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Organic geochemistry of Cretaceous Lamza and Chikila coals, upper Benue trough, Nigeria

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Abstract

Some biomarkers and other compounds in the aliphatic and aromatic fractions of the Lamza and the Chikila coals were characterized and used in assessing the source input, maturity, hence the hydrocarbon generative potentials of the coals. The samples exhibit a slight *n*-alkanes odd carbon preference (CPI $\sim$ 1), high pristane/phytane ratios and a dominance of 20S epimer of C_{29} sterane. The ratio of C_{30} $\alpha\beta/(\alpha\beta + \beta\alpha)$ sterane and 22S/(22S + 22R) C_{31}-homohopane gave values of 0.77–0.83 and 0.58–0.60, respectively. The low Ts/Tm ratios are in agreement with the calculated vitrinite reflectance, R_c (0.60–0.70%). The methylphananthrenes maturity derived parameters (1-MP/9-MP; MPR; MPI-1; R_c) revealed a very slight variation and a consistent order of samples maturity with the exception of the R_c values. All these together with some other hopanoid ratios, show that the organic matter is terrestrially derived, deposited in an oxic environment and at marginal maturity for hydrocarbon generation.

Keywords: Biomarkers; Hydrocarbon generation; Cretaceous coals

1. Introduction

Coal is an important source rock not only for natural gas but also for crude oil. Some typical examples include the oil field in the Junggar and Tarim basins in northwestern China [1], the Herald and Lulita fields in the Danish Central Graben of the North Sea [2] and the Greater Green River Basin in Southern Wyoming [3]. Nigeria is endowed with a large coal deposit [4], most of which are reported to be within the Benue trough [5,6]. Despite the reported occurrence of these deposits and the effort of the Nigerian Government in petroleum exploration to increase its oil reserve, only a little attention is paid to the coal bearing basins [8].

In the absence of migrated inputs, the distribution of biological markers in sedimentary organic matter is a function of the depositional environment, types of organisms that prevailed and the maturity of the sediment [8,9]. Therefore the isolation and identification of biological markers have been useful in developing the understanding of the relationships between coals and their parent materials. One of the most significant applications of biological markers is in the assessment of hydrocarbon generative potentials of sedimentary materials such as coals. For example specific triterpanes ratios can be used to indicate the thermal maturities of potential source rocks. Although there is a general decrease in the concentration of the individual isomers which are as a result of biomarker generation from the kerogen (mainly) and other macromolecules/polar fraction [10], the concentration of the thermodynamically less stable 17β, 21β(H) isomers usually decrease with a corresponding increase in the concentration of 17α, 21β(H) stereochemistry with maturation [10]. It was initially assumed that only diagenesis and maturation of the organic material containing the precursor leads to the

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formation of saturated hopanes with thermodynamically more stable 17α, 21β(H) configuration possessed by the majority of hopanes [11]. Even though simple isomerization in the bitumen may also be occurring, it appears to be of relatively minor contribution. Oleanane is a biomarker derived from angiosperms and its index is used to indicate the terrestrial and marine input into the organic matter [12]. A research conducted on the Lafia-Obi coals in the middle Benue trough, revealed that 17α, 21β(H)-hopanes and 17β, 21α (H)-hopanes were the major biomarkers present while the minor ones include 18α-oleanane, spiro-oleanane and onoceranes [7]. The presence of onoceranes may be an indication of sediment from a brackish depositional environment [13]. Obaje [14], also reported the presence of these hopanes in the Lafia-Obi coals and used their transformation indices together with *n*-alkanes odd/even ratio, to conclude that the coals are matured with respect to oil generation.

Steranes are derived from sterols which are widely dispersed in plants and microorganisms, with C_{27} and C_{28} sterols most abundant in aquatic organisms and C_{29} sterols in higher plants [15]. Therefore high concentration of C_{29} steranes (24-ethylcholestanes) compared to the C_{27} and C_{28} steranes may indicate a land-plant source [16]. Steranes are also used in maturity determination of oil and sedimentary organic matter. Originally the process was widely assumed to comprise only direct isomerization of the original R configuration at C-20 (called 20R) found in steroid precursors in living organisms, which is gradually converted during burial maturation to a mixture of the R and S sterane configurations. The extent of side-chain epimerization at C-20, measured as 20S/(20S + 20R) for the 5α, 14α, 17α(H) C_{29} steranes, rises with increasing maturity [17]. It is now known that the above process may still be occurring but appears to be of a relatively minor contribution [10]. The changes in the ratio with maturation arise because both the 20R and 20S were initially present in free state with the concentration 20R much greater than that of 20S isomer. With increasing thermal evolution of the kerogen, both isomers are liberated from the kerogen with increasing proportionality of 20S, resulting in a net increase in 20S/(20S + 20R) ratio [10,18].

