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# Structural characterization of the Nigerian sector of Benin Basin using geopotential field attributes

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ABSTRACT

The structural dispositions of the Nigerian sector of the Benin Basin have been investigated using attributes of geomagnetic and gravimetric fields. Aeromagnetic anomalies were reduced to the equator to improve the correspondence of the anomalies with the causative bodies. The residual, upward continued, tilt and horizontal derivatives, and pseudogravity attributes and forward models of both geomagnetic and gravimetric anomalies were computed to accentuate geological features including shallow and regional faults, fracture network, basement block pattern and depth to magnetic basement. Three generations of sinistral faults were identified. The oldest generation of faults (F1) is the NE-SW trend corresponding to the oceanic fracture zones trend. The F1 is truncated by the second generation of faults (F2) with E-W trends. The third generation of faults (F3) assumes NW-SE trend and is offset by F2. Shallow and deep regional faults and fractures envisaged to play major role in migration and entrapment of hydrocarbons and localization of mineral resources in this area were imaged. The coastline, Lagos and Lekki Lagoons surface geometry showed high degree of similarity with their underlying basement block pattern, thus implying that these surface features are structurally controlled. The basement morphology is not flat but of horst and graben architecture in which sediment thickness attained about 4 km within the graben. Hence, the graben has significant hydrocarbon potential. This study has shown the capabilities of geopotential field attributes in providing information about the structural architecture of frontier basin. Such knowledge will aid the understanding of the geology of the basin and its resources.


## 1. Introduction

The Nigerian portion of the Benin Basin (Fig. 1), occupying the southwestern part of Nigeria between longitude 2°30′(320,000 mE) and 4°30′E (580,000 mE), and latitude 6°00′(665,000 mN) and 7°00′N (775,000 mN), is considered to be one of the frontier basins in oil exploration. This Basin has been a subject of renewed exploration interests due to rejuvenated interest of the Nigerian government in increasing her crude reserve through exploration of frontier basins. The study of basin structures is one of the important economic applications of magnetic method in oil and gas exploration. Local variations in magnetic properties of crustal rocks cause anomalies in the earth's magnetic field; and geologic structures (like faults and folds) may produce small magnetic fields that distort the main magnetic field of the earth. Because basin fill typically has a much lower susceptibility than the crystalline basement (Nabighian et al., 2005), and basements commonly exhibit variation in susceptibility; it is commonly possible to estimate the depth to basement and quantitatively map basement structures (Prieto and Morton, 2003). Likewise, gravity method has been used for many years to map the geometry and features of remote basins (Jacques et al., 2003) where density contrast exists. Earlier work in the study area (Coker and Ejedawe, 1987) ascribed a low petroleum potential to the Benin Basin but recent exploratory efforts in the basin have resulted into discovery of commercial oil in Aje field offshore Lagos, thus establishing the fact that the basin is a potential petroleum province (Brownfield and Charpentier, 2006). Despite magnetic and gravity methods being prime tools for assessing the structural prospects of any frontier basin, surprisingly basin-wide geopotential study was not carried out over this basin from the petroleum exploration point of view. Previous geopotential attempts to study the basin were commonly restricted to a section of the basin (e.g Opara et al., 2012; Osinowo and Olayinka, 2013; Oladele and Ayolabi, 2014). In this study, attributes of high resolution aeromagnetic data and coarse satellite derived gravity

