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Organic Geochemistry, Burial History and HC Generation Modelling of Upper Cretaceous Sediments in the Chad (Bornu) Basin

A.K. Adegoke* (University of Malaya) & W.H. Abdullah (University of Malaya)

SUMMARY

The Upper Cretaceous Gongila and Fika Formation sediments, which are believed to be the major source rocks in the Chad (Bornu) Basin, were analysed using organic geochemistry and petrology. The total organic carbon (TOC) contents of the sediments range from 0.42 to 4.90%. The samples analysed have vitrinite reflectance in the range of 0.58 – 1.39 % Ro and pyrolysis Tmax in the range of 429 – 475 oC indicate that the Gongila and Fika sediments contain mature to late mature organic matter. Moderate oil-generating potential is anticipated from the sediments with fairly high hydrogen indices (150 – 250 mg HC/g TOC). This is supported by their Py-GC (S2) pyrograms with n-alkane/alkene doublets extending beyond n-C30. The sediments are dominated by Type II and Type III kerogen and are thus considered oil and gas prone (mainly gas). One-dimensional basin modelling was performed to analyse the hydrocarbon generation and expulsion history of the Upper Cretaceous sediments in the Chad (Bornu) Basin based on the reconstruction of the burial/thermal maturity histories. This is to improve our understanding of the oil hydrocarbon generation potential of the source rocks. Calibration of the model with measured vitrinite reflectance (Ro) and borehole temperature data reveals that the present-day heat flow in the Chad (Bornu) Basin varies from 55.0 mW/m2 to 60.0 mW/m2 and paleo-heat flow value at approximately 68 mW/m2. The source rocks of the Gongila and Fika Formation are presently at a stage of oil, condensates and gas generation with thermal maturity ranging from 0.58% to 1.39% Ro. The modelled burial history also suggest that maximum burial occurred in the late Miocene and that erosion might have been the cause of the thinning of the Tertiary sediments in the present time.
Introduction

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 (Genik, 1993). 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, Niger and Sudan, which are genetically related and have the same structural settings (Obaje et al., 2004). The poor knowledge of the evolution of the subsurface rocks in the Chad (Bornu) Basin, especially with respect to their characteristics and their thermal/burial histories may have been responsible for the unsuccessful exploration attempts within the basin.

Basin modelling in exploration related studies is still a relatively young but extremely useful discipline to reveal the timing, and to understand and quantify the complex processes of petroleum formation (Waples, 1994). The integration of source rock characteristics into basin modelling can give more detailed information needed to answer exploration questions on hydrocarbon generation and expulsion of the source rocks. This current study focuses on the detailed geochemistry of the Upper Cretaceous sediments in Chad (Bornu) Basin, to provide an overview of the organic richness, hydrocarbon generation potential and level of maturity of the organic matter in the sediments. In addition, the results of source rock characteristics are incorporated into basin modelling in order to know and determine the timing of hydrocarbon generation and expulsion of the source rocks.

Samples and methods

A total of 127 cutting samples from five exploratory wells (Kanadi-1, Kemar-1, Kinasar-1, Kuchalli-1 and Tuma-1 Wells) drilled by the Nigerian National Petroleum Corporation (NNPC) in the Chad (Bornu) Basin were selected for this study. The geochemical methods used to evaluate the source rock potential of the sediments include the determination of total organic carbon (TOC) content, pyrolysis and open system pyrolysis-gas chromatography (Py-GC). Whole rock samples were crushed and pyrolysed using Weatherford Source Rock Analyzer-TPH/TOC (SRA) instrument. Open system pyrolysis-gas chromatography (Py-GC) was also applied to provide compositional and structural characteristics of kerogen. This analysis was performed on isolated kerogen samples using Double-Shot Pyrolyzer PY-2020iD from Frontier Laboratories Limited fitted into an Agilent GC chromatograph. Samples for petrographic examinations were made using standard organic petrographic preparation techniques. Petrographic examinations and mean vitrinite reflectance (Ro %) measurements were carried out under oil immersion in a plane polarized reflected light, using a LEICA DM 6000M microscope and LEICA CTR6000 photometry system equipped with fluorescence illuminators.

The reconstruction of the burial, thermal and maturity histories were modelled in order to evaluate the remaining hydrocarbon potential using PetroMod 1-D (version 10.0 SP1) software developed by IES, Aachen, Germany. Major 1-D model input parameters comprise events or formations within the chronostratigraphy, deposition age, present and eroded thicknesses of formations and events, volumetric lithological mixes, kerogen types and kinetics and further geochemical parameters such as initial %TOC. The modelling results are also calibrated with measured vitrinite reflectance and borehole temperatures (BHT) of these five wells in the study area.

Application

The incorporation of source rock characteristics into basin modelling has given more detailed information needed to answer exploration questions on hydrocarbon generation and expulsion of the source rocks. This has provided further insight into the source rocks of the basin, for the current and future petroleum exploration programme and resource assessment in the basin.
**Figure 1** Burial history modelling in one of the wells (Kinasar-1 well) in the Chad (Bornu) Basin.

**Conclusions**

- Organic geochemical and petrographic investigations indicate that the Upper Cretaceous sediments possess generally fair to occasionally good source generative potential. The sediments have attained sufficient burial depth and thermal maturity for significant hydrocarbon generation potential.

- The maturity modelling of the various wells indicates that the Gongila and Fika source rocks are presently at a stage of oil, condensates and gas generation with thermal maturity ranging from 0.58% to 1.39% Ro.

- The modelled burial history suggest that maximum burial occurred in the late Miocene and that erosion might have been the cause of the thinning of the Tertiary sediments in the present time.

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**References**

