The effect of redox conditions on carbon isotopes of alkanes from Type-I oil shale: A hydrous pyrolysis experiment

Q. FU[1*], C. CHANG[2], W. HU[2], Q. LIU[3] AND Q. MENG[3]

[1]Department of Earth and Atmospheric Sciences, University of Houston, Houston, TX 77204, USA (*correspondence: qfu5@central.uh.edu)
[2]School of Earth Sciences and Engineering, Nanjing University, Nanjing, Jiangsu 210023, China
[3]Petroleum Exploration and Production Research Institute, SINOPEC, Beijing 100083, China

Carbon isotopic composition of alkanes has been used extensively to evaluate their origins and thermal maturity of source rocks. The factors controlling the hydrocarbon formation and isotope fractionations include temperature, pressure, redox, and the presence of water. To elucidate the role of environmental redox conditions in carbon isotope values of hydrocarbons during petroleum generation, a series of hydrous pyrolysis experiments are conducted.

The source rock was obtained from the Huadian Basin in Jilin Province, northeast China. It is a shale layer in the Oil Shale Formation, which is Type-1 lacustrine deposit in the middle Eocene. Two sets of experiments were performed at 310°C for 4 days under hydrous conditions. The only difference between them is: one with dissolved H_2 gas in the concentration of 100 mmol/kg, while the other with He gas.

The products in gas phase include carbon dioxide, linear alkanes with the carbon number up to 5 (C_1-C_5), and the branched isomers of C_3 to C_5. The stable carbon isotopic value of straight-chained alkanes increases with the carbon number, following the trend for thermogenic hydrocarbons. However, C_1-C_3 alkanes from experiments with dissolved H_2 are depleted in ^{13}C than experiments with He. For example, the $\delta^{13}C$ value of methane in experiments with H_2 is -40.88 ± 0.1‰, which is 2.71‰ depleted than methane with He (-38.17 ± 0.1‰). This depletion becomes less with increasing carbon numbers. Butanes or pentanes from each experiment have similar carbon isotope values.

The carbon isotope depletion of light alkanes suggest that the predominant pathway of their formation, direct kerogen breakdown vs. bitumen decomposition, may be different under reducing conditions. The on-going isotope measurement of other products, including different groups in bitumen, are necessary to fully undestand carbon isotope fractionations in this process. It would facilitate identification of the pathways of oil/gas formation in different environments and effective use of carbon isotope values for exploration.