Boron isotope ratios in pore fluids from mud volcanoes off Tanegashima

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Mud volcanoes are geological phenomena, where sediments are venting together with gas accumulated in sediments. They play an important role in geochemical cycle as a path from great depths. It is important to investigate chemical and isotopic compositions of pore fluids in surface sediments for understanding geochemical cycle from great depths. Recently, highly accurate topographical survey was carried out over the mud volcanoes off Tanegashima, and a new mud flow was observed on the seafloor of the mud volcanoes off Tanegashima. In this study, we investigated the chemical and isotope compositions of pore fluids from the mud volcanoes off Tanegashima to discuss the origin and migration processes of fluids in the mud volcanoes off Tanegashima.
From August 19 to September 1, 2015, sediments about 350 cm were sampled from the top of two mud volcanoes (MV#1 and MV#14) off Tanegashima during KH-15-2 cruise of R/V Hakuho using a piston corer. From the recovered sediments, pore fluid was immediately extracted on the ship, distributed to a plastic bottle. The sample was added with 3N nitric acid, and was kept in cool and dark place until analysis.
In the pore fluid sample, boron was separated using the micro-sublimation method, and the boron isotope ratio was measured using a multi-collector inductively coupled plasma mass spectrometer. Boron isotopic ratios were expressed as δ^{11}B (‰) as a deviation from the international standard material (NBS SRM 951). Precision was less than 0.9‰. Chloride ion concentration was measured by ion chromatography and oxygen and hydrogen isotope ratios of water were measured at the Kochi Core Center by cavity ring-down spectroscopy.
Concentration of chloride ion decreased below that of seawater with increasing depth in both sites. The δ^{18}O value of water increased with increasing depth and the δD value decreased with increasing depth. In addition, the degree of the change was larger in MV#1 than MV#14. On the other hand, the δ^{11}B value became lower than that of seawater with increasing depth in MV#1, and higher in MV#14.
It suggests that fluids with low-Cl, high-δ^{18}O and low-δD were supplied from the deeper part in both mud volcanoes. In addition, the difference of these change would represent the difference of the flux of deep-sourced fluids, and it suggests that the flux of fluid from the deeper part is larger in MV#1 with larger change than MV#14 with smaller change. Based on the combination of δ^{18}O and δD values of water, the origin of the fluid would be dehydration of clay mineral in both mud volcanoes, and come from a temperature environment of 60 to 160˚C at which the dehydration reaction of clay minerals occurs. Assuming normal geothermal gradient, the temperature environment is estimated to be several kilometers below the ocean floor. Different δ^{11}B values would be due to the degree of secondary processes during ascending through the sediment column, and it could be related to the flux of the deep-sourced fluids.
In this study, the chemical and isotope compositions of pore fluids from two mud volcanoes off Tanegashima were investigated. These mud volcanoes suggested that there was a difference in the flux of fluid from deep layers. In the mud volcanoes with smaller fluid flux, the secondary reactions would occur in the ascending process of the fluid.

Keywords: Boron isotope, pore fluid, mud volcano, off Tanegashima

Hydrocarbon gas accumulation and mud volcanoes in the Nankai subduction margin: Insight from 3D seismic velocity analysis using automatic picking algorithm