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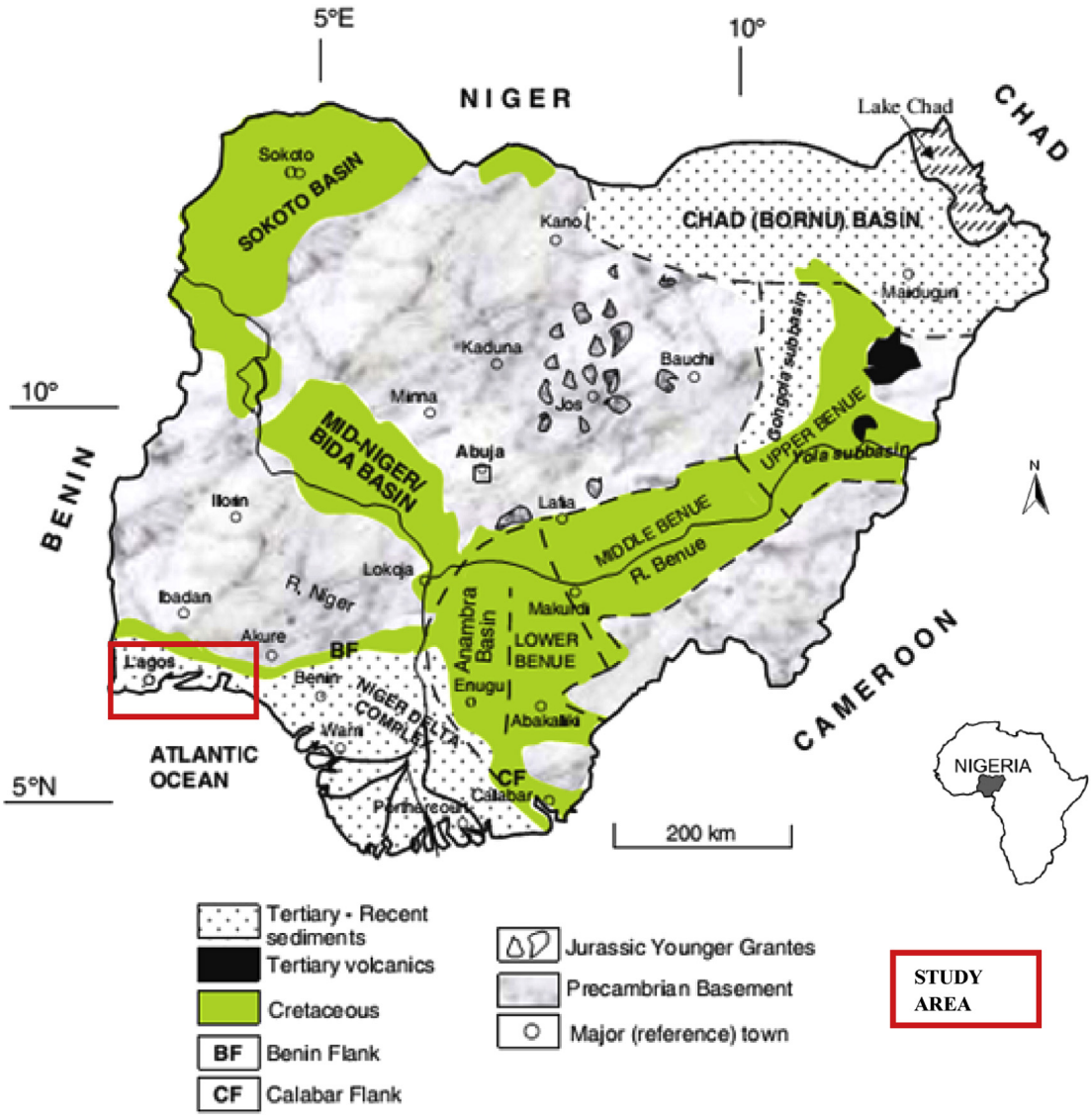


**Fig. 1.** Geological Map of Nigeria Showing the location of the Study Area (Modified after Obaje, 2009).

data were interpreted to understand the basin-wide structures and tectonics of the Benin Basin.

## 2. Geological setting

The Benin Basin is a sedimentary basin that was initiated during the Mesozoic in response to the separation of the African–South American plates and the subsequent opening of the Atlantic. The geology of the basin has been extensively discussed by various authors (Murat, 1970;

Ofoegbu and Onuoha, 1988; Omatsola and Adegoke, 1981, etc). Several workers have worked on the stratigraphic framework of the Benin Basin (Adediran and Adegoke, 1977; Nton et al., 2006). The Cretaceous sequence in the Eastern Benin Basin began with the Abeokuta Group and was capped by Recent Alluvium (Jones and Hockey, 1964). The summary of the lithostratigraphic units of the sedimentary successions of the Eastern Benin Basin by Idowu et al. (1993) is presented in Table 1.

Principal structures in the Benin Basin are those associated with Early Cretaceous rifting and are dominated by normal faults bounding a series of linked half-grabens. Blarez and Mascle, 1988 explained that the thick continental crust of the African and South American continental plates began to breakup in the early Albian time and formed the basins separated by transform faults in the Gulf of Guinea (Fig. 2). Presumably, the offset extension of the Romanche Fracture Zone, confines the basin in the west while the Benin Hinge Line which separates the Okitipupa Structure from the Niger Delta basin, confines it in the east. The Benin Hinge Line supposedly defines the continental extension of the Chain Fracture Zone (Coker and Ejedawe, 1987; Onuoha, 1999). Coker and Ejedawe (1987) identified three structural domains; namely, the onshore, the Okitipupa structure and offshore domains. They emphasized that these three structural domains have gone through three phases of basin evolution. These phases are the initial graben (predrift) phase, prolonged transitional phase and open marine (drift) phase.

## 3. Methodology

### 3.1. Dataset

The dataset employed for this study include High resolution aeromagnetic (HRAM), African Magnetic Map (AMMP), Satellite