Accessibility and mobility of hydrocarbons in lacustrine shale: Solvent flow-through extraction experiments on Eocene oil shales from Bohai Bay Basin

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Abstract

In order to examine the mobility of hydrocarbons in a lacustrine shale oil system, three cylindrical core plugs from the Eocene Shahejie Formation lacustrine shale oil system in the Jiyang Depression were sequentially extracted with dichloromethane (DCM) in flow-through experiments under controlled stress conditions in a tri-axial flow cell (Fig.1). Orientations of the three sample plugs were perpendicular to bedding (#1) and parallel to bedding (#2 and #3) (Fig.2). Post-experiment Micro-CT analysis confirmed three different flow patterns: Cross bedding flow (#1), minor bedding-parallel flow (#2), and extensive bedding-parallel flow along open fractures (#3) (Fig. 3). Extraction times were 28 days, 7 days and 3 days, for samples #1, #2 and #3, respectively. Sequential series of extracts from the samples were analyzed using gas chromatography. For comparison, hydrocarbon compositions also were determined on bulk extracts of powdered original sister-sample material and the residues after flow-through experiments.

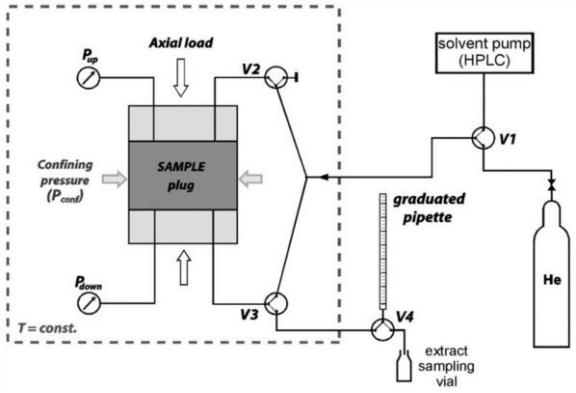

Fig. 1 Schematic diagram of experimental setup for sequential extraction under controlled stress (c.f. Mohnhoff et al., 2016)

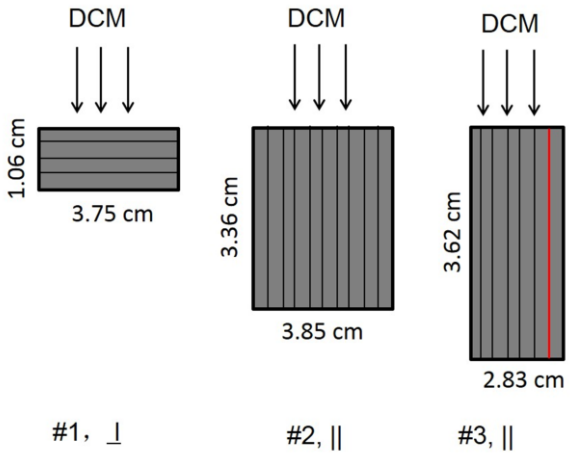

Fig. 2 Schematic diagram of the three cylindrical plug samples.

The mobilities of hydrocarbons are controlled by the flow direction and fracture intensity and orientations. For sample #1, DCM flow-through extraction yielded mostly hydrocarbons associated with matrix kerogen. This flow-extracted bitumen was found to be much heavier than that extracted from the other two samples, and to have a lower mobility. The hydrocarbons extracted from the sample #2 were the lightest. For sample #3, containing micro-fractures along the bedding planes, the

extraction process was apparently very effective, not only dissolving HC from the fractures but also some HC from the kerogen.

The characteristic hydrocarbon compositions of the samples were essentially retained in all extracts, although lighter hydrocarbons (<C19) were extracted somewhat preferentially (Fig. 4). After the flow-through experiments the Rock-Eval S1 values had decreased by 81%, 56% and 84%, respectively, for all three samples, indicating that the hydrocarbons were extracted to different extents during the flow-through tests. Additionally, the Rock-Eval S2 values decreased by 29%, 0.4%, and 16%, for the three samples, respectively, showing that the flow-through tests on two of the samples also extracted significant amounts of organic material commonly interpreted as “heavy-hydrocarbons”. The free hydrocarbons in micro-fractures, especially fractures along the bedding, could be very important for shale oil mobilization and the intervals with well-developed laminae provide horizontal fracturing intervals that are most favorable.

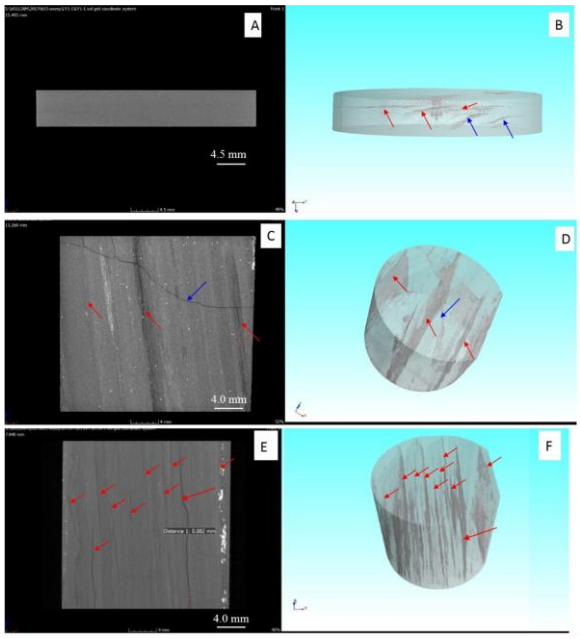

Fig. 1 Micro-CT scans of samples #1 (A, B), #2 (C, D) and #3 (E, F) after solvent flow-through experiments.

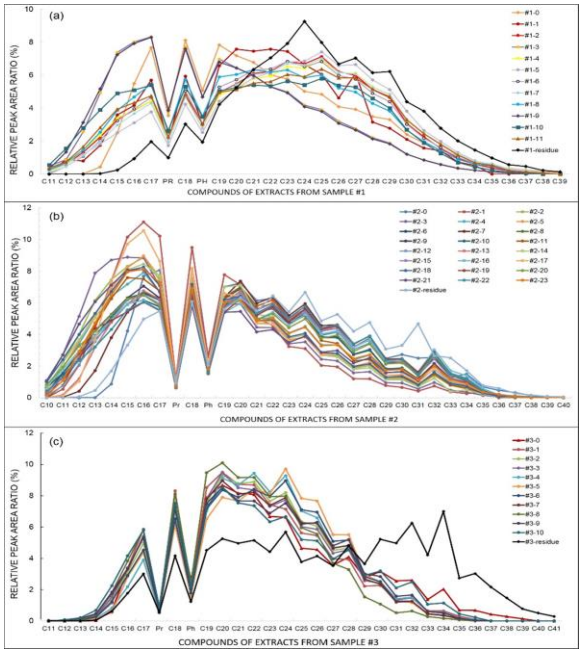

Fig. 2 The relative peak area ratio composition of solvent flow-through extracts of samples #1 (a), #2 (b) and #3 (c).

References

Mohnhoff, D., Littke, R., Krooss, B., Weniger, P., 2016. Flow-through extraction of oil and gas shales under controlled stress using organic solvents: Implications for organic matter-related porosity and permeability changes with thermal maturity. Int. J. Coal Geol. 157, 84–99.