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Geological Framework of Nigeria Linked Shelf Extension and Deepwater Thrust Belts

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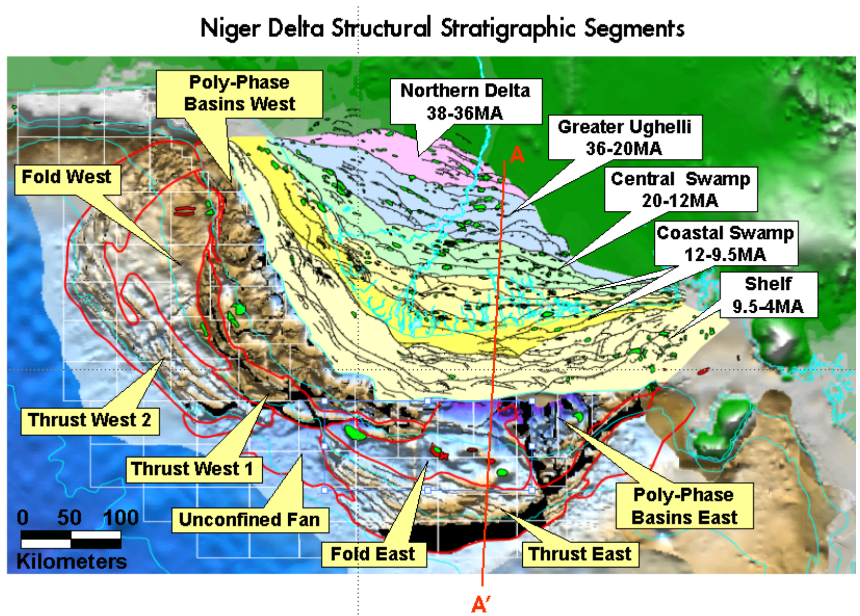
The Niger delta, covering an area of 200,000km2, is one of the world's largest deltas and most prolific hydrocarbon basins. The delta system occupies the Benue Trough, the failed rift arm of a triple junction associated with late Aptian to Albian opening of the South Atlantic Ocean. The rift system linked the Tethys to the South Atlantic through the Sirte, Chad, Anambra, and Niger basins. The Cretaceous delta was deposited in the Anambra Basin until a final Paleocene phase of inversion reactivated the Abakaliki and Onitsha highs (Unomah and Ekweozor, 1993) and shifted sedimentation to the Niger basin.



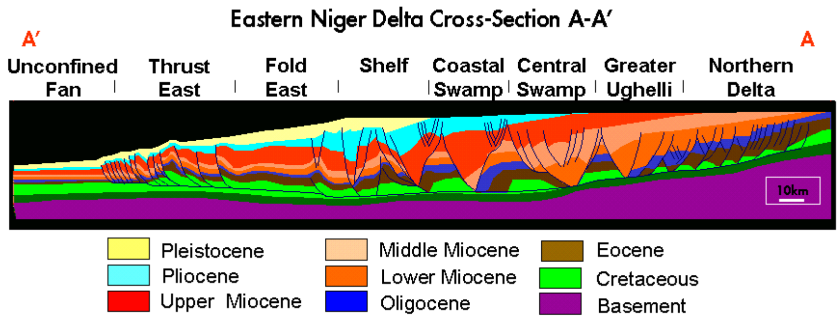


Figure 1. Nigeria Structural stratigraphic domains

The Niger delta is subdivided into 5 onshore and shelf sub-basins, termed "depobelts" that range in age from Eocene to Plio-Pleistocene. Most of the "depobelts" are bounded by a landward normal listric growth fault system and seaward by a counter-regional fault system (Figure 1). Faults sole-out onto a regional detachment surface in Cretaceous bathyal shales that are just above basement.

Extension in the depo-belts is linked along a basal detachment to 3 thrust belts in deepwater; west 1 (inner), west 2 (outer) and the eastern thrust belt where the inner thrust belt is remobilized by the younger thrust system. Several recent papers have described the mechanics of deformation in the thrust belts as consistent with a tapered wedge model (Corredor et. al., 2005, Bilotti and Shaw, 2005). The systems are grossly similar to a conceptual model comprised of a gravity slide complex divided into a head-ward zone of extension, a mid-slope zone of translation, and a toe of slope zone of contraction and thrusting. The distance from the extension in the depobelt to the contraction in the thrust belt is about 150km – spanning the transition from continental to oceanic crust. All of the thrust belts develop over oceanic crust.

