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Lithostratigraphic description, sedimentological characteristics and depositional environments of rocks penetrated by Illela borehole, Sokoto Basin, NW Nigeria: A connection between Gulf of Guinea Basins

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ABSTRACT

The basal unit of the succession in the Illela borehole belongs to the Dange Formation comprising thick calcareous and variably coloured dark-greyish shale of 36.30 m thick which is overlain by a 31.44 m thick limestone of Kalambaina Formation with 1.7 m thick shaly-limestone inclusive. The uppermost part of the section belongs to the Gwandu Formation which has intercalation of silty-clay, muddy siltstones with well lithified ironstone capping the borehole section. The limestone/carbonate microfacie as deduced from their salient lithologic, sedimentologic and paleontologic features are comparable to standard microfacie (SMF) types 9 and 10, i.e. bioclastic wackestone/bioclastic micrite and packstone-wackestone respectively. Diagenetically, syndepositional and early diagenesis have taken place particularly cementation and replacement in the carbonate rocks and these have greatly affected the reservoir potential negatively. The matrix/grain relationships indicate a shallow marine environment of deposition. The borehole section is delineated into upper foraminifera and lower ostracod biostratigraphic units as no formal biostratigraphic zonation could be attempted due to low diversity of both benthic foraminifera, marine ostracods and the absence of planktonic foraminifera. The similarity of the ostracod assemblages between this study area, Illela borehole, West Africa, North Africa (Libya), Mali and Niger Republic) and South-Western Nigeria (West Africa) suggests that a marine connection exists between the Gulf of Guinea and the Sokoto Basin via the area occupied by the River Niger during the Paleocene.

1. Introduction

The Paleocene rocks of Kalambaina limestones and the underlying marine shales intersected by the Illela borehole belong to the Kalambaina and Dange Formation respectively. The Illela bore is situated in the NNW part of Sokoto Basin bordering the Northern Nigeria and the Niger Republic. The Sokoto Basin represents the south-eastern extension of the trans-saharan Paleocene transgression of the Tethys (Reyment, 1981). Lithostratigraphically, the sediments from the borehole comprise the lower marine shales, the interbedding limestones and the upper continental intercalation of siltstones, mudstones and ironstones. Carbonate sediments are particularly sensitive to environmental changes; their sedimentation is rapid but easily inhibited (Mazzullo and Harris, 1992). Temperature variations influence biogenic activities and affects sediment production; thus most carbonate production is strongly depth dependent. Carbonate reservoirs are considered to be extremely challenging in terms of accurate recovery prediction because of their complexity and heterogeneity. When conditions are favourable for carbonate sedimentation, organic productivity is high; when unfavourable, it ceases. Carbonates form within the basin of deposition by biological, chemical and detrital processes. Texture of carbonates is more dependent on the nature of the skeletal grains than on external influences. Carbonate minerals are susceptible to rapid dissolution, cementation, recrystallization and replacement at ambient conditions in a variety of diagenetic environments (Choquette and Pray, 1970). Biofacies and lithofacies often correlate, in other words, organisms produce typical

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lithofacies. Substrates control inhabiting organisms. Basin configuration and energy level of water are other dominant controls on carbonate deposition. Organic productivity varies with depth and light (photic zone); upwelling and water agitation also influence organic productivity. Deep carbonate reservoirs commonly contain evaporate nodules (Schreiber and El Tabakh, 2000; Warren, 2006). The most abundant carbonate form, calcite is chemically unstable and is hence susceptible to change by transformation into other carbonate minerals such as siderite, dolomite, etc. In this research work, an attempt has been made to classify the various facie types present in the carbonate rocks, deduction of their depositional environment and reservoir potentials, correlation of the depositional environment of both the carbonate rocks and shale units, and also to relate the area of study to other African basins paleobiogeographically.

2. General geology of southern part of Iullemmeden Basin (Sokoto Basin)

The southern part of the Iullemmeden Basin is situated in north-western Nigeria where the Sokoto Basin is located (Fig. 1) which is stratigraphically representative of the exposed basin margin. There is close agreement between the stratigraphic succession in north-western Nigeria and the successions in the neighbouring Niger Republic (Radier, 1959; Greigert and Pougnet, 1967; Greigert, 1966). The Iullemmeden Basin covers an area of approximately 800,000 km^2 and it encompasses part of Algeria, Mali, Niger, Benin Republic as well as north-western Nigeria (Bellion, 1989). The stratigraphic relationship of strata in the Sokoto Basin is as shown in Fig. 3 below.

