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Petroleum system elements within the Late Cretaceous and Early Paleogene sediments of Nigeria's inland basins: An integrated sequence stratigraphic approach

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ABSTRACT

Sequence stratigraphic studies have been carried out using subsurface well and 2D seismic data in the Late Cretaceous and Early Paleogene sediments of Anambra and proximal onshore section of Niger Delta Basin in the Southeastern Nigeria. The aim was to establish the stratigraphic framework for better understanding of the reservoir, source and seal rock presence and distribution in the basin. Thirteen stratigraphic bounding surfaces (consisting of six maximum flooding surfaces - MFSs and seven sequence boundaries – SBs) were recognized and calibrated using a newly modified chronostratigraphic chart. Stratigraphic surfaces were matched with corresponding foraminiferal and palynological biozones, aiding correlation across wells in this study. Well log sequence stratigraphic correlation reveals that stratal packages within the basin are segmented into six depositional sequences occurring from Late Cretaceous to Early Paleogene age. Generated gross depositional environment maps at various MFSs show that sediment packages deposited within shelfal to deep marine settings, reflect continuous rise and fall of sea levels within a regressive cycle. Each of these sequences consist of three system tracts (lowstand system tract – LST, transgressive system tract – TST and highstand system tract – HST) that are associated with mainly progradational and retrogradational sediment stacking patterns. Well correlation reveals that the sand and shale units of the LSTs, HSTs and TSTs, that constitute the reservoir and source/seal packages respectively are laterally continuous and thicken basinwards, due to structural influences. Result from interpretation of seismic section reveals the presence of hanging wall, footwall, horst block and collapsed crest structures. These structural features generally aid migration and offer entrapment mechanism for hydrocarbon accumulation. The combination of these reservoirs, sources, seals and trap elements form a good petroleum system that is viable for hydrocarbon exploration and development.

1. Introduction

Although the investigation of the hydrocarbon potentials of Nigeria's inland basins has been ongoing for many years, there have been limited understanding of the sequence stratigraphic framework and the distribution of petroleum system elements. This is because most of the work so far published appear to be restricted mainly to outcrop studies. With renewed and growing interests in the search for commercial hydrocarbon deposits in the Nigerian inland basins, this research work aims at integrating well logs, biostratigraphic, paleobathymetric and 2D seismic data with sequence stratigraphic technique for better understanding of the reservoir, source and seal rock distribution, and their environments of deposition in the Late Cretaceous and Early Paleogene sediments of Southeastern Nigeria (Fig. 1a). Recent developments in sequence stratigraphy offer a more definitive approach for the interpretation of stratigraphic sequence using key stratigraphic surfaces such as marine unconformity (sequence boundaries - SBs) and flooding surfaces (maximum flooding surfaces - MFSs). These surfaces,

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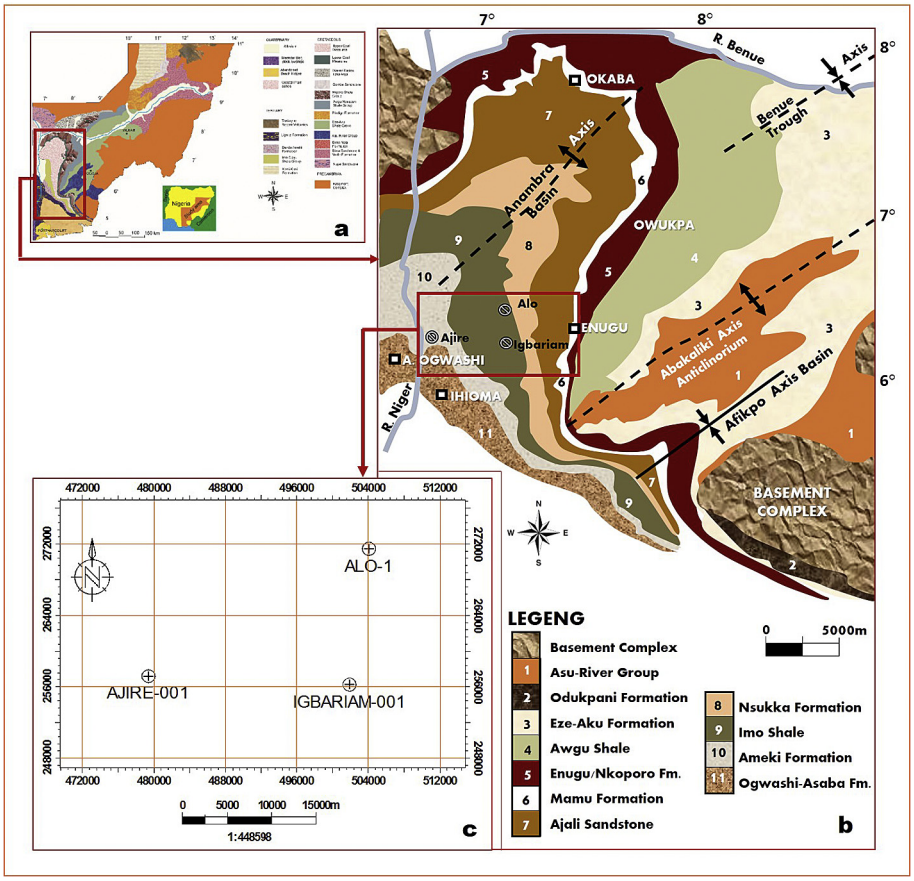

