RECOGNITION AND QUANTIFICATION OF MIGRATED OILS IN LIQUID RICH SHALES BASED ON BULK PYROLYSIS AND MOLECULAR GEOCHEMICAL DATA

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In a restrictive source rock reservoir, such as those in rift basins, it is common that oils expelled from mature organic-rich laminae immerse into indigenous organic matter as a result of primary/secondary migration, which can cause anomalous Rock-Eval parameters. Data interpretation can be difficult as the Rock-Eval parameters do not follow the general pattern shown by un-affected samples. The direct use of the Rock-Eval parameters from affected samples without correction may cause problems in over-stating the hydrocarbon generation capacity and incorrect kerogen types. The use of the affected pyrogram for kerogen generation kinetics can lead to incorrect generation kinetic model, and in turn affect data interpretation and basin/petroleum system modeling results.

In the Qianjiang Formation, Jianghan Basin, central China, inter-salt liquid rich shale reservoir beds occur within thick salt layers. Based on petrographic analysis, these shales contain type I and type II1 organic matter, dominated by fluorescing amorphous kerogen. In thermally immature samples, oil-prone type I OM (hydrogen index (HI) = 700-850 mg HC/g TOC) were commonly observed based on Rock-Eval pyrolysis, and pyrolysis of the whole rocks produced mainly n-alkanes and n-alkenes and some thiophenic organo-sulphur compounds. The solvent extracts of organic-rich shale facies are dominated by short chain n-alkanes (C14-C18) with pronounced even-over-odd carbon number preference, whereas the reverse is true for the organic-lean facies that are dominated by long chain alkanes. This indicates that terrestrial input of organic material into the basin was dominant during those periods when thin organic lean muds and evaporites were deposited and that algal rich phytoplankton were dominant during the deposition of the inter-salt highly laminated organic-rich black shales. Grice et al. (1998) studied the distributions and stable carbon isotopic compositions of hydrocarbon biomarkers, and identified isorenieratane indicating the presence of Chlorobiaceae, and thus periods of euxinic conditions extended into the photic zone. The distributions of hydrocarbon biomarkers appear to indicate an initial step of sulphurization during early diagenesis and a later release of such compounds during early thermal maturation.

The isomeric distributions of steroid and hopanoid alkanes obtained from solvent extracts of these inter-salt liquid rich shale samples from wells drilled in the structurally uplifted Wangchang region and southern slope of the Banghu sag in the Jianghan Basin show much higher thermal maturity levels than those in the intra-salt thinly bedded shales, indicating that the migrated hydrocarbons were most likely derived from the more mature source rocks within the same stratigraphic unit. Due to the presence of thick halite beds at the top and bottom of each inter-salt cycle, expelled oils from effective source rocks in the oil generation window probably migrate up-dip along interconnected pores and /or bedding planes, and then accumulate in less mature source beds with larger pore spaces.

The presence of large amount of migrated oil in the source rock beds shows high S1/TOC (>105) and PI value (>0.3) with low T_{max}. From hydrocarbon pyrogram, the affected sample shows a high S1 peak with a retarded S1 as a transitional hump interfering with normal S2 curve. The estimated activation energy of the affected samples displays widespread energy distribution, particularly in the left side of low activation energies, reflecting the impact of a retarded S1 hump. All key Rock-Eval parameters associated with hydrocarbon generation potential are affected, overestimated S1, S2, subsequently PC and TOC, elevated PI and usually depressed T_{max}. Because peak temperature of the S2 curves are pulled down and the presence of retarded S1, the estimated activation energies show a dispersed distribution in the low activation energy side and resulting in unrealistic hydrocarbon generation history and a fake opportunistic picture of resource potential.

This paper reports methods based on kerogen kinetics for characterizing the impacts, estimating the severity and subsequently minimizing the effects by removal of the migrated components from the oil-stained samples through a numerical approach (Li *et al.*, 2018a; Chen *et al*., 2018). This study applies the numerical method proposed by Li *et al*. (2018b) for estimation of total oil yield in source rock as a tool to separate the migrated petroleum from that of self-generated in the source rock sample. The restored hydrocarbon pyrograms are then used for recalculation of relevant Rock-Eval parameters and proper construction of generation kinetic models. The proposed methods and work flow were applied to the source rock samples from the Qianjiang Formation, a confined source rock system imbedded in salt layers, where contamination from migrated hydrocarbons is common. An additional Rock-Eval dataset consisting of whole-rock samples and post-solvent extracted replicates was used to validate the methods. The validation results show that the proposed numerical approach is a cost-effective alternative to the traditional laboratory solution.

Recognition and quantitative estimation of migrated oils in liquid rich shales based on bulk pyrolysis and molecular geochemical data provide valuable insights into the nature and magnitude of hydrocarbon resources in a shale play. A clear understanding of the spatial relationship between the migrated hydrocarbon resource in shale fracture traps versus self-generated and self-reservoired in-situ hydrocarbon resource in a continuous shale play is vital for the development of a drilling and completion plan.

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