

Geophysical characterization and functioning of highly active fluid escape structures derived from near bottom multi-scale investigations, offshore northern Egypt

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Fluid-escape structures on the Nile Deep Sea Fan, including large mud volcanoes located above gas chimneys, pockmarks and carbonate crust structures, were investigated during several MEDIFLUX expeditions. Firstly identified from surface echo-sounding data, recent *in-situ* geological observations, geochemical sampling and analyses, and new high resolution geophysical records provide further constraints on the type, distribution, intensity and functioning of these structures. The active seeps were successively surveyed with the *Nautilie* submersible, the *EdgeTech DTS-1* high resolution deep towed side scan sonar (75 kHz) coupled with a 2-8 kHz chirp sediment sounder, and with the *Aster^X* AUV equipped with a high resolution multibeam echosounder *Simrad EM2000* (200 kHz) and a fishery echosounder (70 kHz) to detect possible gas escapes in the water column.

The Central Nile Province seeps are characterized by an intense activity, principally dominated by hydrocarbon gas emissions, mostly composed of thermogenic methane. At the mud volcanoes, high methane concentrations in the water and sediments are associated with high thermal gradients (more than 40°C at 10 metres bsf). Additionally, several gas plumes were detected acoustically in the water column from side scan data above Isis and Amon mud volcanoes, as well as above numerous pockmark fields. Patches of highly reduced blackish sediments, mats of sulphide-oxidizing bacteria, and precipitates of authigenic carbonate were detected, indicative of anaerobic methane consumption. The chemosynthetic fauna was, however, not very abundant, inhibited most likely by the high and vigorous fluxes, and was associated mainly with carbonate-crust-covered seafloor (southwestern flank of Amon and especially in the Central Nile Province). Mud expulsions are not very common at present and were found limited to the most active emission centres of two mud volcanoes, where slow extrusion of mud occurs, responsible for the concentric compressional features, ridges and gullies that composed the surface of mud volcanoes.

Newly acquired bathymetric (<1m pixel) and acoustic maps image clearly morphologies and structures of sizes usually far below the resolution of most of the geo-acoustic tools operated in marine geosciences. Meter-scale fluid related structures, e.g. relief created by mud breccia extrusion at the centres of mud volcanoes, authigenic carbonate chimneys, small vertical offsets (<1m) of the seabed corresponding to fractured authigenic carbonate pavements and pockmarks can be easily identified. Seafloor mapping analysis combining multibeam data at different frequencies, high resolution backscatter imagery and detailed geological maps based on in situ observations provide accurate information on the distribution and activity of seep-related structures. Shallow depth subbottom sediment profiler records reveal wipe out and disturbed areas explained by ascending fluids. Acoustic mosaics and geological observations point to broad seafloor areas covered with carbonate crusts, more than previously inferred and thought. The amplitude of the acoustic backscatter presents spatial variability, which we relate to the type and intensity of present or past seepage activity, e.g. the presence of a variable distribution and thickness of carbonate crust pavements. Each of the mud volcanoes is fed principally by a main narrow channel, not exceeding a few tens of metres in diameter and located below the most elevated areas, most commonly in the centres of the structures. Lateral extent of ascending fluid channels in carbonate covered areas, as shown by wipe out dimensions, may reach a maximum of several tens of metres. The distribution of the mud volcanoes in the upper slope domain of the Central Nile Deep Sea Fan and associated seeps on and close to the mud volcanoes, together with their overall shape, are clearly controlled by the local and regional tectonics.