PETROLEUM EXPLORATION AND DEVELOPMENT
Volume 43, Issue 3, June 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: PETROL. EXPLOR. DEVELOP., 2016, 43(3): 451–456.

RESEARCH PAPER

Radioactivity and hydrocarbon generation potential of sediments, Gongola Basin, Nigeria

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Abstract: Samples taken from Well Kolmani-1 in the Gongola Basin in the Upper Benue Trough of Nigeria were studied to estimate the radiogenic heat generated and to analyze the possible impact of radiogenic heat on hydrocarbon generation potential of the sediments. Thirty-eight samples taken from the different formations at intervals of 73.2 m including sand, shale, coaly shale, sandy shale, and shaly sand were analyzed for ^{40}K, ^{238}U, and ^{232}Th using the well calibrated NaI (Tl) Gamma Ray detector System. The results showed that the activity concentrations of the radio-nuclides varied significantly within the sediments. The ^{40}K concentrations were the highest. The radiogenic heat produced ranges widely from 228.44 pW/kg to 1 412.82 pW/kg. In Well Kolmani-1, sands and sandy shale are low heat production sediments, while the shale, coaly shale and silty sands are medium heat production sediments, the potential source rock (shale and coaly shale) medium in heat production (750 pW/kg to 1 500 pW/kg), can produce liquid and gaseous hydrocarbons. It is estimated that the radiogenic heat from the sediments contributed about 10.9% to 20.9% to the total surface heat flux in the basin. Therefore, the radiogenic heat generated by the sediments contributed significantly to the total surface heat flux, and should be taken into consideration in the simulation of basin thermal evolution.

Key words: radioactivity; radiogenic heat; hydrocarbon generation potential; Gongola Basin

Introduction

Thermal parameters such as thermal gradient, radiogenic heat production (RHP) and heat flux are crucial to modeling of the thermal maturation of oil-source rocks and dynamic evolution of a basin[1]. Among all the parameters, RHP is an important component in the thermal parameter analysis of a basin which has generally been neglected. The hydrocarbon generation potential of organic matter in the basin strongly depends on the magnitude of heat available to maturate the organic matter[2]. Heat sources from the interior Earth originate from three major aspects, including primordial energy of planetary accretion, segregation and solidification of the Earth's core, and RHP from the decay of uranium (U), thorium (Th), and potassium (K). RHP has three components including heat generated from the lithosphere, the crust beneath the basin (i.e. basement), and the sedimentary rocks within the basin[2–3]. Measurements of RHP in sediments indicate wider variations compared to that of basement, with a general decreasing trend for RHP from shales to mudstones, sandstones, coals, carbonates, and evaporates[4–5]. Heat generated from heat source in the lithosphere and the crust is transferred into the basin by tectonic movements (faulting, diapirism, etc.) or fluid flow (convection)[6]. Therefore, the heat flux of the formation is the sum of the heat flux from the basement below and the contribution of heat production within the sediments. Hermanrud (1993)[7] suggested that RHP within the sedimentary sections of basins was generally insignificant, with a few percent or less contribution to heat flux density. However, Mckenna and Sharp (1998)[5] published measurements of heat generation on sediments from several units from the Gulf Coast region in Texas, the United States. They discovered significant heat generation in the region, and strongly recommended that it should not be ignored during basin modeling. Current studies have been mostly concentrated on the organic geochemical evaluation of the source rock potentials of the sediments in the Upper Benue Trough, Nigeria. Little data has been published on RHP and its effect on the overall thermal parameters of the sediments within the Yola basin and the Nigerian sector of Chad basin[8–9]. This work is to assess the possible impact of RHP on the hydrocarbon generation potential of the sediments within the Gongola Basin, Upper Benue Trough, Nigeria.

1. Overview of the research area

Gongola basin is a NNE-SSW trending rift basin (Fig. 1)

Received date: 01 Apr. 2015; **Revised date:** 31 Mar. 2016.
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about 800 km long and 150 km wide containing about 6 000 m of thick Cretaceous-Tertiary sedimentary rocks. The basin constitutes the Upper Benue Trough with Yola basin. The evolution of the Gongola basin is related to the origin of the Benue trough which has been variously discussed in the literature and is currently controversial. King and Obaje (1950)[10–11] was the first to suggest that the evolution of the Benue Trough was related to the stresses associated with the separation of the African and South American continents. Benkhelil (1982)[12] believed that the Benue trough does not have a tensional feature but is composed of sinistral strike-slip faults connected to oceanic transcurrent faults and that consequently the trough contains a collection of pull-apart basins and uplifted blocks. In addition, Benkhelil (1989)[13] also suggested that slightly modified model of the strike-slip is applicable to explaining the evolution of the Benue trough, i.e. a combination of extensional and strike-slip movements. Well Kolmani-1, which was drilled in 1999 with a depth of 3 000 m, was located in Upper Benue Trough, Gongola basin.

