Carbon isotopes of Chlorobiaceae-derived aryl isoprenoids of the early Cambrian in the Tarim Basin: implications of the origins of the marine hydrocarbons

Jin Su[1,2*], Shuichang Zhang[1,2], Yu Wang[1,2], Xiaomei Wang[1,2], Bin Zhang[1,2], Kun He [1,2], Huajian Wang[1,2]

[1] Key Lab of Petroleum Geochemistry, China National Petroleum Corporation, China
[2] State Key Lab of Oil Recovery Elevation, Research Institute of Petroleum Exploration and Development, PetroChina, China
(*correspondence: sj41@petrochina.com.cn)

Introduction

The Cambrian period marks an important point in Earth's history. The Cambrian explosion is the most significant evolutionary event in the history of life on the planet, with an abrupt transition from primitive microbial forms to predominance of protists and taxonomically diverse multicellular organisms [1]. The Cambrian explosion is commonly described as a complex succession of cycles of extinction and radiations [2]. Generally the first stages of the Cambrian radiation of metazoan life and spreading of skeletal reef fauna occurred in the early Cambrian (Terreneuvian and Series 2). However, the carbon isotope and biomarker analyses of the black shale of the Yurtus Formation (>521 Ma) indicate that euxinic conditions prevailed in the palaeowater column during the early Cambrian stage in the Tarim Basin, northwest China.

Results

$\delta^{13}C_{carb}$ from the Yurtus Formation varies from -3.3‰ to 2.0‰ with a mean value of -1.2‰, while $\delta^{13}C_{org}$ exhibits abnormally negative values from -37.0‰ to -33.1‰, leading that the values of εTOC exceed 32 during this stage. Occurrences of εTOC>32 indicate significant inputs from sulfide-oxidizing or other chemoautotrophic bacteria [3] which resulted in depletion of $\delta^{13}C$ in the preserved biomass. The biomarkers of the Yurtus Formation are characterised by indicators of stratified water including abundant Gammacerane derived from tetrahymanol and abundant aryl isoprenoids (1-alkyl,2,3,6-trimethylbenzenes). The prevalence of abundant aryl isoprenoids that derived from green sulphur bacteria (Chlorobiaceae) using hydrogen sulfide as electron donor in anoxygenic photosynthesis [4] provides reliable evidence for photic zone euxinic during the early Cambrian in the Tarim Basin. So, the early Cambrian probably inherited the ecological conditions of the Ediacaran in the Tarim Basin. And, it is quite interesting that the Carbon isotope of bitumen "A" in the Yurtus Formation ranges from -30‰ to -28‰, which is much more heavy then that of the kerogen.

Discussion

Carbon isotopic value in oil is dependent upon the value of the kerogen in the source rock from which it was derived. The isotopic value of kerogen, in turn, depends on the types of organisms preserved and the values of its substrate. Therefore, carbon isotopic value is widely used as oil-source correlation parameter. In the case of the Palaeozoic oils in the Tarim Basin, the majority oils have their $\delta^{13}C$ values in the range of -31.0‰ and -33.0‰ with a few exceptions [5-6]. Because the TD2 oil has the heaviest $\delta^{13}C$ value and it is preserved in

the Cambrian strata, it was regarded as the typical end member for the Cambrian sourced oils in all studies. Only a few oils from wells TZ62(S), T904(O) and ZS1C (Cambrian) have similar bulk carbon isotopic values as the TD2 oil, which were regarded as of pure Cambrian-Lower Ordovician origin [7]. The most $\delta^{13}C$ depleted oil is automatically selected as the O_{2-3} sourced end member. The early selection with $\delta^{13}C$ around -35‰ was oil from well YM2. Recently, Li et al. (2015)[8] reported one more $\delta^{13}C$ depleted oil from Well YG2 with $\delta^{13}C$ value of -37‰, which was selected as new end member for the O_{2-3} sourced oil. Most other oils were considered as mixtures from both the O_{2-3} source rocks and the Cambrian-Lower Ordovician source rocks. Based on our present research, carbon isotopes of bulk organic matter can be influenced by many factors including carbon isotope fractionation during primary and secondary production, detrital organic carbon input, post depositional alteration through diagenesis / metamorphism, and hydrocarbon contamination. So, we tend to correlate oils with potential source rocks using aryl isoprenoids and their carbon isotopes.

An entire distribution of aryl isoprenoids has been discovered in a few oils form marine reservoirs of the Tarim Basin in our laboratory. The carbon isotopes of the aryl isoprenoids are almost all above -19‰ (Fig. 1). These geochemical evidence offer conclusive proof that the origin of the bulk hydrocarbons is from organic matter deposited in photic zone euxinic (PZE), which is the dominant sedimentary context in the early Cambrian of the Tarim Basin.

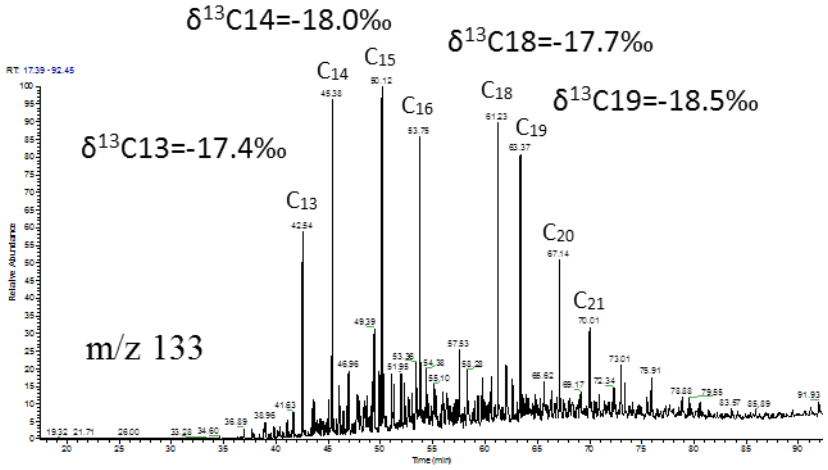

Figure 1 *Distribution and carbon isotopic characteristics of aryl isoprenoids of a typical oil (Well YM-2-14) form the Lower Cambrian source rock.*

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