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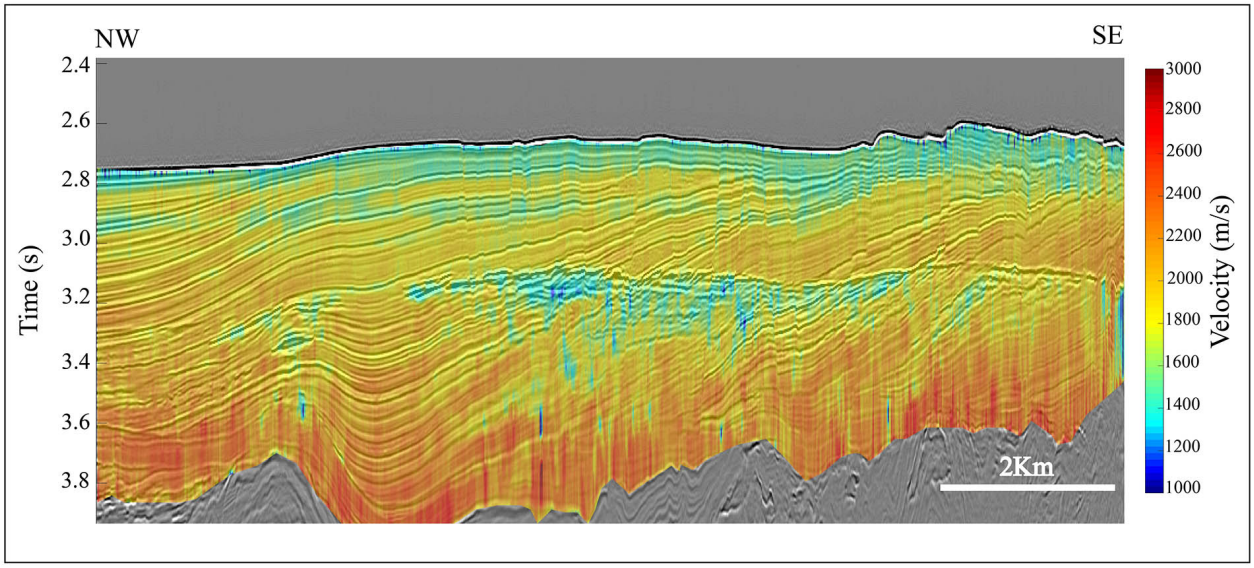
Numerous studies of submarine mud volcano (MV) deposits disclosed subduction-related liquid and gaseous fluids which form and discharge due to the overpressured deep subsurface caused by the overburden of overlying sediments at active continental margins. A variety of MVs have been investigated and known in the Kumano Forearc Basin, which is situated above the Nankai accretionary prism off the Kii peninsula, Japan. When we apply seismic velocity analysis to the 3D seismic data via automatic velocity picking, the results reveal the presence of gas hydrates widespread in this region. The Bottom-Simulating Reflector (BSR) at the base of the gas hydrate stability zone has imaged as a strong acoustic impedance contrast on the seismic profiles. The high accumulation of gas hydrates above BSR and free gas beneath BSR was identified due to high and low velocity anomalies respectively. Based on the results, we suggest that the gas hydrates concentrated due to the free gas influx which migrated upward through the steeply dipping strata and faults or fractures cutting through the basin. The gas (or hydrates) accumulated area is further controlled by the gas charged mud conduits deep rooted in the MVs, and large faults in the accretionary prism. Therefore these factors generated by intensive tectonic movement control the distribution and saturation pattern of gas hydrate and free gas formation, and major sources of these gases may be derived from the deep MVs. When we characterize the features of gas hydrate (i.e., double BSR caused by variation in temperature and pressure within the required duration of thermal equilibrium), we could discuss the history of tectonic and faulting activity in the accretionary prism and specifically the dynamics of the hydrocarbon origin and MVs phenomena.

Keywords: Nankai Trough, Mud volcano, Gas reservoir, Automatic velocity analysis

Seismic velocity overlapping with a stack data IL2528



Preliminary Results of the RV SONNE cruise SO251b in the Kumano Basin (Nankai Trough subduction zone, Japan)

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Mud volcanoes are topographic highs on the ocean seafloor related to expulsion of sediments and fluids from depth. The characterization of the ejecta is helping to constrain the source origin of mud volcanoes and, at the same time, provides important mineralogical, geochemical and rheological information at depths not reachable trough scientific drilling. Off the Kii-peninsula, on the Kumano Basin seafloor, 13 mud volcanoes have been identified from previous scientific investigations in the area (Kuramoto et al., 2001; Morita et al., 2004; Pape et al., 2014). The mud volcanoes' ejecta have been suggested to originate both in the inner accretionary prism and below it, on the plate interface between the Philippine and Eurasian plates (Pape et al., 2014; Toki et al., 2014; Nishio et al., 2015). The Kumano region is known to be subject to large earthquakes, with last occurrences in 1944 (Tonankai, M_w=8.2) and 1946 (Nankai, M_w=8.3) (Ando et al., 1975; Cummins et al., 2002; Linde and Sacks, 2002; Kodaira et al., 2004). Multiple evidences from other regions affected by mud volcanism suggest that mud volcanoes activity is linked with earthquake (Mellors et al., 2007; Kopf et al., 2010; Rudolph and Manga., 2012). Tsunogai et al. (2012) hypothesized such link could also exist for the Kumano Basin mud volcanoes. However, full understanding of this relationship needs to be supported by detailed studies on mud volcanoes to understand their evolution both in time and space, as well as to link them with the seismogenic zone at depth.

