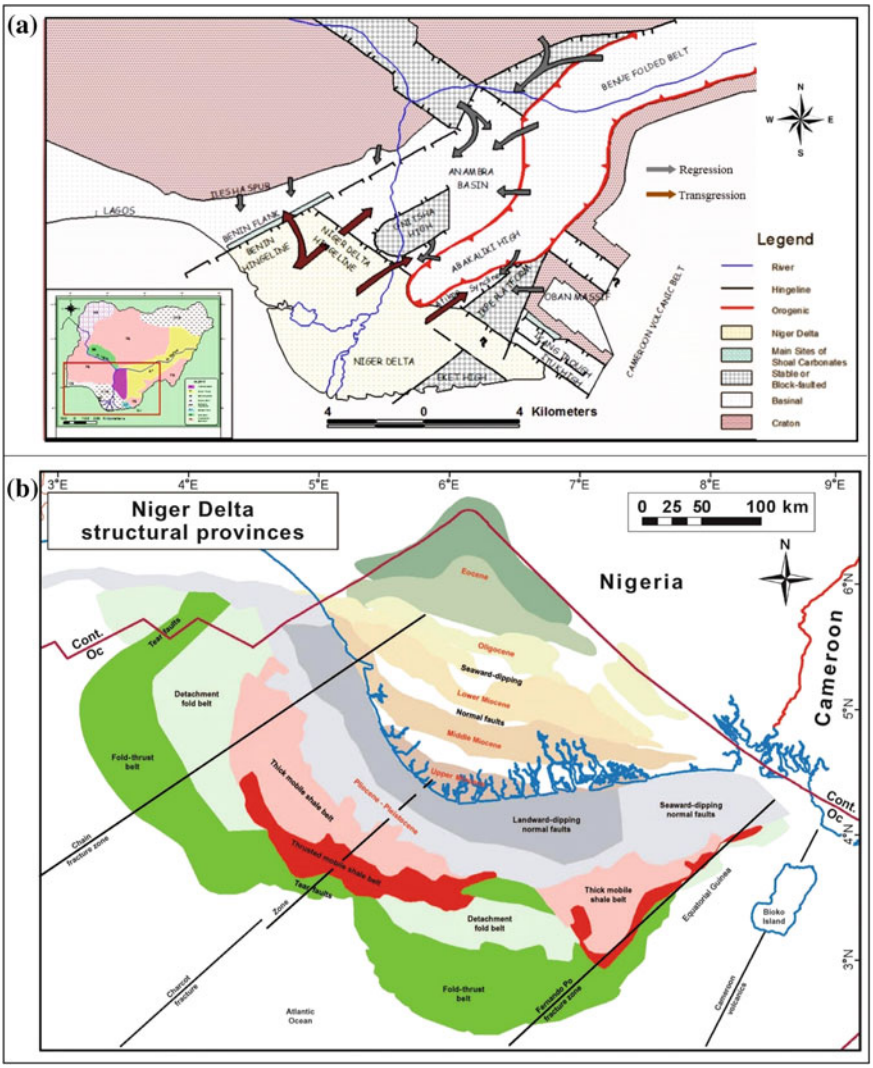


Fig. 2.1 Tectonic setting and structural elements of the Niger Delta Basin. **a** Tectonic Map showing the Niger Delta (After Kogbe 1989). **b** Regional structural provinces map of the Niger Delta showing the Fracture Zones (Wiener et al. 2010)

The Niger Delta stratigraphic sequence comprises an upward-coarsening regressive association of Tertiary clastics up to 12 km thick (Weber and Daukoru 1975; Evamy et al. 1978). It is informally divided into three gross lithofacies: (i) marine claystones and shales of unknown thickness, at the base; (ii) alternation of sandstones, siltstones and claystones, in which the sand percentage increases upwards; (iii) alluvial sands, at the top (Doust 1990). Three lithostratigraphic units

