



Miocene cold seeps and their plumbing systems, New Zealand: Ancient analogues for the modern Hikurangi Margin seep system?

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Discrete occurrences of ancient seep carbonates crop out in thick deep-water mudrocks of Miocene age in the East Coast Basin forearc of North Island, New Zealand. The seep carbonates form two kinds of deposits: limestones and concretions. The limestones occur as scattered pods and lenses measuring a few to several hundred metres across and up to 5-15 m thick. They contain chemosynthesis-based paleo-communities (e.g. worm tubes, bathymodioline mussels, and vesicomyid, lucinid and thyasirid bivalves), there are some significant spatial differences in facies (e.g. in situ, current reworked, brecciated, slumped, debris flow, hardground), and they include development of digitate thrombolites of clotted microbial micrite encased in thick, isopachous horizons and botryoids of aragonite. The moderately to strongly depleted carbon isotopic signatures record oxidized methane as a carbon source. The limestones are inferred to have been constructed at localised sites of seafloor methane seepage, typically at slope water depths. The concretions are generally tubular in shape and cemented by calcite, dolomite, or mixed calcite-dolomite. The tubular concretions are morphologically variable, and have central conduits that may be either empty or (partly) filled by sediment and/or multiple generations of cement. The concretions range in diameter from a few centimetres to several metres, while their visible length is dependent

on outcrop size and perspective and can be up to many metres. Carbon isotopic signatures indicate both a thermogenic and microbial methane source, and trends can also be identified based on morphology and mineralogy. We infer the tubular concretions mark the sub-surface migration pathways of former methane seepage within the host mudrocks. The widespread geographic distribution and diverse characteristics of the concretions create the most comprehensive database of seep plumbing to date. The Miocene seep limestones and their concretionary plumbing networks in the onland East Coast Basin may afford ancient analogues of the modern offshore methanotrophic seep-carbonate system and associated gas hydrates along the Hikurangi Margin off North Island. In particular, the ancient seep systems provide some spatial and temporal insight into the nature and evolution of fluid flow in sedimentary basins, which could assist in the evaluation of future hydrocarbon resources and any potential hazards associated with their recovery.