State of the Nankai Trough seismogenic zone inferred from thermal and hydrological regime of the mud volcanoes

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Mud volcano is a conical-shape mound with its diameter ranging from several hundred meters to several kilometers. It is characterized by a sub-seafloor seismically-transparent diapir underlying the cone. Intensive surveys of mud volcanoes have been carried out in many areas; Mediterranean accretionary complex, North Sea (Stregga landslide, etc.), Black Sea, Lake Baikal, Taiwan, East China Sea, Nankai Trough, Cascadia, Costa Rica margin, and Barbados. A driving mechanism for the mud diapirism is the buoyance by a negative density of the diaper and the triggering by the tectonic compression due to plate convergence. Depending on the hydrological property of the sediment, pore fluid cannot drain out from the sediment generating overpressures that also promotes the fluid seepage to the seafloor.
In the Kumano forearc basin there are some mud volcanoes. The Li-isotope analysis of pore water in the core samples obtained from the mud volcano revealed that the origin of the fluid is at depth where formation temperature reaches ~300 degC (Nishio et al., 2015EPSL). A simple extrapolation of surface thermal gradient ~40 mK/m gives the depth of 7-8 km for 300 degC. However, the actual depth is deeper because the thermal gradient should decrease with increasing depth. More importantly, the thermal regime is neither one-dimensional nor in steady state. You need 2D or even 3D numerical simulation, taking into consideration of the advective effect of plate subduction, sediment compaction, geological-scale sediment deformation (fold and thrust), frictional heating due to coseismic fault slip, etc. Through matching the surface heat flow data to the model, Harris et al. (2011 G-cubed) inferred the 300degC depth at ~20 km.
An important factor affecting the evolution of mud volcano is the fluid expulsion rate. Since it is important to directly measure the rate, some proxies are used such as nonlinear profile in pore fluid chemistry (Cl, SO4, etc.) and geotherm, or BSR depth anomaly as indicating the base of methane hydrate stability. Goto et al. (2007AGU) reported the heat flow distribution across the Kumano Knoll No. 4 (KK4); the heat flow higher than 70 mW/m2 in the base of the mud volcano, low heat flow (20-30 mW/m2) in the western slope, and heat flow of ~60 mW/m2 in the summit area. Through numerical calculation considering the topographic effect (thermal refraction), they suggest an upward fluid flow rate of ~1mm/year. The driving force of the flow can be the overpressure at ~20km, which is about the depth of plate boundary fault zone causing M8 great earthquakes. The overpressure may be generated along the fault zone due to the dehydration of clay minerals or coseismic dynamic thermal pressurization if combined with the hydrologically undrained condition. As such, we expect that the mud volcano activity can be an important proxy (or window to the seismogenic zone activity) for the assessment of seismic urgency.
Recently, Asada et al. (2016, this meeting) discovered a giant mound and mud flow activity at the seaward edge of the Kumano basin, where a previous 3D seismic survey revealed a distinctive diaper structure. The depth to the mega-splay fault (seismogenic fault) is only 3 km and the inferred temperature is only 100 degC. A further in-depth research should reveal the state of the fault zone, improving our understanding on the Nankai seismogenesis.

Keywords: Nankai Trough seismogenic zone, mud volcano, heat flow anomaly