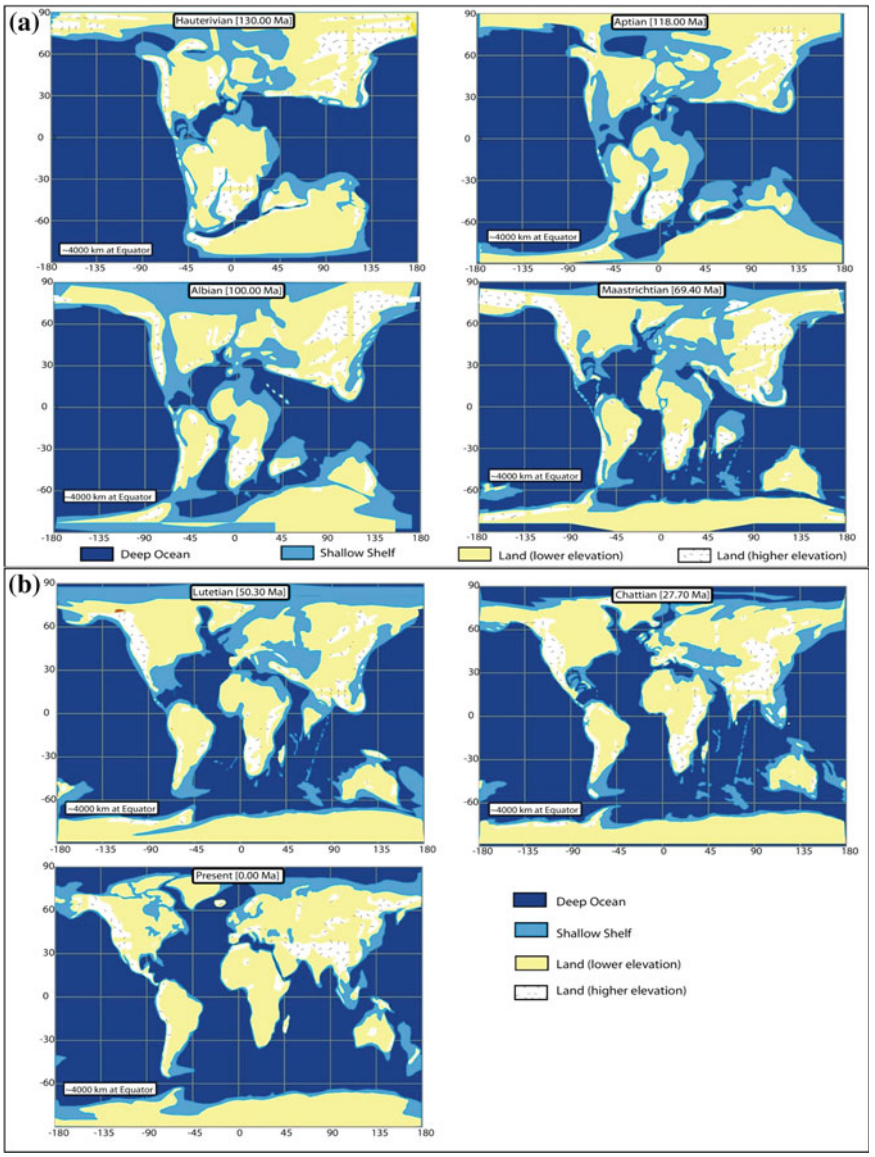


Fig. 2.2 Paleogeography showing the opening of the South Atlantic, and development of the region around Niger Delta. **a** Cretaceous paleogeography (130.0–69.4 Ma). **b** Cenozoic paleogeography (50.3 Ma to present). Plots generated with PGIS software (Tuttle et al. 1999)

have been recognized in the subsurface of the Niger Delta (Short and Stauble 1967; Frankl and Cordy 1967; Avbovbo 1978). These are from the oldest to the youngest, the Akata, Agbada and Benin Formations all of which are strongly diachronous (Fig. 2.3a, b).

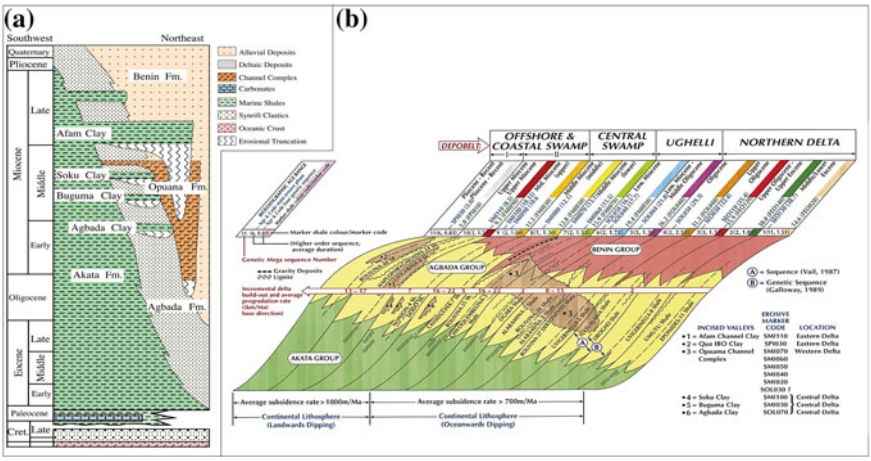


Fig. 2.3 Stratigraphy of Niger Delta Basin. **a** Stratigraphic column showing the three formations of the Niger Delta (modified from Lawrence et al. 2002). **b** Diagrammatic representation of the stratigraphic evolution of the Niger Delta (After Reijers 2011)

