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A Case Study of Carbonate Deposition and Deformation in the Greater Ughelli Depobelt, Niger Delta, Nigeria

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Introduction

The growth and development of structural and depositional systems in the hydrocarbon-rich Niger Delta off Nigeria's Atlantic coast, West Africa, involves a complex interaction of extension, contraction, and subsidence, with up-dip extensional systems kinematically linked to down-dip contractional systems via a transitional zone at any given point in time. Local structural and depositional systems connected with individual extensional faults and thrust-cored folds, local subsidence and withdrawal associated with shale diapir formation are all shown on the regional tectonostratigraphic zonation. The study focuses on growing faults and accompanying deltaic sedimentation in the Niger Delta's Greater Ughelli Depobelt. A regional sequence stratigraphic framework of the study was developed using 3D seismic, a variety of well log suites, and biostratigraphic data, study area was produced. Six Flooding Surfaces at Maximum Levels Within the constraints of available data, MFSs and five Sequence Boundaries SBs were identified. A structural interpretation model and framework for the research area was also developed using these regional horizons/markers (MFSs and SBs) and the events pattern in the seismic volume. Fault activity began well before 31.3 Ma and extended well beyond 20.7 Ma, according to structural study, and has had a significant impact on the development of accommodation space and sediment buildup. Stratigraphic thickness has increased in the basin ward direction as a result of structural deformation and structurally driven accommodation creation, and 'local depocenter' has migrated to the NW at various periods in the structural development of the study area and then to the SE resulting also in lateral changes in stratigraphic thicknesses in these directions.

Discussion

The Niger Delta is located in the Gulf of Guinea at a formal triple junction of the south Atlantic rifting. Covering an approximate areal extent of 70,000 km, the delta is recognized as a classic example of continental-margin structural collapse under sediment loading. The delta originally developed inland during Late Cretaceous to Eocene and has prograded from collapsed continental onto the oceanic crust from Oligocene to present. The delta is a long-lasting system supplied by the Niger and Benue rivers. Both rivers have extensive drainage basins which delivered a high sediment supply accommodated by large growth faults. The resulting succession of deltaic, inters lope and abyssal plain deposits has reached a thickness of approximately 12 km. Deltaic growth faults and associated strata record the interaction between sedimentary processes and fault movements, and as such they are good for detailed studies of the interaction of tectonics and sedimentation. Structure and depositional systems have migrated with the progradation of the delta through time. Throughout the history, the delta has prograded in a step-like fashion such that at any one time sedimentation was concentrated in an arcuate depobelt bounded by large-scale growth faults. These depobelts are defined by one or more paleontologically distinct, transgressive shale horizons, and include temporally related smaller-scale structures and depocenters. Subsidence within the depobelts ceased episodically, at which time alluvial sands advanced rapidly across the delta top, concurrent with a seaward shift in deposition and subsidence.

Lithostratigraphic framework

The sedimentary fill of the Niger Delta basin has been subdivided into three broad lithofacies units, which include the marine shales (Akata Formation); marginal marine sandstones, shales and clays (Agbada Formation); and massive continental sandstones (Benin Formation). The Akata Formation is the oldest units and forms the base of the sequence in each depobelt and has stratigraphic thickness which may reach 7000 m in the central part of the delta. Overlying the Akata Formation is the paralic Agbada Formation represented by sands, shales and clays alternations in various proportion and thickness deposited in a number of deltafront, delta-topset and fluvio-deltaic environments. It has a maximum thickness of about 3000 m. The Benin Formation is the youngest unit with variable thickness which becomes thinner offshore. This generally regressive clastic sequence of the delta reaches a maximum thickness of about 9 km-12 km.

Structural framework

The Niger Delta is subdivided into structural zones that are characterized by distinctive basinwards variations in structural styles and deformation linked on a regional scale by slow gravity collapse of thick deltaic prism. The zones are an inner extensional zone of listric growth faults beneath the outer shelf; a translational zone of diapirs and shale ridges beneath the upper slope; and an outer compressional zone of imbricate toe-thrust structures beneath the lower slope. However Corredor, further subdivides the Niger Delta into five major structural zones based on structural styles imaged in seismic data and high resolution bathymetry. They are an extensional zone beneath the continental shelf that is characterized by both basinward-dipping and counter-regional growth normal faults and associated rollovers and depocenters; a mud-diapir zone located beneath the upper continental slope which is characterized by passive, active, and reactive mud diapirs including shale ridges and massifs, shale overhands, vertical mud diapirs that form mud volcanoes at the seafloor; the inner fold and thrust faults (typically imbricated) and associated folds, including some detachment folds; a transitional detachment fold zone beneath the lower continental slope that is characterized by large areas of little or no deformation interspersed with large, broad detachment folds above structurally thickened Akata Formation; and the outer fold and thrust belt characterized by both basinward and hinterlandverging

thrust faults and associated folds. Deformations across these structural zones are very much active today.

Data availability and quality

Materials used for this study included seismic volume, well log suites and biostratigraphy data. The seismic volume is characterized by a series of nearly parallel reflections from strata offset by growth normal faults that dip offshore to the southwest. The reflections are quite chaotic close to and behind faults while they are continuous at zones away from faults. Reflections within the upper 0.9 s TWT (two-way-travel time) are slightly discontinuous and of relatively low amplitude. Based on regional studies of the basin these can be inferred to be reflections off layers of the sandy Benin Formation. At intervals between 1 s and 4.5 s TWT, the reflections are relatively continuous and of good amplitude. These are inferred to be reflection from the marginal-marine Agbada Formation and marine Akata Formation. Data quality generally deteriorates at depth below 4.5 s TWT, characterized by zones of discontinues and chaotic low amplitude reflection; and zones of continuous and high amplitude reflections. Well log suites comprise Gamma Ray logs and Spontaneous Potential SP logs. In some wells the whole length of the bore were logged while in some others only a small portion, mainly in the productive zone, were logged. The quality of the logs is quite good especially where the whole length of the well bore is logged. Bio stratigraphic data comprises Biofacies data, Palyno logical zone (P-Zone) and Foraminifera zone (F-Zone) (Shell Petroleum Development Company SPDC, Nigeria zonation scheme). The bio faces data contains information on total foraminifera abundance and diversity, total planktonic foraminifera abundance and diversity, total benthic calcareous foraminifera abundance and diversity, total benthic arenaceous foraminifera abundance and diversity, pale bathymetry and environment of deposition for various depth intervals of the well bore.