

Study on Oil-Source Correlation Methods of Severely Biodegraded Oils in the Liaodong Bay Sub-basin, Bohai Bay Basin, China

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Abstract

There are three organic-rich, oil-prone source rock intervals in Liaodong Bay sub-basin, Bohai Bay Basin: the third and the first members of the Eocene Shahejie Formation (Es_3 , Es_1) and the third member of the Oligocene Dongying Formation (Ed_3). Over 60% of the oils discovered in the Liaodong Bay sub-basin are heavy oil ($\rho \geq 0.934\text{g/cm}^3$, 20°C). Most heavy oils with burial depth ranging from 800m (2625ft) to 2000m (6562ft) are severely biodegraded as evidenced by the occurrence of 25-norhopanes and the consumption of n-alkanes. To recognize the origin of the biodegraded oils, biomarker characteristics of the three source rock intervals are concluded and several oil-source correlation methods are applied. The Es_3 source rock is dominated by semi-deep and deep lacustrine facies mudstone with the highest TOC contents (up to 8.88%) and Rock-Eval S2 values (up to 72.4 mg HC/g rock), and it has low C27 20R/C28 20R tri-aromatic steroid (TAS), high C28 20S/C27 20R TAS and 4-methyl-24-ethyl triaromatic sterane contents, indicating fresh to brackish water and abundant dinoflagellates Bohaidina and Parabohaidina paleoenvironment. The Es_1 source rock is saline lacustrine facies mudstone, oil shale and lime mudstone with relatively high TOC contents (up to 5.62%) and Rock-Eval S2 values (up to 31.1 mg HC/g rock), and it has high 4,23,24-trimethyl triaromatic dinosterane contents and low 4-methyl-24-ethyl triaromatic sterane contents. The Ed_3 source rock is semi-deep and deep lacustrine facies mudstone with relatively high TOC contents (up to 4.74%) and Rock-Eval S2 values (up to 30.6 mg HC/g rock), and it has low C28 20S/C27 20R TAS and high C27 20R/C28 20R TAS, indicating fresh water and suboxic or dysoxic

environments with substantial terrigenous organic matter input. The biodegradation has little effect on carbon isotope of whole oil. The whole oil carbon isotopes of Es source rocks are heavier than that of Ed source rocks. The C₂₈ 20S/C₂₇ 20R TAS, C₂₇ 20R/C₂₈ 20R TAS, 4-methyl triaromatic sterane homologues and carbon isotope of whole oil can be used to distinguish oil source of the severely biodegraded oils (oil biodegradation level ranges from 6 to 9 according to criteria by Peters and Moldowan, 2005) and source rocks deposited in different sedimentary environments, as they are seldom influenced by biodegradation. These biomarkers are successfully applied in the oil-source correlation of severely biodegraded oils in the Liaodong Bay sub-basin.