2.2 Regional Stratigraphic Setting

2.2.1 Akata Formation (Marine Shales)

The Akata Formation (Eocene–Recent) is the oldest lithostratigraphic unit in the Niger Delta. It is a marine sedimentary succession that is laid in front of the advancing delta and ranges from 1,968 to 19,680 ft in thickness. It consists of mainly uniform under-compacted shales, clays, and silts at the base of the known delta sequence with lenses of sandstone of abnormally high pressure at the top (Avbovbo 1978). These streaks of sand are possibly of turbidite origin, and were deposited in holomarine (delta-front to deeper marine) environments. The shales are rich in both planktonic and benthonic foraminifera and were deposited in shallow to deep marine environments (Short and Stauble 1967). Marine shales form the base of the sequence in each depobelt and range from Paleocene to Holocene in age. They outcrop offshore as diapirs along the continental slope, and onshore in the northeastern part of the delta, where they are known as the Imo Shale.

2.2.2 Agbada Formation (Paralic Clastics)

The Agbada Formation (Eocene–Recent) is characterized by paralic interbedded sandstone and shale with a thickness of over 3000 m (Reijers 1996). These paralic clastics are the truly deltaic portion of the sequence and were deposited in a number

of delta-front, delta-topset, and fluvio-deltaic environments. The top of Agbada Formation is defined as the first occurrence of shale with marine fauna that coincides with the base of the continental-transitional lithofacies (Adesida and Ehirim 1988). The base is a significant sandstone body that coincides with the top of the Akata Formation (Short and Stauble 1967). Some shales of the Agbada Formation were thought to be the source rocks, however; Ejedawe et al. (1984) deduced that the main source rocks of the Niger Delta are the shales of the Akata Formation. The Agbada Formation forms the hydrocarbon-prospective sequence in the Niger Delta. As with the marine shales, the paralic sequence is present in all depobelts, and ranges in age from Eocene to Pleistocene. Most exploration wells in the Niger delta have bottomed in this lithofacies.

2.2.3 Benin Formation (Continental Sands)

The Benin Formation is the youngest lithostratigraphic unit in the Niger Delta. It is Miocene—Recent in age with a minimum thickness of more than 6000 ft and made up of continental sands and sandstones (>90 %) with few shale intercalations. The shallowest part of the sequence is composed almost entirely of nonmarine sand. The sands and sandstones are coarse-grained, sub-angular to well-rounded and are very poorly sorted. It was deposited in alluvial or upper coastal plain environments following a southward shift of deltaic deposition into a new depobelt. The oldest continental sands are probably Oligocene, although they lack fauna required to date them directly. Offshore, they become thinner and disappear near the shelf edge.

2.3 Depobelts

Deposition of the three formations occurred in each of five offlapping siliciclastic sedimentation cycles that comprise the Niger Delta (Fig. 2.4a, b). These cycles (depobelts) are 30–60 km wide, prograde southwestward 250 km over oceanic crust into the Gulf of Guinea, and are defined by synsedimentary faulting that occurred in response to variable interplay of subsidence and sediment supply rates (Doust and Omatsola 1990; Stacher 1995). Depobelts become successively younger basinward, ranging in age from Eocene in the north to Pliocene offshore of the present shoreline. These depobelts are separate unit that corresponds to a break in regional dip of the delta and is bounded landward by growth faults and seaward by large counter-regional faults or the growth fault of the next seaward belt. Each depobelt contains a distinct shallowing-upward depositional cycle with its own tripartite assemblage of marine, paralic, and continental deposits.

