Chapter 9
The Niger Delta Basin

The Cenozoic Niger Delta is situated at the intersection of the Benue Trough and the South Atlantic Ocean where a triple junction developed during the separation of the continents of South America and Africa in the late Jurassic (Whiteman, 1982). Subsidence of the African continental margin and cooling of the newly created oceanic lithosphere followed this separation in early Cretaceous times. Marine sedimentation took place in the Benue Trough and the Anambra Basin from mid-Cretaceous onwards. The Niger Delta started to evolve in early Tertiary times when clastic river input increased (Doust and Omatsole, 1989). Generally the delta prograded over the subsidizing continental-oceanic lithospheric transition zone, and during the Oligocene spread onto oceanic crust of the Gulf of Guinea (Adesida et al., 1997). The weathering flanks of out-cropping continental basement sourced the sediments through the Benue-Niger drainage basin. The delta has since Paleocene times prograded a distance of more than 250 km from the Benin and Calabar flanks to the present delta front (Evamy et al., 1978). Thickness of sediments in the Niger Delta averages 12 km covering a total area of about 140,000 km².

Whilst the early Niger Delat is interpreted as being a river-dominated delta, the post-Oligocene delta is a typical wave-dominated delta with well-developed shoreface sands, beach ridges, tidal channels, mangrove and freshwater swamps. It is one of the world’s largest deltas and shows an overall upward transition from marine shales (Akata Formation) through a sand-shale paralic interval (Agbada Formation) to continental sands of the Benin Formation. Depending on sea level changes, local subsidence and sediment supply, the delta experienced phases of regressions and transgressions. The stratigraphic framework and the detailed Tertiary stratigraphy of the Niger Delta are based on correlation of palynomorphs and foraminifera zones.

Stratigraphic Framework

The stratigraphic sequence of the Niger Delta comprises three broad lithostratigraphic units namely, (1) a continental shallow massive sand sequence – the Benin Formation, (2) a coastal marine sequence of alternating sands and shales – the
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a) Stratigraphic succession in the Niger Delta

b) Stratigraphic succession, subsidence and progradational cycle model of the Niger Delta

c) Hydrocarbons are generally trapped in rollover anticlines and sand growth fault closures in the Niger Delta

d) Depo-belts of the Niger Delta

Fig. 9.1 Stratigraphy, structural elements and modes of hydrocarbon occurrence in the Tertiary Niger Delta

Agbada Formation and a basal marine shale unit - the Akata Formation (Fig. 9.1). The Akata Formation consists of clays and shales with minor sand intercalations. The sediments were deposited in prodelta environments. The sand percentage here is generally less than 30%.

The Agbada Formation consists of alternating sand and shales representing sediments of the transitional environment comprising the lower delta plain (mangrove swamps, floodplain, marsh) and the coastal barrier and fluviomarine realms. The sand percentage within the Agbada Formation varies from 30 to 70%, which results from the large number of depositional offlap cycles. A complete cycle generally consists of thin fossiliferous transgressive marine sand, followed by an offlap sequence which commences with marine shale and continues with laminated fluviomarine sediments followed by barriers and/or fluviatile sediments terminated by another transgression (Weber, 1972; Ejedawe, 1989).

The Benin Formation is characterized by high sand percentage (70–100%) and forms the top layer of the Niger Delta depositional sequence. The massive sands were deposited in continental environment comprising the fluvial realms (braided and meandering systems) of the upper delta plain.

The Niger Delta time-stratigraphy is based on biochronological interpretations of fossil spores, foraminifera and calcareous nonnoplankton. The current delta-wide stratigraphic framework is largely based on palynological zonations labeled with Shell’s alphanumeric codes (e.g. P630, P780, P860). This allows correlation across
all facies types from continental (Benin) to open marine (Akata). There have been concerted efforts, within the work scope of the stratigraphic committee of the Niger Delta (STRATCOM), to produce a generally acceptable delta-wide biostratigraphic framework (Reijers et al., 1997) but not much again has been accomplished after several data gathering exercise by the committee.

The sediments of the Niger Delta span a period of 54.6 million years during which, worldwide, some thirty-nine-eustatic sea level rises have been recognized (Adesida et al., 1997). Correlation with the chart of Galloway (1989) confirms the presence of nineteen of such named marine flooding surfaces in the Niger Delta. Eight of these are locally developed. Adesida et al. (1997) defined eleven lithological mega sequences marked at the base by regional mappable transgressive shales (shale markers) that are traceable across depobelt boundary faults and proposed these as the genetic sequences that can be used as the basis for lithostratigraphy of the Niger Delta.