Fig. 1. Map of the study area (a) Geologic map of the Benue Trough with inset of the Anambra Basin (After Uma, 1998); (b) Geologic Map of Southeastern Nigeria (Akande et al., 2007) and (c) Map of the study area showing the spatial distribution of wellbores across the study area.

which serve as chronostratigraphic markers, reflect eustatic changes associated with transgressive and regressive events. Previous studies by Nwajide and Reijers (1996) reveal that the Anambra Basin sedimentary fill is bounded at the base by the Santonian (83 Ma.) and at the top by Eocene (38.6 Ma.) unconformities, and reflects a second-order cycle (ca. 44 Ma.) composed of one transgressive-regressive parasequence pairs. In addition, the post-Santonian sea level movement was transgressive, and lasted well into the Maastrichtian, while the succeeding regression ended in the Danian. Thus the Anambra Basin fill was deposited during one major transgressive and one major regressive episode (Reijers, 1996). Stacher (1995) and Reijers et al. (1997) documented that there is a combined influence of eustatic cyclicity and local tectonics on the stratigraphic succession of the inland and Niger Delta basins. Hancock and Kauffman (1979) reported that global sea level movement resulted in characteristic, basin-wide genetic sequences, or parasequence sets and two allocyclic events in the Anambra basin. Based on evaluation of hydrocarbon potentials of the Anambra basin (Fig. 2), outcrop investigation and geochemical analytical studies have shown the existence of possible reservoir and source rocks within the Nkporo, Mamu and Ajali Formations (Ekweozor, 1982; Obaje et al., 1999; Onuoha, 2005). However this present work focuses on providing more insight into the sequence stratigraphic framework of the Anambra Basin and basal intervals of Niger Delta Basin, which will serve as an exploration tools that could help in furthering the understanding of presence and distribution of key petroleum system elements (reservoir, source and seal).

2. Geologic framework

The study area consists of sediment packages deposited within the Late Cretaceous sequence of the Anambra Basin and Early Paleogene sequence of the Niger Delta Basin in the southeastern part of Nigeria (Fig. 1b). The evolution of the sedimentary basins of southeastern Nigeria started with the break-up and separation of the African and South American plates in the Late Jurassic, which was initiated by the Y-shaped, RRR-triple junction ridge system (Burke et al., 1971; Benkhelil, 1982). Basin fills were controlled by three mega-tectonic cycles (Albian, Santonian and the Late Eocene or Early Oligocene times), which resulted to the displacement of the axis of the main basin giving rise to these three successive basins, namely, the Abakaliki –Benue Trough, the Anambra and the Niger Delta Basin (Murat, 1972; Benkhelil, 1986). The Santonian compressional upliftment of the Abakaliki-Benue Trough, with its resultant sediment folding, displaced the depo-centre from the Abakaliki Basin, to the Anambra Basin and finally, in the Tertiary, to the Niger Delta (Fig. 3). The Late Cretaceous – Paleocene sediment packages (?) and the Post- Santonian Anambra Basin which is situated on the northwestern flank of the Abakalilki Fold Belt, began to develop as a regressive offlap sequence during the Campanian (Nwajide and Reijers, 1996). The Anambra Basin consists of four formations of Campanian – Latest Maastrichtian age (Fig. 2; Murat, 1970; Hoque and Nwajide, 1985; Petters, 1991; Ojoh, 1992).

Sedimentation in the Anambra Basin commenced in the Campanian with a short marine transgression depositing the units of the Nkporo Group (Owelli sandstone, Nkporo Shale, Enugu Shale),