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Methane-related carbonates from mud volcanoes and pockmarks of the Nile deep-sea fan.

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During the NAUTINIL cruise (September-October 2003), nineteen submersible dives have been realized at subbottom depths between 3019 m and 1130 m in selected sites of the Nile deep-sea fan. Three different morphological structures have been studied in the western, central and eastern part of the Nile deep-sea area (caldera where brines are seeping along the flanks, pockmarks and an active mud volcano). Benthic macrofauna (mainly vestimentiferan worms, rarely small bivalves) and microbial mats are associated with the cold seeps. Carbonate crusts cover irregularly the sea floor at the central most active part of mud volcanoes ; and dispersed concretions are contained in the topmost sediments. The strong H_2S smell of the sediments from venting areas characterizes an active sulfate-reduction. Mineralogical analysis of the carbonate crusts and of the concretions from the sediments indicate that aragonite and high-Mg calcite are predominant ; they may be associated with low-Mg calcite and dolomite as minor components. Scanning Electron Microscope observations show that aragonite crystals occur as elongated acicular crystals, generally infilling bioclasts or voids. Dolomite crystals are less frequently observed and often associated with aragonite needles. Other authigenic minerals (barite, pyrite, gypsum) have been found in the crusts as well as in the microconcretions. The stable carbon and oxygen isotopic analysis of carbonate crusts and concretions have been realized to identify the different sources of carbon and oxygen. The isotopic compositions display very large variations (-2.67 $< \quad \delta^{18}$O ‰ PDB < 3.87 ; -37.97 $< \quad \delta^{13}$C ‰ PDB < 2.96). The large ^{13}C depletions indicate that methane was the main source of carbone ; this methane was oxidized as CO_2 either through anaerobic oxidation coupled with bacterial sulfate reduction within the sediment or via bacterial aerobic oxidation at the sea floor. In a few

carbonate crusts, seawater-derived carbon was the main source of carbon. Mineralogical and geochemical analysis have been made in a vertical transect of a decimeter-thick carbonate crust from a pockmark. Aragonite content decreases with depth while high-Mg calcite and dolomite contents increase with depth. The decrease of δ^{13}C with depth indicates the predominant source of methane-derived carbon. The δ^{18}O values increase slightly with depth due to the increase of ^{18}O-rich dolomite content.