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Black Sea mud volcanoes and their relation to the search for methane gas hydrates and environmental security

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As of today, the number of known offshore mud volcanoes in the Black Sea is 68. The areas possessing the greatest abundance include the northern part of the Black Sea (Sorokin trough, Tuapsinskaya trough, Shatskiy arch) and the Kerch downfold (the area south of the Kerch peninsula). An intensive study of mud volcanoes has been performed in the course of on-shore and off-shore expeditions carried out by Ukrainian scientists since 1990. They brought to light new geological, geophysical, and geochemical data on the properties of mud volcanoes by (1) high resolution hydro-acoustic, seismic-acoustic, and gravity methods, (2) geothermal observations of the thermal regime of the water and uppermost sediments, (3) gravity core sampling of bottom deposits, (4) dredges and buckets, and (5) study of these samples by lithological, geochemical, paleontological, and biological methods.

Methane gas hydrates have been recovered in about 28 localities largely associated with mud volcanoes below 600-700 m water depth, which suggests their close genetic relationships. Age of the sediments hosting methane gas hydrates as well as their lithological properties (e.g., grain-size) vary significantly. Relatively coarse-grained sediments make better hydrate reservoirs than fine-grained sediments. The area of the Black Sea suitable for gas hydrate formation is estimated at 288,100 km^2, representing about 68% of the total Black Sea, or almost 91% of the deep-water basin; the volume of gas hydrates has been set at 4.8 km^3 corresponding to 0.1-110^{12} m^3 of free methane.

A peculiar morphological structure of the sea bottom—conical hills (anticlinals) with low geostatic pressure and subsidence in their central part—provide a target in the search for underwater mud volcanoes. Our data show that such structures are formed by mud breccia and rock debris that are brought to the surface by methane flows, which escape along tectonic ruptures from the deep part of the lithosphere located beneath a Mesozoic sediment cover. The amount of escaped methane is enormous. For example, the mud volcano “Yuzhmorgeologiya” ejects about 17.8 billion m^3 of breccia during one eruption, which requires trillions of cubic meters of gas. As a result of huge movements of sediment mass from the depths to the surface, areas of low geostatic pressure and subsidence are formed that are framed by ring or half-ring grabens, or compensation synclines. These ring structures serve as vents for gas emissions that catch sediments on their way and form gas-soaked ice (gas hydrates) if the volcanoes are located below 600-700 m water depth where thermodynamic conditions allow gas hydrates to crystallize. In fact, mud volcanoes are the sea floor’s expression of endogenic processes, serving as “cheap windows” into the deep geosphere. Our presentation will show that they can be used as high-efficiency, low cost indicators in the investigation of gas hydrates, including those suitable for industrial exploration, and that their eruptions play a harmful role in the environment.