The abundance and distribution of polycyclic aromatic hydrocarbons and their structural isomers have also been used to assess the maturation of coals, source rock bitumens and oils. A variety of aromatic maturity parameters have been proposed on the basis of ratios of the relative concentrations of more thermally stable isomers to less stable ones [19,20]. Phenanthrene maturity parameters are based on the greater stability of 3-MP and 2-MP compared to 9-MP and 1-MP [19]. The mathylphenanthrene index (MPI) proposed by Radke is a widely used molecular maturity parameter [19]. This parameter depends on the relative stability of the isomers. Changes in the relative abundances of naphthalenes and their substituents have also been used to obtain information about thermal maturity of sediments [21–23].

Organic geochemical studies indicated the potentials of some coals as petroleum source rocks within the Benue trough [24]. In a study conducted at a nearby Gongola basin, the occurrence of migrated oil absorbed in to a coaly facies was reported [25]. Since investigations have shown that some coals are good petroleum source rocks, the authors suggested that the migrated oil may have been sourced by some of the coals intercalated within the trough sediments [25].

This paper therefore, identifies some biomarkers and other organic compounds in the aliphatic and aromatic fractions of Chikila and Lamza coals and uses them to assess the organic matter source input, maturity and the hydrocarbon generative potentials of the coals.

2. Geological setting

The Benue trough is a rift basin in Central West Africa that extends northeast-southwest for about 800 km in length and 150-km in width (Fig. 1). The trough contains about 6000 m of Cretaceous–Tertiary sediments, including those predating the middle Santonian which were

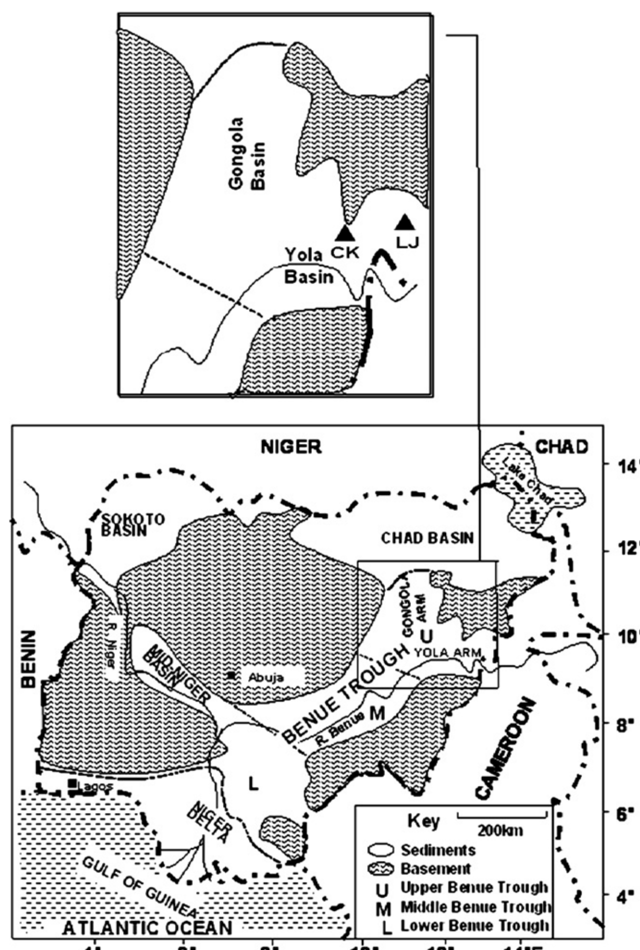

Fig. 1. Geological map of Nigeria showing Benue trough, sample locations and other sedimentary basins.