

MAIN FACTORS INFLUENCING THE FORMATION OF THERMOGENIC SOLID BITUMEN

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Introduction

Solid bitumen preserved in paleo-oil reservoirs and migration pathways has experienced the entire process of thermal maturation, meaning that variations in its physical and chemical properties could provide insights into the evolution of the hosting reservoir. Therefore, the amount and distribution of solid bitumen could be used to delineate the range of paleo-reservoirs and further assess the scale of paleo-oil reservoirs and oil-cracked gas reservoirs (Wang et al., 2007; Xiong et al., 2016). However, the formation of solid bitumen during oil cracking is dynamic. Therefore, the use of indices based on solid bitumen under actual geological conditions is not simple, and a number of issues must be addressed, e.g. thermal alteration, oil composition within a reservoir, secondary alteration, and tectonic activities.

This study investigated the formation of thermogenic solid bitumen and the effects of oil composition and reservoir environment. Seven series of gold-tube pyrolysis experiments were conducted: three series of anhydrous pyrolysis experiments were performed at 50 MPa on three main group fractions (i.e., saturated, aromatic, and resin+asphaltene) of crude oil to evaluate the effect of oil composition on the formation of solid bitumen during cracking; the other four tested the reservoir environment by comparing the effects of the presence or absence of water and three different pressures (25, 75, and 100 MPa).

Results

The solid bitumen generation curves of the different group fractions are obviously different. For example, solid bitumen from saturated and aromatic fractions emerges mainly in wet gas-generation stage and dry gas-generation stage of oil cracking (saturated fraction: 1.5%–4.5% EasyRo; aromatic fraction: 1.5%–3.5% EasyRo), and the maximum yields of these fractions are 45.9% and 58.6%, respectively. In contrast, solid bitumen sourced from the resin+asphaltene fraction is generated mainly in the oil-generation stage and the condensate-generation stage (0.8%–1.5% EasyRo), and its maximum yield is 60.6%. From the composition of the present oil and the solid bitumen yield curves of the different fractions, the solid bitumen yield of the whole oil at a certain maturity level can be calculated from the curves in Fig. 1. The calculated curves for solid bitumen yield (Fig. 1) show that the content of resin and asphaltene fractions in oil controls the yield of solid bitumen in the main oil-generation stage (~0.5%–1.5% EasyRo), while the content of saturated and aromatic fractions governs the formation of solid bitumen at >1.5% EasyRo. The calculated maximum yield of solid bitumen reaches 45.7% of the original mass of the oil at 4.5% EasyRo. Approximately 52% of the maximum yield is generated from the saturated fraction, 22% from the aromatic fraction, and 26% from the resin+asphaltene fraction.

In highly overmature regions, the $\delta^{13}\text{C}$ values of methane and solid bitumen are useful indicators of the origin and source of natural gases. The result shows that methane generated from all fractions is depleted in ^{13}C relative to its precursors. In contrast, solid bitumen

generated by the different components in crude oil is relatively enriched in ^{13}C compared with the initial reactants. It has largely stable $\delta^{13}\text{C}$ values ($-31.5\text{‰} \pm 0.5\text{‰}$) during the main formation stage.

The production of solid bitumen does not vary greatly under different conditions (hydrous versus anhydrous and at different pressures), all yield curves follow similar trends, i.e., solid bitumen first forms at EasyRo $\sim 1.5\%$, rapidly increases between 2.0% and 3.5% EasyRo, and then slowly increases up to a maximum at 4.0% EasyRo.

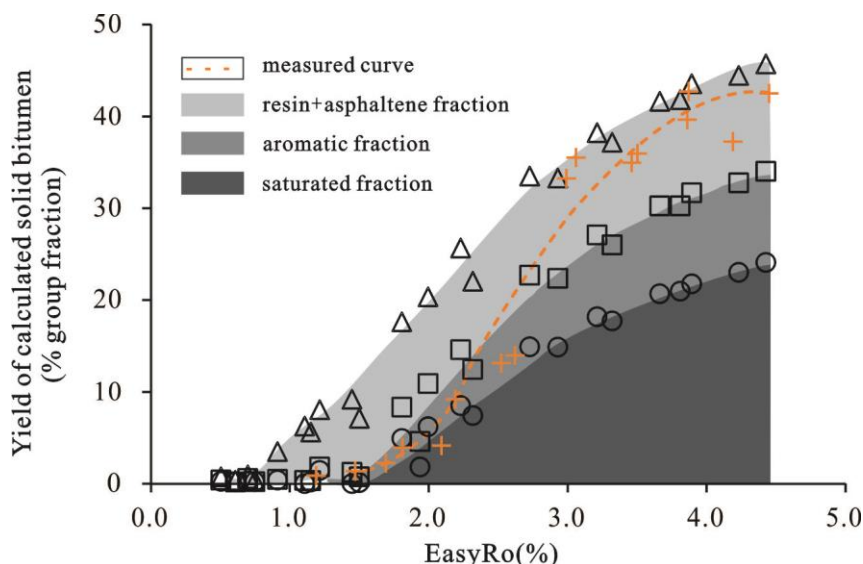


Figure 1 Measured and calculated yield curves of solid bitumen generated during oil cracking. The measured data are from Xiong et al. (2016).

Conclusions

- (1) Different fractions in oil have distinct capacities of solid bitumen generation and different main stages of formation. These results indicate that oil composition is a critical factor controlling the formation and yield of solid bitumen during oil cracking.
- (2) The $\delta^{13}\text{C}$ values of solid bitumen generated by different fractions of crude oil are relatively constant during thermal maturation. Therefore, the $\delta^{13}\text{C}$ value of solid bitumen preserved in paleo-oil reservoirs can be used to identify its source rock.
- (3) Water and pressure in reservoirs appear to have no remarkable effect on the formation of solid bitumen.

References

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