2.1. Lower cretaceous

The Sokoto Basin is overlain by various formations ranging in age from Pre-Crataceous to Recent (see Fig. 2). The "Continental Intercalaire" Group is the basal sandstone sequence in the Iullemmeden Basin. In the north-western Nigeria the sandstones and clays of the "Continental Intercalaire" Group rest directly on crystalline basement and have yielded fossil wood, vertebrate and invertebrate fossils of Late Jurassic –Early Cretaceous age in the north-western Nigeria (Kogbe and Lemoigne, 1976). In the Sokoto State of north-western Nigeria, the "Continental Intercalaire" Group is known as the Gundumi Formation in the north-eastern part and as Illo Formation in the south-western part (Jones, 1948). Both Formations are lateral equivalent and are up to 300 m thick. The Illo-Gundumi sequence comprises a lower, white conglomeratic, arkosic, cross-bedded sandstone with interbedded concretionary and highly aluminous clays, and an upper coarse to medium, cross-bedded sandstone.

2.2. Cenomanian-Turonian

Marine Cenomanian-Turonian deposits are not widely distributed in the Iullemmeden Basin. They are exposed north of Tahoua where Cenomanian fauna comprising *Exogyra Columba minor Lamarck, Strombus incertus D' Orbigny and Ostrea biauriculate* var. *Hippopodium Furon* are in occurrence (Furon, 1963). The Lower Turonian fauna comprises *Exogyra olisiponensis sharpe, Paravascoceras cauvini chudeau and Paracanthoceras chevalieri* (Furon, 1963). The Upper Turonian is sandy and regressive. Cenomanian-Turonian marine beds are known in boreholes in the Gao trough (Radier, 1959) and between the Gao trough and the Adrar des Iforas (Krasheninnikov and Trofimov, 1969; Hazzard et al., 1971).

2.3. Maastrichtian

A Late Cretaceous transgressive sandstone sequence disconformably overlies the Continental Intercalaire Group in the Iullemmeden Basin. In Niger Republic, this transgressive sandstone sequence is referred to as the Cenomanian continental hamadien (Furon, 1963). Its equivalent in north-western Nigeria is the Taloka Formation and this comprises a lower brown, laminated and carbonaceous mudstone with lignite beds, and an upper sequence of alternating thin, parallel-bedded, tabular, laterally persistent, clayey, fine grained sandstone, siltstones and massive, tabular mudstones. The lower mudstones and siltstones are cross-

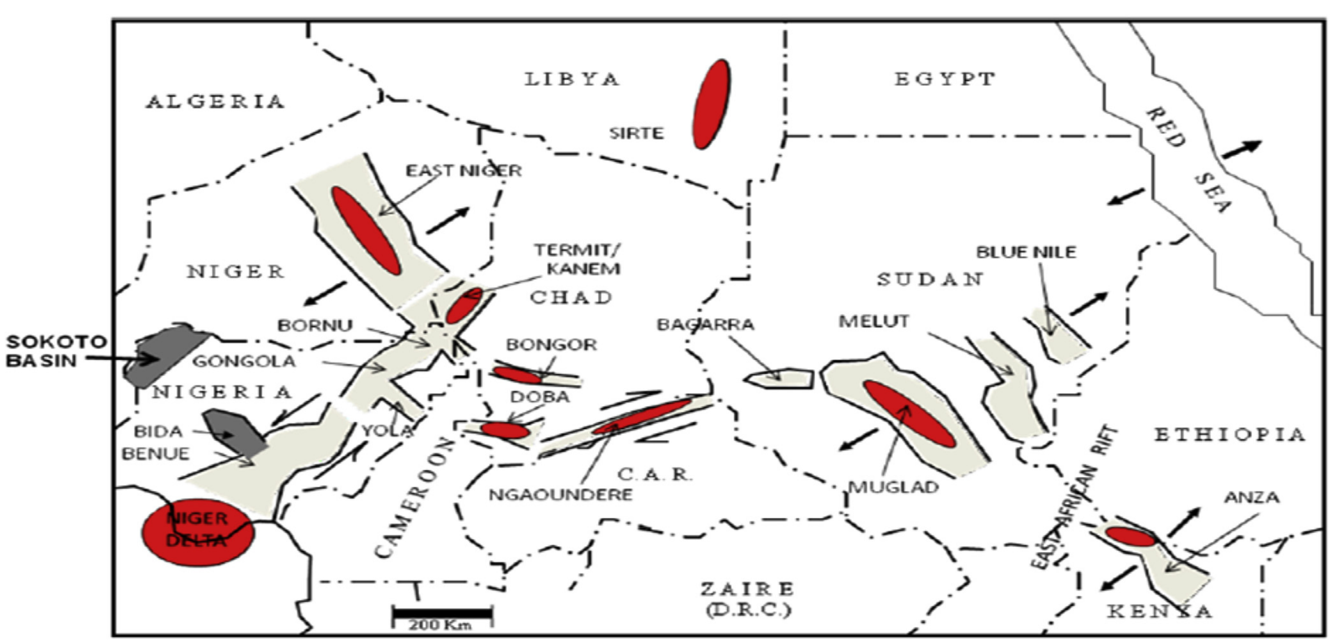

Fig. 1. Regional tectonic map of western, central and eastern African rifted basins showing the Sokoto basin and other related African basins (modified from Obaje et al., 2004).