Mud Volcano, Gas Chimney and Methane Hydrates

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Mud diapirs and volcanoes occur in many parts of the world, on land as well as in the shallow and deep waters. Mud diapirs are composed of brecciated clasts of older rocks and mud which are mixed with fluids and gases. They rise through a sediment sequence, piercing or deforming younger sediments, may reach the seabed, then they are termed a mud volcano. Mud volcanoes periodically or continuously vent fluids and liquified mud. Driving forces for mud diapirism are excess pore fluid pressure (overpressure) and bulk-density inversion (buoyancy). Overpressure is generated by poor drainage of pore fluids and tectonic lateral compression in mobile belts (Judd and Hovland, 2007). A number of mud volcanoes occur in and around Japan islands, the Kumano forearc basin (e.g., Kuramoto et al., 2001), Tanabe Group in Kii Peninsula (e.g., Miyata et al., 2009), the Upper Miocene-Pliocene sequences of Tokamachi-City, Niigata Prefecture (e.g., Kakizaki et al., 2018), and others.

“Columnar blanking zones” have been identified by geophysical survey in deep sea sediments worldwide. They have been considered to represent mud diapirs and volcanoes, however, some acoustic profiles have shown horizontal reflectors to indicate bedding planes, e.g., “pagoda structure” in Nigerian deep waters (Emery, 1974). Vertical blanking zones are not always mud diapirs but may correspond to something else, and they were descriptively named as “acoustic shadow” in Cascadia margin (Chapman, 2001), “acoustic wipeout zone” in Mississippi Canyon, Gulf of Mexico (Roberts, 2001), and “acoustic turbid zone” in Tatar Strait (Lomtev et al., 2009). Acoustic blanking indicates lower acoustic energy due to free gases and fluids, as well as chaotic sedimentary units, then Emery (1974) proposed the possibility of the accumulation of gas and gas hydrate in shallow sediments. Nowadays, gas related blanking is collectively termed as “gas chimney” (e.g., Matsumoto et al., 2009; Fraser et al., 2016; Yang et al., 2018; Waage et al., 2019).

Intensive geophysical survey and coring for gas hydrates in the Sea of Japan since 2004 have revealed that, (1) aproximately 1,700 gas chimneys exist along the eastern margin of the Sea of Japan and around Hokkaido, (2) gas chimneys are often capped by low relief mounds, which are covered by chemosynthetic communities, carbonate concretions and crust, with occasional methane seeps, (3) chimney is not composed of chaotic aggregate but stratified beddings. Sedimentary layers of surrounding zone are traceable into gas chimneys, (4) gas hydrates and AOM-related carbonates were formed in shallow subsurface, and (5) the transport of fluids and gases are not by migration of liquified sediments but by diffusion and advection through the sequences.

“Acoustic blanking” of gas chimneys have been often misinterpreted as mud diapirisms because the resolution of conventional seismic survey was not high enough to reveal bedding structure in blanking zones. Sediment layers and stratigraphic sequence within chaotic blanking zones are the critical criteria to distinguish between gas chimney from mud volcano. High resolution seismic survey (HR3D) clearly exhibits bedding structure within blanking and wipeout zone of gas chimneys.

Geologic background and implication of mud volcanoes and gas chimneys are totally different. Mud volcanoes are formed by overpressure, liquefaction and lateral tectonic stress, while gas chimneys imply enhanced production, migration and accumulation of gases. Mud volcanoes are rather common in Nankai

subduction margin and Ryukyu trench, while gas chimneys are concentrated in the Sea of Japan. The contrasting occurrence is likely to reflect the difference in tectonics, sedimentation and diagenesis.

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