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Research paper

Geochemical and petrographic characterisation of organic matter from the Upper Cretaceous Fika shale succession in the Chad (Bornu) Basin, northeastern Nigeria: Origin and hydrocarbon generation potential

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ABSTRACT

The Upper Cretaceous Fika shales in the Chad (Bornu) Basin, northeastern Nigeria were analysed to evaluate the origin of the organic matter and the hydrocarbon generation potential. This study is based on geochemical analyses (total organic carbon (TOC) content, pyrolysis (SRA), pyrolysis gas chromatography (Py–GC), bitumen extraction and biomarker distributions) and kerogen analysis of organic matter by microscopy. The present-day TOC contents range between 0.50 and 2.37 wt.% and Hydrogen Index (HI) values are largely below 200 mg HC/g TOC, suggesting that the shales are organically lean and contain Type III and Type IV kerogens. This is evidenced by palynofacies investigation whereby the kerogen is characterised by large amounts of non-fluorescent amorphous organic matter (AOM) and phytoclasts. Pyrolysis GC analysis proved that all the investigated Fika shale samples contain Type III kerogen that produces mainly gaseous hydrocarbons. The Fika shales have high gas-generation potential due to a combination of kerogen type and thermal maturity. The Fika shales have vitrinite reflectance and T_{max} values in the range of 0.70–1.34% and 430–465 °C, respectively, indicating early to late oil-window maturity, thus higher maturity levels have affected the HI of the samples and the hydrocarbon generation potential, decreasing both. The higher thermal maturity level is attributed to the presence of volcanic intrusives, which occur as diorite sills at numerous horizons in the Fika Formation.

1. Introduction

The Chad Basin is an extensive structural depression, covering an area of about 2,335,000 km^2 in Chad Republic, Niger Republic and extending into Cameroon, Central Africa Republic, Sudan and northeast Nigeria (Fig. 1). The Nigerian part of Chad Basin, also known as Bornu Basin, is one of Nigeria's frontier inland sedimentary basins where exploration activities are currently being undertaken. These inland basins constitute parts of a series of rift basins in Central and West Africa whose origin is linked to the separation of the African crustal blocks in the Cretaceous as part of the West and Central African Rift System (Fairhead, 1986; Genik, 1992, 1993) (Fig. 1). Apart from the Chad (Bornu) Basin in Nigeria, commercial hydrocarbon deposits have been discovered in the other parts of the rift trend in neighbouring countries of Chad (Doba, Doseo and Bongor fields), Niger (Termit-Agadem Basin) and Sudan (Muglad Basin), which are genetically related and have the similar structural settings (Mohammed et al., 1999; Obaje et al., 2004; Alalade and Tyson, 2010).

Hydrocarbon accumulations discovered in the neighbouring Chad and Niger Republics are reported to have been sourced from Lower Cretaceous and Eocene lacustrine shales and Upper Cretaceous marine shales (Genik, 1993). Although the presence of lacustrine shales has not been reported in the Nigerian sector of the basin, about 2 km of Upper Cretaceous marine (potential source rock) shales have been penetrated by exploration wells drilled in this sector (Okosun, 1995; Olugbemiro et al., 1997; Alalade and Tyson, 2010). Potential hydrocarbon source rocks in the Chad (Bornu) Basin are found in the Cretaceous Bima, Gongila and Fika Formations, which are similar and correlative to Abu Gabra Formation in the Muglad Basin (Mohammed et al., 1999; Obaje et al.,