Two scientific cruises with the RV SONNE were held on the Kumano Basin in 2012 (SO222) and 2016 (SO251b). The main purposes of the SO251b cruise were (1) to recover the long-term monitoring devices installed in 2012 on 3 mud volcanoes (MV#2, MV#3, MV#4) and (2) to monitor heat flow, pore water geochemistry, bathymetric and subbottom variations on the Kumano Basin seafloor in order to compare the newly acquired data to the SO222 ones.
Four long-term observatories, measuring pressure and temperature in MeBo boreholes, were recovered during multiple dives with the ROV PHOCA from Geomar and are currently under analysis. The long-term data series, together with records from the DONET network, will allow to define the link between mud volcanoes and earthquakes. At the same time, the multibeam echosounder survey (Kongsberg EM122, 12 kHz) was expanded from 2012 to cover most of the Kumano Basin, from 136º10' to 137º30' East. The recently acquired data unraveled a new mud volcano (MV#14, which was also groundtruthed with the recovery of mud breccia) and interesting bathymetric changes in correspondence of some of the most active mud volcanoes (MV#2, MV#13). The differential bathymetry provides constraints on mud flows occurrence between 2012 and 2016. Several loci of possible gas emission (>40) were discovered on the basin seafloor, often situated on top of mud volcanoes or near suspected ones, characterized by strong acoustic signals within the water column. Geochemistry results from sediment cores scattered through the research area showed, according to preliminary analyses conducted onboard, slight freshening with increasing depth, pointing towards a possible deep-seated fluid source. Heat flow measurements with a violin-bow probe through the basin and the active mud volcanoes (identified in 2012) revealed marked differences from the SO222 measurements, supporting ongoing fluid/mud emissions especially on MV#2 and MV#13.

Keywords: Mud Volcano, Kumano Basin, Long-term observation

Why and where submarine mud volcanoes existing? A case study of the Kumano Basin, Naikai Trough subduction zone

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Mud Volcano (MV) is one of topographic feature which derives sediments and fluid from depth to surface of the Earth, which observed over the world (Kopf et al., 2002). They are mainly reported from oilfields, areas of high sedimentation rate, and convergent plate margins. Such loci of MVs suggest that MVism needs stable compressional tectonic setting and/or enough amount of source making MV. MV emits sediment and fluid (gas, water, oil, dissolved salt) (Milkov, 2005). The reason why buried materials intrude upward is that they have buoyancy because of heating (relates to magmatic activity) and difference in density (degassing, dehydration, hydrolysis reaction of mantle wedge, etc.) at the buried depth. Faults maybe help for making upwelling of materials, at some occasions. Because the “MV” is just a topographic feature made by ejecta from depth, background geology of the MVism is too complicate to overview the activity. In order to understand MV itself and desterilize information which MV brings, at least around Japan Island, it is now required that we focus on MV activities around our country and similar geological settings.

MV on and around Japan Island is reported on land (Niigata and Hokkaido area, and hot mud pools) and also at submarine environments (off-Tanegashima and Kumano Basin). There are at least 14 of MVs in the Kumano Basin, the forearc basin at off Kii peninsula (Kuramoto et al., 1998, 2000; Morita et al., 2004; Pape et al., 2015, Asada et al., submitted). Kumano Basin is forearc basin overlying an older accretionary prism along the Nankai Trough, where Philippine Sea Plate subducts under the Eurasia Plate (Moore et al., 2009; Boston et al., 2016). A megasplay fault from the base of the accretionary prism cuts to the seafloor (Moore et al., 2009; Kimura et al., 2011). A fluid sampled from a MV in the Kumano Basin indicate that it comes from deeper than 15 km below seafloor, possibly meaning along plate boundary (Nishio et al., 2015). Results from seismic survey over the Kumano Basin partly show diapiric structure below MVs in the northern Kumano Basin (Morita et al., 2004; Moore et al., in this session). A recently confirmed MV along the Kumano Basin Edge Fault Zone (Asada et al., submitted; Walter et al., in this session) also is considered existing with larger mud diapir nearby, and maybe activated by faults cutting surface of the diapir (Asada et al., submitted). Trying overview the MVism in the Kumano Basin, to pick up characteristic feature of this area, a possible scenario is: (1) ejecta from MV maybe derived from accreted part, (2) environment below a lower sediment layer may decide presence of mud diapir and rough distribution of connecting MV, and (3) tectonic deformation near seafloor controls activity of each MV. Comparative discussion with other submarine MVs are efficient for further understanding of MV in the Kumano Basin. An original depth, history, degree of volcanism, differences between each MV, to know unknown MVs around Japan, and relationship with earthquake remains as unsolved problems.

Keywords: mud volcano, plate convergent margin, mud intrusion/dirpir

