GEOLOGICAL SIGNIFICANCE OF SOLID BITUMEN PRESERVED WITHIN PHOSPHOROUS CONCRETIONS FROM THE LOWER CAMBRIAN NIUTITANG FORMATION, UPPER YANGTZE REGION

Lipeng Yao[1], Ningning Zhong[1], Imran Khan[1] Jiayi Ai[1], Yu Zhang[1]

State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum Beijing

Introduction

Solid bitumen, formed as a result of the transformation of the primary organic matter, has important geological significance within both source and reservoir rocks (Jacob, 1985). Presence of solid bitumen within a rock succession is diagnostic of hydrocarbon generation, migration, and accumulation (Lomando, 1992). The geochemical characteristics of solid bitumen (i.e. biomarkers, stable isotopes, and trace element abundances), are widely used to determine the origin and source of solid bitumen (Curiale, 1986; Parnell, 1992). Within vitrinite-free rocks, optical properties of solid bitumen are used as an indicator for the thermal maturity of the host rocks (Bernard, 1993; Jacob, 1989; Landis and Castaño, 1995; Schoenherr et al., 2007)

Solid bitumen is widely distributed in Sinian-lower Paleozoic carbonate reservoirs in the upper Yangtze region but has not been reported from the Niutitang Formation. Based upon a comparison of solid bitumen in these overlying and underlying hydrocarbon reservoir, Niutitang Formation of lower Paleozoic is thought to be the main source rock. However, the origin of solid bitumen still remains controversial for two reasons. Firstly, the absence of solid bitumen in the Niutitang Formation has proved that the previous studies are based mostly on circumstantial evidence. Secondly, extracting effective geochemical information from source rock and solid asphalt in high evolution stage is difficult. Non-availability of reliable geothermal indicators (e.g. vitrinite and reservoir solid bitumen) and non-reliability of geochemical parameters upon the high-maturation stage, also resulted in controversies regarding the maturations within Niutitang Formation. It is difficult to distinguish whether the organic matter is primary or secondary component in high evolution stage(Mastalerz et al., 2018).

For the first time, the presence of solid bitumen in phosphorous concretions distributed at the bottom of Niutitang Formation has been reported. The organic petrological and geochemical characterization of these solid bitumen has been done on the bases of their optical properties, organic element composition, carbon isotope composition and trace (rare earth) elements composition.

Results

The presence of solid bitumen in phosphorous concretions distributed at the bottom of Niutitang Formation was generating from source rock Niutitang Formation and shows a short distance migration and preservation within phosphorous concretions. The solid bitumen and the source rock have encountered the same thermal evolution. Organic petrographic results of these solid bitumen of Niutitang Formation shows a high random reflectivity (mean 4.20%). Scanning electron microscopy (SEM) of these solid bitumen and organic matter fiied in the pores within source rock reveals the presence of a large concentration of nano-scale pores, resulted from the contribution of the natural gas reservoir. Solid bitumen also shows a high

organic carbon content up to 85.6%. The characteristics of H/C and O/C atomic ratios indicate that the solid bitumen has a high degree of carbonation. The carbon isotope value of the solid bitumen is -33.6‰ which are similar to the carbon isotope value of the black shale in the Niutitang Formation i.e. -33.4‰, thus providing a clear inheritance relationship between the solid bitumen and the source rock. Trace elements analysis of solid bitumen shows that it is enriched in Ba, V, and Ni. The trace elements distribution pattern and PAAS normalized plots of rare earth element concentrations also provide the same inheritance relationship between the source rock of Niutitang Formation and solid bitumen in phosphorous concretions.

Conclusions

The mode of occurrence of solid bitumen and similarity in geochemical characteristics to that of Niutitang Formation proves an in-situ origin of solid bitumen. The current studies reported the in-situ origin of solid bitumen for the first time and show that it has undergone the same thermal evolution history as the source rock. The mean reflectance value of 4.20%, indicating that the Niutitang Formation is currently in over-mature stage. The presence of nano-scale pores within the solid bitumen and organic matter filled in the pores within source rock combined with the optical characteristics, indicates that the pore-rich organic matter is residual solid bitumen in source rock.The characteristics of organic petrology, stable carbon isotope and trace elements of solid bitumen within Niutitang Formation are revealed for the first time. These characteristics can be used as the comparison standard for solid bitumen in other strata within Upper Yangtze area.

References

Bernard, 1993. Standardization of Solid Bitumen Reflectance to Vitrinite in Some Paleozoic Sequences of Canada. Energy Sources, 15(2): 269-287.

Curiale, J.A., 1986. Origin of solid bitumens, with emphasis on biological marker results.Org. Geochem. 10, 559–580.

Jacob, H., 1985. Dispersed solid bitumens as an indicator for migration and maturity in prospecting for oil and gas. Erdöl und Kohle-Erdgas-Petrochemie 38 (8) (365 p)

Jacob, H., 1989. Classification, structure, genesis and practical importance of natural solid oil bitumen ("migrabitumen"). International Journal of Coal Geology, 11(1): 65-79.

Landis, C.R., Castaño, J.R., 1995. Maturation and bulk chemical properties of a suite of solid hydrocarbons. Organic Geochemistry, 22(1): 137-149.

Lomando, A.J., 1992. The influence of solid reservoir bitumen on reservoir quality. Am.Assoc. Pet. Geol. Bull. 76, 1137–1152

Parnell, J., 1992. Metal enrichment in bitumens from Carboniferous-hosted ore deposits of the British Isles. Chem. Geol. 99, 115–124

Schoenherr, J., Littke, R., Urai Janos, L., Kukla Peter, A., Rawahi, Z., 2007. Polyphase thermal evolution in the Infra-Cambrian Ara Group (South Oman Salt Basin) as deduced, by maturity of solid reservoir bitumen. Organic Geochemistry, 38(8): 1293-1318.

Mastalerz, M., Drobniak, A., Stankiewicz, A.B., 2018. Origin, properties, and implications of solid bitumen in source-rock reservoirs: A review. International Journal of Coal Geology, 195: 14-36.