Depobelts define a series of punctuations in the progradation of this deltaic system. As deltaic sediment loads increase, underlying delta front and prodelta marine shale begin to move upward and basin-ward. Mobilization of basal shale caused

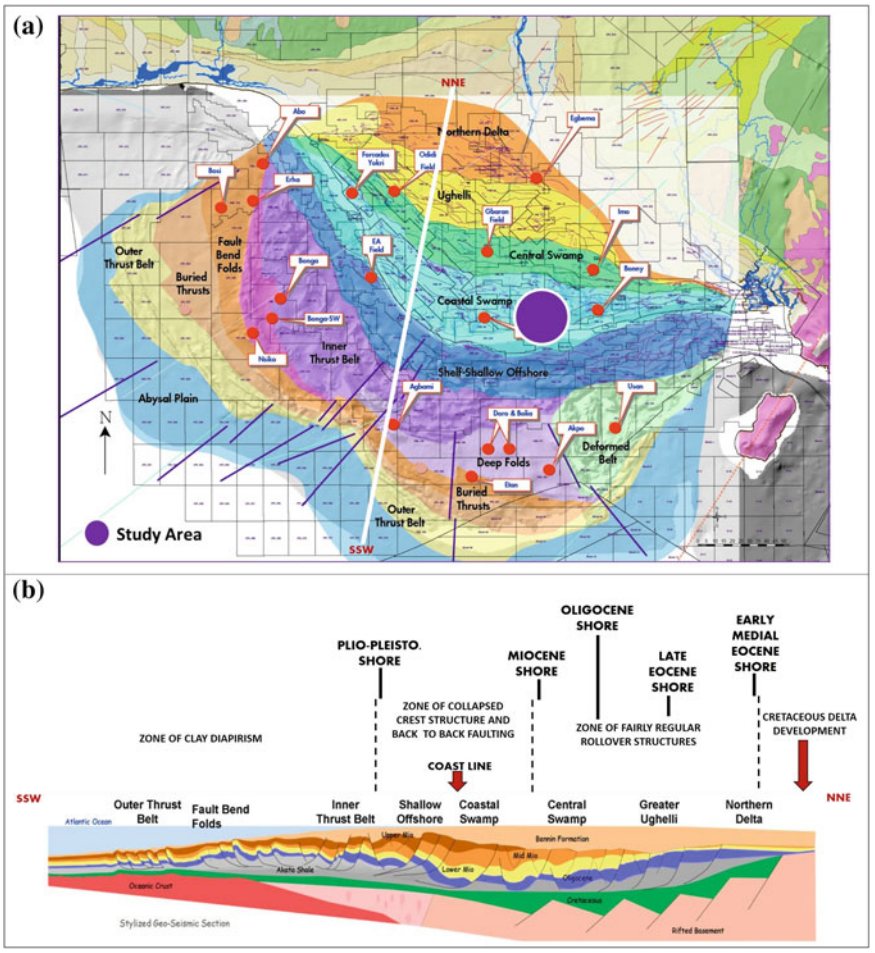


Fig. 2.4 Depositional belts showing the study area and Dip section of the Niger Delta Basin. **a** Depobelt map with the structural play segments, onshore and offshore Niger Delta Basin showing the study area. *Source* Shell (2007). **b** Schematic Dip section of the Niger Delta (After Shell 2007; Weber and Daukoru 1975)

structural collapse along normal faults, and created accommodation for additional deltaic sediment accumulation. As shale withdrawal nears completion, subsidence slows dramatically, leaving little room for further sedimentation. As declining accommodation forces a basinward progradation of sediment, a new depocenter develops basin-ward. The northern delta province, which overlies relatively shallow basement, has the oldest growth faults that are generally rotational, evenly spaced, and increase in steepness seaward. The central delta province has depobelts with well-defined structures such as successively deeper rollover crests that shift seaward for any given growth fault. The distal delta province is the most structurally complex

due to internal gravity tectonics on the modern continental slope. The study area lies within the coastal swamp depobelt (Fig. 2.4a). It is described as shelf contained entities with respect to stratigraphy, structure building, and hydrocarbon distribution (Unukogbon et al. 2008).

References

Adesida, A., & Ehirim, B. O. (1988). *Cenozoic Niger Delta: A guide to its lithosedimentary analysis* (pp. 1–10). SPDC Exploration note 88.002 (Ref: on-shore wells).

Avbovbo, A. A. (1978). *Tertiary lithostratigraphy of Niger Delta* (pp. 96–200). Tulsa, OK: American Association of Petroleum Geologists Bulletin.

Doust, H. (1990). Petroleum geology of the Niger Delta. *Geochemical Society, London, Special Publications, 50*, 365.

Doust, H., & Omatsola, E. (1990). Niger Delta. In J. D. Edwards & P. A. Santogrossi (Eds.), *Divergent/passive margin basins* (p. 239–248). American Association of Petroleum Geologists Bulletin Memoir 48.

Ejedawe, J. E. (1981). Patterns of incidence of oil reserves in Niger delta basin. *American Association of Petroleum Geologists Bulletin, 65*, 1574–1585.