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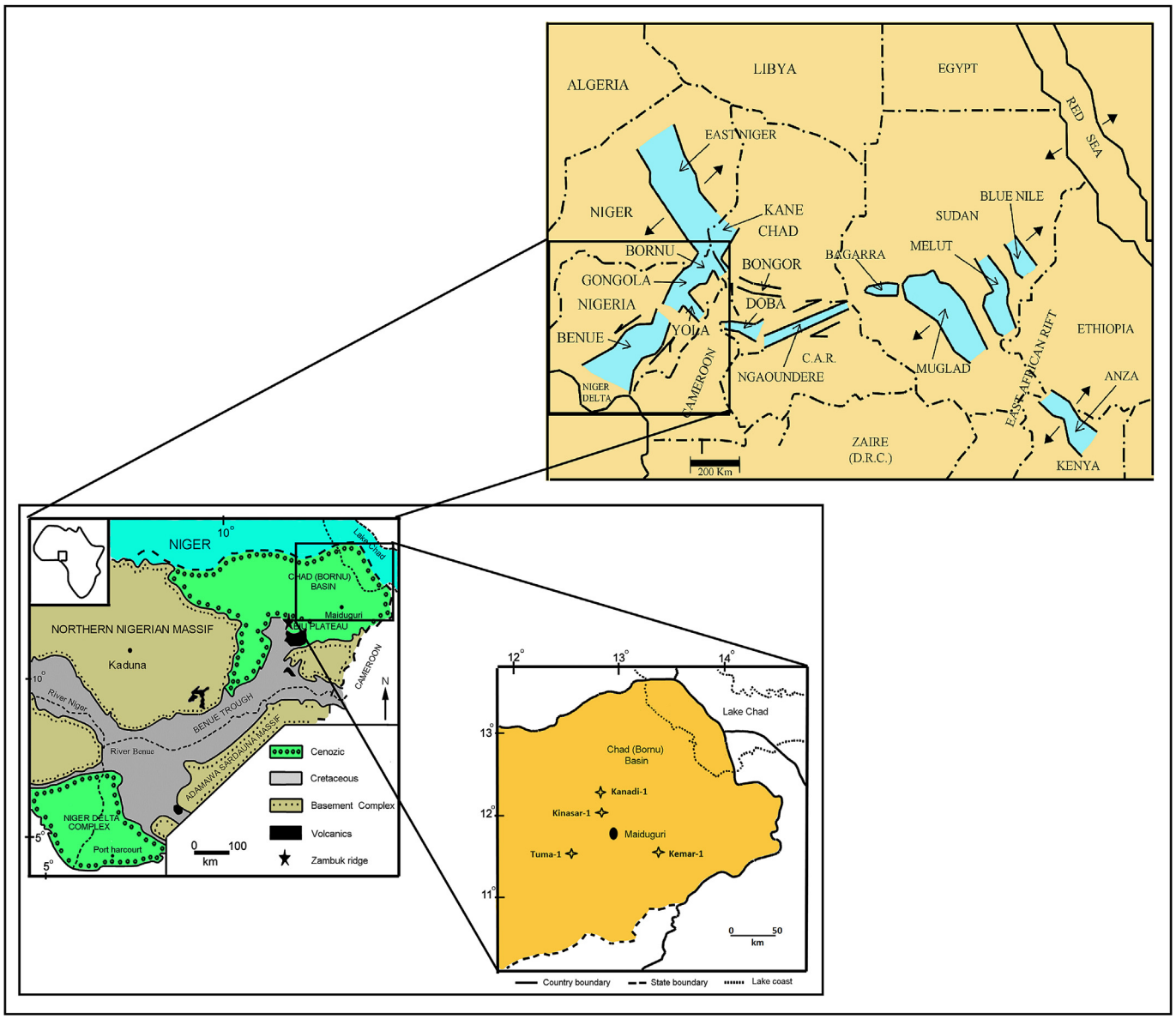

Figure 1. Regional tectonic map of western and central African rift basins showing the Chad (Bornu) Basin and studied exploratory wells (after Whiteman, 1982). Note: locations of regional shear zones (marked with half-arrow) and major zones extensions (complete arrow) are shown (adapted from Schull, 1988).

2004). Several publications have addressed the source rock richness, quality and maturity of the Fika source rocks (Petters and Ekweozor, 1982; Olugbemiro et al., 1997; Obaje et al., 2004; Alalade and Tyson, 2010). Most of the previous studies of the basin have established the predominantly gas-prone nature of the potential source rock in the study area, but without adequate examination of the source input and the depositional conditions of the organic matter. The major significance of this study is related to improving our knowledge on the origin and hydrocarbon generation potential of organic matter in the Fika source rocks. The present analyses of the Upper Cretaceous Fika Formation in the Chad (Bornu) Basin are based on the interpretation of organic petrological and organic geochemical data, including total organic carbon (TOC) content, pyrolysis, kerogen microscopy, and vitrinite reflectance (%Ro) data as well as biomarker distributions. The integration of organic geochemistry and petrography can give more detailed information on the types of organic matter and the hydrocarbon generation potential.

2. Geologic setting

The Nigerian part of the basin (also known as Bornu Basin), which represents about one-tenth of the total areal extent of the Chad Basin, is believed to be genetically linked with the Benue Trough, thus representing the northern border of a NE–SW extension of the basin (Olade, 1975) (Fig. 1). The Chad Basin is genetically and structurally related to the fault and rift systems termed the West and Central African Rift Systems (WCARS), whose origin is generally attributed to the Cretaceous breakup of Gondwana and the opening of the South Atlantic Ocean and the Indian Ocean (Fairhead, 1986). According to Fairhead (1986), the WCARS have two subsystems namely; the West African Rift Subsystem (to which the Chad Basin belongs) and the Central African Rift Subsystem. The Benue–Chad axial trough is believed to be the third and failed arm of a triple junction rift system that preceded the opening of the South Atlantic during the early Cretaceous and the subsequent separation of the African and South American