The stratigraphic column for the Gongola and Yola basins is illustrated in Fig. 2. The main rifting in the evolution of the Benue trough was immediately followed by sedimentation. Carter et al. (1963)[14] recognized the various Formations which Thompson (1958)[15] described as a sedimentary sequence covering Bima Formation, Yolde Formation, Pindiga Formation, Gombe Formation, and the Kerri-Kerri Formation. The geology as well as the stratigraphy is well described in works by Oyebanjo et al., 2014[16].

2. Data and methodology

Ditch-cuttings from well Kolmani-1 were sampled from drilling fluid pond (depth from 18.30 m to 2 724.90 m) at a regular interval of 73.15 m. Thirty-eight ditch-cutting samples were processed in total for the radioactivity measurements. The samples consist of sands, shales, shaly sands, and sandy shales with some containing coal fragments. Firstly the density of the samples was determined. All the weighing operations were done with ADAMPW 214 electronic scale from geological department, Obafemi Awolowo University. After the samples were pulverized and weighed, they were put into a plastic container, which was tightly sealed for no less than 28 days, for the sample to attain secular equilibrium and to prevent Ra-226 gas from leaking. An empty container was also weighed and sealed for the same number of days to serve as the background count.

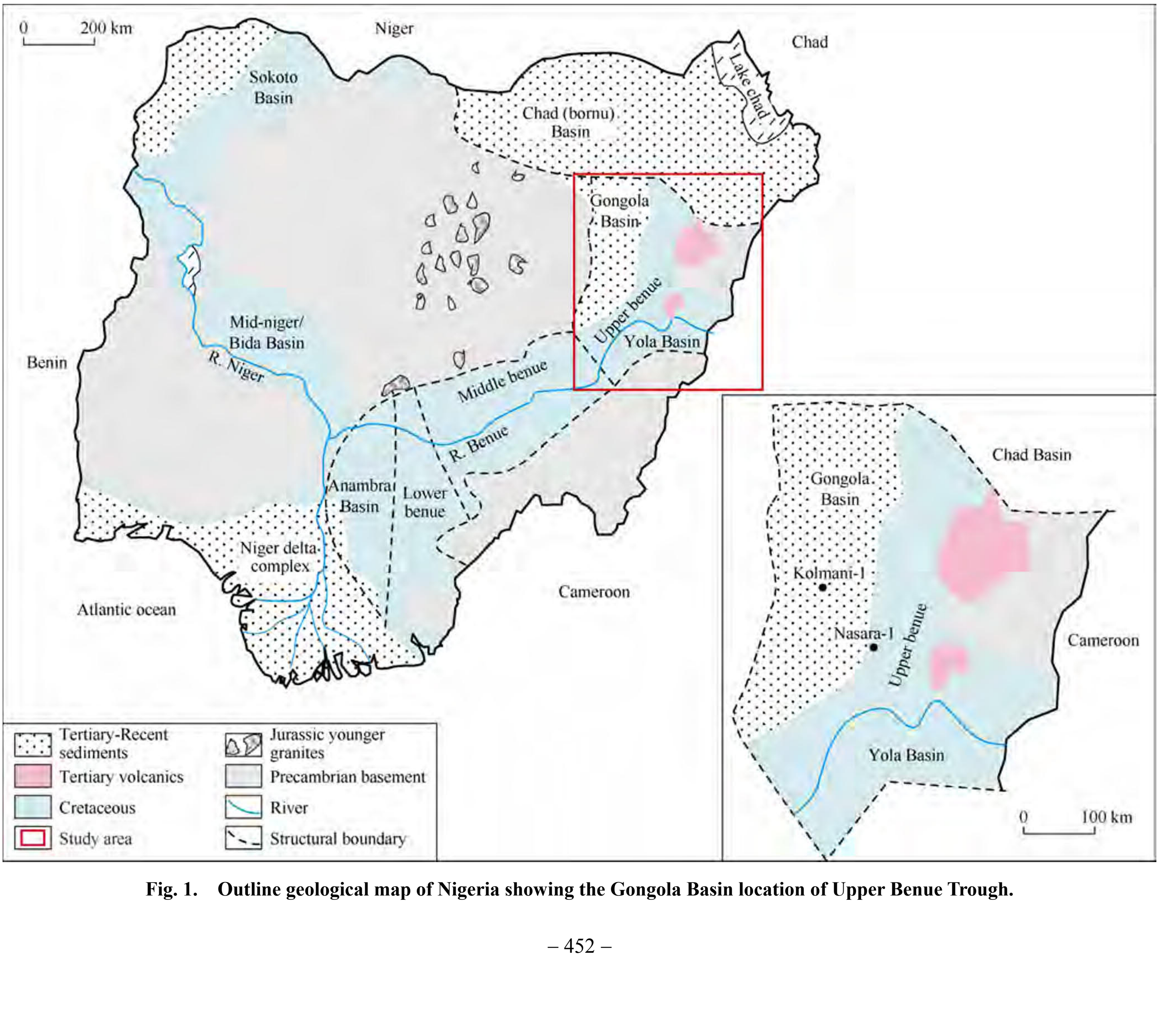

Fig. 1. Outline geological map of Nigeria showing the Gongola Basin location of Upper Benue Trough.