The outer thrust belts extend for 600km, rimming the deepwater basin from Benin to Equatorial Guinea in ultradeep water depths of 2000 to 3000m. Oceanic crust paleo-topography along the Charcot Fracture zone segmented the outer thrust belts into an eastern and western thrust system. Contraction in the outer thrust belts commenced in the upper Miocene and has present day topography. Upper Miocene extension occurred along the present day shelf in a depobelt that is entirely filled by Upper Miocene sediments. The counter regional fault planes bounding the Upper Miocene depobelt flatten to horizontal – essentially gliding basinward with the entire stratigraphic section in deepwater along the detachment surface. Gravity glide creates additional accomodation space at the headward extensional fault system and contraction in the thrust belt as well as reactivating older thrust systems.

Older thrust systems of Middle Miocene to Oligocene in age are inboard of the western outer thrust belt. The older thrust systems are displaced along the detachment by younger up dip extension in the Upper Miocene and Plio-Pleistocene Depobelts. The result was renewed shortening expressed by a variety of over-steepened, complex, thrust-cored structures that were previously interpreted as shale diapirs or mobile shale cored structures.

Depositional Mega-Sequences

The Tertiary stratigraphic section in the Niger Basin is divisible into 4 Mega-sequences; Eocene, Oligocene-Lower Miocene, Middle Miocene, and Upper Miocene to Recent. Each mega-sequence is characterized by major deltaic sequences cut by submarine canyons that source submarine fans onto the slope and basin floor. The Eocene depositional sequence is located in the onshore Northern and Ughelli Delta depobelts 125km from the present-day coastline. The Eocene sequence includes a submarine canyon system draped by a 34Ma transgressive shale, the oldest canyon system identified in the Niger Basin. The canyon sources a sand-rich submarine fan identified onshore on the upper slope.

The Oligocene – Lower Miocene system is focused in western Nigeria in the Ughelli and Central Swamp depobelts. Oligocene deltas are cut by a series of canyons collectively referred to as the Opuama canyon. The Opuama Canyon was active from 24.9 to 12.8Ma. Fan systems sourced by the Opuama are primarily channel levee systems that can be mapped for 250km to the limits of outer thrust belt.

The Middle Miocene is Mega-sequence shelf extends across the Niger delta near the present day coast in the Coastal Swamp depobelt. The shelf margin delta system is cut by numerous canyon systems including the Afam, Soku, Buguma, and Agbada along the entire shelf margin. The canyons source sand-rich submarine fans comprised of channel levee systems ands sand-rich sheets across the deepwater basin.

The deltaic shelf of the Upper Miocene –Pliocene mega-sequence extends across the present-day shelf. The sequence depocenter located in eastern Nigeria and includes the Qua Ibo Canyon, a Lower Pliocene massive shelf collapse and canyon system. The depocenter is deltas, forms a linked extensional-growth fault - contractional thrust belt. Large canyon systems are present in the depocenter in eastern Nigeria and source fans that are syn-kinematic with the thrust belt. Small point sourced canyon systems source minor fan systems across western Nigeria.

Petroleum Systems

The most prospective portions of the gravity slide – thrust belt complex in Nigeria are deltaic sequences in the growth fault extensional zone and deepwater reservoirs in the mid slope zone of translation characterized by thrust cored folds. Deltaic reserves total 61BBOE and deepwater reserves total 11BBO (IHSE 2009). The translation portion of the gravity slide includes most Nigeria's deepwater giant fields, Bonga, Agbami, Akpo, N'nwa-Doro, and Erha. The prospectivity is due to large simple closures, excellent sheet and channel deepwater reservoirs, and mature source rocks in the oil window. Three petroleum systems have been described in Nigeria; a Lower Cretaceous lacustrine system and marine systems in the Upper Cretaceous- Paleocene and Eocene (Haak et. al., 2000, Ekwozor and Dakuru, 1994). Basin modeling and drilling indicates that the Eocene petroleum system is present across deepwater Nigeria but becomes immature in the outer thrust belt. Upper Cretaceous source rocks if present, should be mature in the outer thrust belt but are below the detachment. All outer thrust belt wells that are solely dependent on charge from the Upper

Cretaceous source rock have failed, probably due to ineffective charge focus beneath the detachment and hydrocarbon migration across the detachment.

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