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Gas hydrate accumulation associated to the Bonjardim mud volcano (Gulf of Cadiz): mechanisms of formation, thermal models, quantitative gas budget estimations

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Investigation of the submarine gas hydrate formation processes and mechanisms are necessary in order to define shape and size of separate gas hydrate accumulations. About 30 mud volcanoes occurring within the gas hydrate stability zone are known in the Gulf of Cadiz (NE Atlantic). Gas hydrates were recovered from several of them including Bonjardim mud volcano (Kenyon et. al., 2001; Mazurenko et. al., 2002). The hydrate accumulation associated with the Bonjardim mud volcano forms both due to precipitation from ascending water solution oversaturated with gas through to reduction of the gas solubility in water and by molecular diffusion of gas segregating sediment pore water. Methane comes into zone of gas hydrate formation mainly in water solution through the crater of the volcano from assumed depth of about 5 km (Hensen et. al., 2007). The infiltration of the ascending water occurs along with the centrifugal diffusion of gas from an active zone of the volcano to the periphery. Gas hydrate formation occurs owing to decrease the solubility of the diffusing gas in water within the gas hydrate stability zone that is resulted in capture of the in situ water

into hydrate structure. Conditions favorable for the filtrogenic gas hydrate formations occur at the active mud volcano zones, whereas diffusion-segregation mechanism of hydrate formation takes place at the periphery of the volcano.

The sizes of gas hydrate accumulations associated to mud volcanism are defined by sizes of separate mud volcanoes and by surrounding thermal field. Heat flow data (Kopf et. al., 2004), porosity, permeability, and PT conditions at the Bonjardim mud volcano were used for geothermal modeling of the gas hydrate accumulation. Conceptual 2D models considering velocities of the mud volcano fluids, pressure, and a heat transfer by conduction and convection were built. The numerical models of the thermal field of the Bonjardim mud volcano allowed to define a base of hydrate stability zone, size and shape of associated gas hydrate accumulation, to analyze velocity distribution mode for the ascending mud volcano fluid, and to deduce temperature distribution with depth. An approbation of the developed models has shown that depth of the fluid source should not exceed 1000 m. Based on the obtained data one can estimate the quantity of ascending gas captured by hydrates. Within the Bonjardim mud volcano velocity of the ascending fluid was estimated as much as 1.3 cm/yr (Hensen et. al., 2007). Based on this value, about $0.8 \cdot 10^4$ m^3/yr of the fluid will be erupted through the mud volcano crater with 450 m radius. And the total amount of water erupted during the mud volcano activity (100 thousand years according to Kenyon et. al. (2001)) one can estimate by value of $0.8 \cdot 10^9$ m^3. Since no manifestations of free gas on the seafloor were observed above the Bonjardim mud volcano, concentration of gas in the mud volcano fluid can not exceed 1.5 m^3/m^3(Ginsburg & Soloviev, 1998). Thus, total methane quantity carrying by the mud volcano during its activity is estimated by value of $1.25 \cdot 10^9$ m^3. Taking into account estimated budget of gas captured by gas hydrates at the sediments of the Bonjardim mud volcano ($5.7 \cdot 10^9$ m^3 (Matveeva et. al., 2007)), about of 22% of gas discharging from the mud volcano will transform into hydrate phase.

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