Ejedawe, J. E., Coker, S. J. L., Lambert-Aikhionbare, D. O., Alofe, K. B., & Adoh, F. O. (1984). Evolution of oil-generative window and oil and gas occurrence in Tertiary Niger Delta Basin. *American Association of Petroleum Geologists, 68*, 1744–1751.

Evamy, B. D., Haremboure, J., Kamerling, P., Knaap, W. A., Molloy, F. A., & Rowlands, P. H. (1978). Hydrocarbon habitat of Tertiary Niger Delta. *American Association of Petroleum Geologists Bulletin, 62*, 1–39.

Frankl, E. J., & Cordy, E. A. (1967). The Niger Delta oil province: Recent developments onshore and offshore. In *Proceedings of the Seventh world petroleum congress* (Vol. 2, pp. 195–209). Mexico.

Knox, G. J., & Omatsola, E. M. (1989). Development of the Cenozoic Niger delta in terms of the "Escalator Regression" model and impact on hydrocarbon distribution. In *Proceedings of the KNGMG Symposium on Coastal Lowlands, Geology and Geotechnology, 1987* (pp. 181–202). Dordrecht: Kluwer.

Kogbe, C. A. (1989). The cretaceous paleocene sediments of southern Nigeria. In C. A. Kogbe (Ed.), *Geology of Nigeria* (pp. 320–325). Jos: Rock View Ltd.

Lawrence, S. R., Munday, S., & Bray, R. (2002). Regional geology and geophysics of the eastern Gulf of Guinea (Niger Delta to Rio Muni). *The Leading Edge, 21*, 1112–1117.

Lehner, P., & De Ruiter, P. A. C. (1977). Structural history of Atlantic margin of Africa. *American Association of Petroleum Geologists Bulletin, 61*, 961–981.

Reijers, T. J. A. (1996). *Selected Chapters on Geology: With notes on sedimentary geology, sequence stratigraphy and three case studies and a field guide* (197 p.). Warri, Nigeria: S.P.D.C. Corporate Reprographic Services.

Reijers, T. R. A. (2011). Stratigraphy and sedimentology of the Niger Delta. *Geologos, 17*(3), 133–162. doi:10.2478/v10118-011-0008-3

Shell. (2007). Onshore to deep-water geologic integration, Niger Delta. In J. Ejedawe, F. Love, D. Steele, & Ladipo K (Eds.), Presentation pack of Shell Exploration and Production Limited, Port-Harcourt.

Short, K. C., & Stauble, A. J. (1967). Outline of geology of Niger Delta. *American Association of Petroleum Geologists Bulletin, 51*, 761–779.

Stacher, P. (1995). Present understanding of the Niger Delta hydrocarbon habitat. In M. N. Oti & G. Postma (Eds.), *Geology of deltas* (pp. 257–267). Rotterdam: A. A. Balkema.

Tuttle, W. L. M., Brownfield, E. M., & Charpentier, R. R. (1999). The Niger Delta Petroleum System. Chapter A: Tertiary Niger Delta (Akata-Agbada) Petroleum System, Niger Delta Province, Nigeria, Cameroon and Equatorial Guinea, Africa. U.S. Geolgical Survey, Open File Report. 99-50-H.

Unukogbon, N. O., Asuen, G. O., & Emofurieta, W. O. (2008). Sequence stratigraphic appraisal: Coastal swamp depobelt in the Niger Delta Basin Nigeria. *Global Journal of Geological Sciences, 6*(2), 129–137.

Weber, K. J., & Daukoru, E. M. (1975). Petroleum geology of the Niger Delta. In *Proceedings of the 9th World Petroleum Congress, Geology* (Vol. 2, pp. 210–221). London: Applied Science Publishers, Ltd.

Wiener, R. W., Mann, M. G., Angelich, M. T., & Molyneux, J. B. (2010). Mobile shale in the Niger Delta: Characteristics, structure, and evolution. In L. Wood (Ed.), *Shale tectonics* (pp. 145–161). American Association of Petroleum Geologists Memoir 93.

Xiao, H., & Suppe, J. (1992). Origin of rollover. *American Association of Petroleum Geologists Bulletin, 76*, 509–229.

http://www.springer.com/978-3-319-44626-4

Hydrocarbon Prospectivity in the Eastern Coastal Swamp Depo-belt of the Niger Delta Basin
Stratigraphic Framework and Structural Styles

Dim, C.I.P.

2017, XII, 71 p. 49 illus. in color., Softcover
ISBN: 978-3-319-44626-4