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Gas seeps and methane in the water column at the Makran accretionary wedge

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In order to investigate the fluid and gas migration in an active continental margin with high organic carbon and gas contents we monitored the sediment surface and the water column above the Makran accretionary wedge off Pakistan. In April 1998, SONNE cruise SO-130 detected areas of active gas seeps at the front of the Makran accretionary complex at different water depths. Methane- and hydrogen sulfide-rich "cold seeps", were discovered along the accretion between 250 to 800 m water depth and a single location at 2500 m water depth (Fig. 1). Cm- to m-scale pockmarks and gas seepage structures were identified. Isotopically light methane of bacterial origin is emanating from the seeps that is partly oxidized to HCO_3^- in the sedimentary sulfate reduction zone. This results in the precipitation of irregular dark-gray to black crusts of authigenic carbonates, mainly cryptocrystalline Mg-calcite and Ca-rich dolomite, near the sediment/water interface. The authigenic carbonates are extremely depleted in ^{13}C. This suggests that they were derived from bacterial methane that was oxidized through bacterial sulfate reduction.

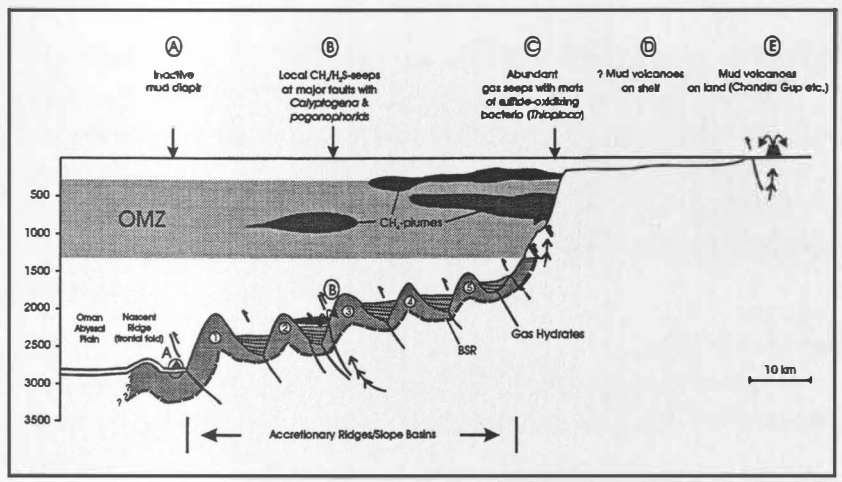

Fig. 1: Schematic cross-section of the Makran accretionary margin with locations of gas seeps, distribution of gas plumes in the water column and mud diapirs.

Methane concentrations in the water column above the seep vary between 290 and 500 nl/l and carbon isotope ratios of methane in ocean waters are shifted by +10‰ to +20‰ compared to those of the seep, pointing to severe methane oxidation. Plumes of bacterial methane, indicated by concentration changes and shifts in the carbon isotopic composition, occurs at this site in the oxygen-minimum zone of the Arabian Sea. Vertical and horizontal concentration changes and variations of carbon isotope ratios suggest that methane seeping from the sediments of the Makran accretionary complex is largely oxidized within the "intermediate water" below the salinity unconformaty. Microbiological investigations show that bacterial methane oxidation rates in the ocean water reach values of up to 0.09 nmol/l per day. Methane of the plumes of the "intermediate water" does not reach the atmosphere. High methane concentrations (150 to 608 nl/l) in the oxygen-rich surface waters of the NE Arabian Sea and carbon isotope ratios of methane point to new generation through bacterial processes. Carbon isotope ratios of co-existing dissolved methane and carbon dioxide point to fermentation as a pathway for bacterial methane generation in the surface waters. These surface waters are enriched in methane and resemble a source for atmospheric methane. Methane fluxes between surface waters and atmosphere can be high and may reach values up to 288.5 $kg \cdot km^{-2} \cdot yr^{-1}$ in the NE Arabian Sea at wind speeds of about 6 $m \cdot s^{-1}$.