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Multi-sphere driving model for the formation and distribution of Cambrian hydrocarbon source rocks in the Tarim Basin

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The Cambrian source rocks are the most important hydrocarbon source rocks in the Tarim Basin, and their formation and distribution are crucial for petroleum exploration. From the perspective of multi-sphere interactions and Earth system evolution, this study proposes a multi-sphere-driven model for the formation and evolution of Cambrian source rocks, based on analyses of supercontinent reorganization, atmosphere–ocean evolution, and regional tectono-sedimentary variations. During the Cambrian, the breakup of Rodinia and the assembly of Gondwana controlled the tectonic activity, paleogeographic shifts, and climate evolution of the Tarim Block. In the Early Cambrian, Tarim drifted to the equatorial Intertropical Convergence Zone (ITCZ), where warm and humid conditions promoted the flourishing of plankton and benthic algae, providing the material basis for organic enrichment. The Basal Cambrian Carbon Isotope Excursion (BACE, ~540 Ma) shows a negative δ^{13}Ccarb anomaly exceeding 5‰, coinciding with global shelf anoxia and massive organic carbon burial, which led to the formation of the Lower Cambrian Yuertusi Formation source rocks. These are dominated by siliceous mudstones and black shales with TOC of 2 wt.%–16 wt.% and are distributed as “thin in the west and thick in the east”. The Steptoean Positive Carbon Isotope Excursion (SPICE, ~497–494 Ma) displays a positive δ^{13}Ccarb shift of 4‰–6‰, accompanied by global oceanic anoxia and organic burial, corresponding to the Upper Cambrian source rocks. Geochemical and petroleum data suggest that these are mainly distributed in the northeastern Manjiaer Sag, Tazhong No. 10 Structural Belt, and southeastern Maigaiti Slope. Tectonic events and sedimentary differentiation resulted in the distribution pattern “favorable in the north, poor in the south” and “high-quality thin in the west, thick and homogeneous in the east”. This hierarchical coupling model of “supercontinent assembly and breakup–climate change–tectono-sedimentary environment–source rock development” provides a new perspective for understanding and predicting Cambrian source rocks in other basins worldwide.