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Climate and Environmental Controls on Organic Matter Production and Preservation in Biogenic Gas Source Rocks

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Organic matter (OM) in source rocks plays a critical role in biogenic gas formation, as it serves as the fundamental carbon substrate for microbial metabolic processes. The Hetao Basin in northern China is dominated by Quaternary Pleistocene fluvial-lacustrine sediments, with biogenic gas widely developed throughout the region. It lies at the northern margin of the East Asian summer monsoon, within an arid to semi-arid transition zone. The basin' s two major depressions, Linhe and Huhe, have experienced distinct paleoenvironmental conditions, resulting in differences in OM accumulation, preservation, and biogenic gas distribution. To investigate climate and environmental controls on OM burial, we analyzed geochemical proxies (TOC, TN, XRF, trace elements, $\delta^{13}C$ of organic carbon and n-alkanes) from two wells: HT-T01 (Huhe Depression) and HT-T02 (Linhe Depression). Additionally, dating data from optically stimulated luminescence (OSL) and electron spin resonance (ESR) were used to establish an astronomical timescale. The results indicate that the Huhe Depression, strongly influenced by the East Asian summer monsoon, experienced higher precipitation and deeper lacustrine conditions, creating a stable, long-term anoxic environment that facilitated OM enrichment and preservation. Consequently, the source rocks in this region are thicker, leading to higher biogenic gas yields. In contrast, the Linhe Depression, located closer to the influence of the westerlies, was subjected to stronger windblown dust input, which diluted OM. Additionally, high sedimentary dynamics and increased oxidation hindered OM preservation, resulting in thinner source rock layers and lower biogenic gas production. This study provides new insights into the interplay between climate, sedimentary environments, and organic matter burial, highlighting their role in regulating the carbon cycle and biogenic gas formation in lacustrine systems.