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Massive carbonate cemented structures related to hydrocarbon-seepage (Lower Eocene, Bulgaria): morphology and stable isotope geochemistry linked to seepage mode

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The Pobiti Kamani area (Varna, Bulgaria) envelopes dispersed outcrops of massive carbonate-cemented (1) chimneys (up to 1.5m diameter, 8m high), (2) "pisoid"-covered structures and (3) horizontal interbeds. Field observations, petrography and stable isotope geochemistry from five locations revealed that varying seepage rates of a single, warm (deep-seated?) hydrocarbon-bearin fluid, probably ascending along actieve faults, controlled the macroscopic shape of the structures formed and their stable isotopic geochemical signature. Slow seepage allowed methane to oxidize within the sediment under ambient seafloor conditions (δ^{18}O = -1 $\pm$0.5‰ V-PDB), explaining chimneys'depleted δ^{13}C values as low as -43‰. Increasing seepage rates caused methane to emanate into the water column (δ^{13}C = up to -8‰) and raised calcite precipitation temperatures with δ^{18}O values down to -8‰ V-PDB, suggesting the system was not a true "cold" seep. Calcite-cemented conduits with concentric zoned isotopic signatures, thus developed and upward migrating fluids also affected cementation of horizontal interbeds. An even higher-energy seepage regime likely controlled the formation of "pisoid"-like structures (diameters up to 4 cm), in which sediment was whirled up and cemented. In the proposed seepage-model, this would correspond to the involvement of warm fluids near the seafloor, which can indeed explain the strongly depleted δ^{18}O ratios of "pisoid" calcite cements, down to -13‰ V-PDB.