Significance of source rock heterogeneities: A case study of Mesoproterozoic Xiamaling Formation shale in North China

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High quality source rocks are generally laminated organic-rich shale and organic-poor siliceous rock or carbonate. Further research shows that the heterogeneity of source rocks, rather than chaotic, are regular. But few researchers have targeted the quantification and hydrocarbon accumulation significance of source rock heterogeneity at different time scales, especially in the unconventional hydrocarbon exploration.

Here, we take Mesoproterozoic Xiamaling Formation as an example, to study the heterogeneities at different scales and hydrocarbon microscopic occurrence, based on observation of outcrops and observation with microscopy, and geochemical analysis. The large scale heterogeneities of source rocks are considered to be controlled by the plate movement and paleo-latitude location, while the micro-scale might be controlled by climate changes driven by the astronomical orbit. The constant existence of heterogeneities includes the differences of organic matter, debris sources and porosities. Geochemical analysis also reveals that source rock heterogeneity lead to hydrocarbon migration from the black shale tends to adjacent siliceous rock, which was also proved by FIB-SEM observation.

The alternating shale and clastic rock or carbonate layers, with strong heterogeneity can act as excellent source-reservoir combinations. Organic-matter-rich layers can generate massive hydrocarbons, the pores and fractures in inter-layers can provide space for hydrocarbon accumulation and paths for hydrocarbon migration, and the alternating siliceous rock or carbonate layers are effective reservoirs responsible for hydrocarbon accumulation. This kind of heterogeneous source rocks provides excellent source-reservoir assemblage of oil and gas generation, expulsion and accumulation, and new reference indexes for the economic evaluation of unconventional oil and gas.

Thus, quantitative evaluation of source rock heterogeneity and study on interlayer modification would definitely beneficial for petroleum resource assessment and exploration and development of unconventional oil and gas. More studies should be carried out on the source rock heterogeneity and interlayer modification.