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Multi-stage hydrocarbon generation model of saline lacustrine source rocks: Insights from clay mineral-organic matter interactions and hydrous pyrolysis

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The multi-stage hydrocarbon generation of saline lacustrine source rocks is widespread but rarely reproduced in pyrolysis experiments, so the mechanism still needs further study. In order to investigate the influence of changes in mineral-organic matter (OM) interactions during mineral transformation on hydrocarbon generation, the smectite-rich immature source rocks deposited in saline lacustrine facies were selected to carry out hydrous pyrolysis. The geochemistry of source rocks indicates that, in addition to insoluble particulate OM (POM), there is abundant primary soluble OM produced by lipid accumulation of algae in saline lacustrine source rocks, which exist as mineral adsorbed soluble OM (MOM) due to the adsorption of clay minerals. Organic geochemical and mineralogical analyses of pyrolysates at different temperatures show that the evolution of OM is accompanied by the transformation of bulk and clay minerals, resulting in three stages of hydrocarbon generation. At 25-250°C, the slow smectite illitization causes the desorption of MOM to free soluble OM (SOM), thus resulting in the first reversal of isomerization ratio of biomarkers and the peak of low mature oils dominated by resins and asphaltenes. At 300-400°C, the degradation of POM promoted by clay minerals produces many polar NSO compounds, which are further converted to saturates and aromatics through decarboxylation and hydrocracking induced by solid acids of clay minerals, resulting in the second reversal of the isomerization ratio and the peak of mature oils. At 450-500°C, the high degree of illitization limits the ability of the Brønsted acid to supply inorganic hydrogen and transfer hydrogen from water. The SOM and residual POM undergo cross-linking and cracking reactions to produce gaseous hydrocarbons and coke at high temperatures, creating a peak of gaseous hydrocarbons dominated by methane and ethane. The multi-stage hydrocarbon generation of saline lacustrine source rocks can be attributed to the desorption of MOM, the decarboxylation and hydrocracking of POM induced by solid acids, and the cross-linking and cracking reactions of SOM and residual POM at high temperatures, respectively (Fig. 1). Clay mineral-OM interactions run through the three stages of hydrocarbon generation of saline lacustrine source rocks and provide new insights into the mechanism of hydrocarbon generation.

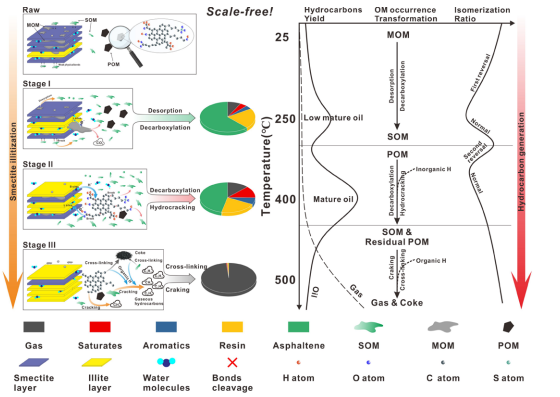

Fig. 1. The coevolution of smectite illitization and hydrocarbon generation in the saline lacustrine source rocks during hydrous pyrolysis.