Deciphering the Genesis of Methane-Derived Authigenic Carbonates in the Enigmatic Makassar Strait, Indonesia: A Multiproxy Approach

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Abstract

Methane-derived authigenic carbonates (MDAC) have garnered significant interdisciplinary attention due to their potential impact on the global marine carbon cycle and future energy sources. Despite their importance, the origin and formation of MDAC, especially in ancient subsurface environments, remain contentious. The Makassar Strait basin in Indonesia, characterized by geological complexity, presents an ideal yet unexplored setting for MDAC study. In this pioneering investigation, we conducted a multi-proxy analysis integrating well logs, petrography, mineralogy, and stable isotopes to unravel the origin and formation mechanisms of subsurface MDAC in well XS-1. Gas chimneys in the subsurface and nearby biogenic and gas hydrate accumulations hinted at potential associations with either biogenic or thermogenic hydrocarbon plays. Petrographic and mineralogical analyses unveiled unique features, such as clotted peloidal micrite and amorphous silica precipitation, within a specific interval in the Plio-Pleistocene sedimentary sequence (2932-3030 mTVDSS). These characteristics were linked to microbial activity during carbonate mineral precipitation stimulated by Anaerobic Oxidation Methane (AOM) processes, supported by an anomalous negative excursion in δ13C values from -1‰VPDB to -27.5‰VPDB within the clotted peloidal micrite zone. Building on these findings, our hypothesis suggests that MDAC formation in this basin may be tied to either the adjacent migration of parent thermogenic methane from deeper strata or isotopically fractionated biogenic methane influenced by later methane-hydrate generation. These insights emphasize the potential direct linkage between seafloor seepage and subsurface fluid flow, highlighting the utility of carbon isotopes for basin-wide correlation in geologically complex settings with methane carbonates.