Structural Geology

The escalator regression model of Knox and Omatsola (1989) describes the one-way step-wise outbuilding of the Niger Delta through geologic time. The units of these steps are the depobelts. Depobelts, as defined therein, represent successive phase of delta growth. They are composed of bands of sediments about 30–60 km wide with lengths of up to 300 km. They contain major fault–bounded sequences which contain a shoreface alternating sand/shale sequence limited at the proximal end by a major boundary growth fault and at the distal end by a lithofacies change, a counter-regional growth fault, a major boundary fault of a succeeding depobelt, or any combination of these. Seawards, successive depobelts contain sedimentary fills markedly younger than the adjacent ones in a landward direction.

On a delta dip section, a relationship is apparent between successive depobelts. The base alluvial sand facies of an updip (older) depobelt is approximately time equivalent to the initiation of the base sand/shale sequence in the down-dip depobelt. The deposition of parallic sequences within any depobelt is terminated by a rapid advance of an alluvial sand facies over the proximal and central areas of the belt. This advance initiates deposition of the parallic sand/shales sequences in the succeeding depobelt. A parallic sequence develops in this new depobelt, and in the exterior part of the older depobelt, while the continental sands/gravels advance dischronously. This sequence of events repeated itself five to six times over the last 38 million years to define a series of depobelts in the Niger Delta. Five major depobelts are generally recognized namely, *Northern Delta, Greater Ughelli, Central Swamp, Coastal Swamp, and Offshore* (Fig. 9.1). The most striking structural features of the Niger Delta are the large syn-sedimentry growth faults, rollover anticlines and shale diapirs which deformed the delta complex (Evamy et al., 1978). The greater percentage of the on fields in the Niger Delta is associated with rollover anticlines.
Sand Fairways and Sequence Stratigraphy

Applying sequence stratigraphic concepts in the Niger Delta, a shelf-break/slope model with well developed lowstand, transgressive and high stand systems tracts can be applied in various parts of the northern and coastal delta where bathyal paleo-water-depths were interpreted (Weber, 1986), whilst a shallow ramp model with mainly transgressive and highstand systems tracts is applicable in major parts of the central delta where paleo-water-depths did not exceed 150–200 m (outer neritic).

Sand percentages versus depths for selected wells were studied by Obaje (2005) as a basis for understanding the sand/shale ratios as well as the stacking patterns of sedimentary sequences in the Niger Delta. This was also with the aim to enhance a clearer understanding of the sequence stratigraphic framework of the Niger Delta based on the vertical sand-stacking pattern.

In the Niger Delta, the Galloway’s (1989) genetic sequence concept is followed as a basis for lithostratigraphy. The mfs’s within the marker shales are the boundaries of the sequences. They can be traced from seismic (Vail, 1987) and/or derived from wireline logs (Durand, 1995) and confirmed biostratigraphically. Sand percentages are derived form wireline logs including Gamma Ray log of which the vertical sand stacking pattern is an inversion (mirror image). Thick shale units separate reservoir sands and are candidates for the mfs’s; the thin ones are usually interbedded in shoreface deposits and contain lower-order flooding surfaces (Reijers et al., 1997). Stacking pattern between mfs allow recognition of sequence boundaries. Progradation is reflected by upward-increasing sandiness and retrodegradation by an upward-decreasing sandiness or upward-increasing shalyness. Two such patterns are separated by a surface, which reflects the time of maximum basinwards shift of the shoreline (sequence boundary: SB). The mfs must be checked against the maximum depth reflected in the biofacies, and should coincide with the level showing the highest foraminiferal and planktonic abundance and diversity.

The Niger Delta “channels” are relics of incised valleys (Reijers et al., 1997) and they are seismically detectable sequence boundaries of large magnitude. The position of the SB may also be marked by condensed sequences, by sharp bases of thick sand units, by the inflection point between coarsening sequences, and fining-up abound by faunal evidence of shallow environments. The interval between an SB (below) and mfs (above) is a transgressive systems tract (TST). In the Niger Delta it usually is a thin unit (Reijers et al., 1997). A sequence boundary may also be overlain by a low stand systems tract (LST) which should be checked against the bathymetry indications of the fauna, the log response of possible basin floor fans (sharp-based, blocky massive sands); slope fans (sand-poor facies with rounded shapes of spiky sand packages) or lowstand prograding complexes (thick intervals with increasing upward-sandiness). The interval between mfs (below) and a SB (above) is a highstand systems tract (HST) in which a variety of depositional systems may occur.

The trends derived from the sand percentage maps of Obaje (2005) revealed better the delta morphology with time and also emphasized the depositional control on lithofacies distribution. The maps constructed indicate regional trends in
the depositional pattern of the delta for the given pollen subzone and mfs interval. The points of major sand inputs (channels, mouth bars) from the onshore into the shallow, deep and ultra-deep offshore are reflected by lobes protruding in a seaward direction. These lobes (sand fairways) are expected to constitute pathfinders to deep-water reservoir prospects. Intervals with average high sand percentage with paleobathymetry interpreted from fauna that indicate middle-outer neritic paleowater depth and other slope environments are expected to be possible turbidite targets (Mitchum et al., 1994).