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Petrology and geochemistry of seep carbonate on the northern continental slope of the South China Sea: A review

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Gas hydrate and cold methane seeps are common on the northern continental slope of the South China Sea, where seep carbonates were sampled from over forty sites. These carbonates consist of concretions, nodules, chimneys, fragments, and massive blocks. Mineralogically, the carbonates are dominated by aragonite and high-Mg calcite. However, a certain amount levels of dolomite are present in some samples. The carbon isotopic compositions (δ^{13}C) of the carbonates are variable and the ranges are from -29.6 to -13.3‰ (PDB) in Xisha Trough samples, from -36.1 to -18.2‰ in southwestern Dongsha samples, from -40.4 to -38.7‰ in Shenhu samples, from -61.4 to -32.8‰ in northeastern Dongsha samples, and from -57.6 to -35.7‰ in southwestern Taiwan samples. The δ^{13}C values indicate complex carbon sources that include ^{13}C-depleted biogenic methane and thermogenic methane. A similarly large variability in δ^{18}O values (0.4 to 7.5‰ PDB) demonstrates the geochemical complexity of the slope, with some samples pointing toward to ^{18}O-enriched oxygen source that is possibly related to advection of ^{18}O-enriched formation water and/or to the destabilization of locally abundant gas hydrate. The dynamic seep system of the South China Sea is also indicated by rare earth element (REE) patterns of the carbonates. The shale-normalized REE pattern of the carbonates from Jiulong methane reef of northeastern Dongsha and Shenhu area show both positive and negative Cerium anomalies, suggesting that the redox conditions changed significantly. A considerable range of mineralogical, isotopic and elemental variations in seep carbonate composition was noted across the slope and even within individual study sites, suggesting that local controls on fluid and gas flux, types of seep hydrocarbons, the presence gas hydrate in the near-surface sediment, and chemosynthetic communities, as well as the temporal evolution of the local hydrocarbon reservoir, all may play an important role in determining the petrology and geochemistry of the seep carbonates. Besides inorganic geochemical approach, the organic method is also a promising tool to better assess the variability and diversity of past fluid and gas expulsion at seeps.

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