Surface deformation of a mud volcano in azerbaidzhan detected by InSAR and its source modeling

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Interferometric synthetic aperture radar (InSAR) allows us to observe a wide area and two-dimensional information of Earth’ s surface without a need for ground-based measurement tool with a precision on the order of a few centimeters. This technique has been mainly used to investigate ground deformation associated with earthquakes and volcanic eruptions. However, there have been fewer cases that applied the technique to the deformation related to the activity of mud volcano. The purpose of this study is to detect surface deformation of a mud volcano in Azerbaizhan by L-band InSAR and to estimate its source modeling.
Azerbaidzhan, located on the western edge of the Caspian Sea in Central Asia, is one of the most abundant countries in term of the population of mud volcanoes over the land. We used the SAR images derived from two L-band satellites, ALOS/PALSAR and ALOS-2/PALSAR-2, launched by JAXA in 2006 and 2014 respectively. As a result, we could obtain 31 interferograms and detect surface deformation mostly uplifting signals at more than 10 mud volcanoes. These observations indicate that the mud volcanoes around the studied areas are highly active. In particular, we focused on a large and unique, Ayaz-Akhtarma mud volcano. Benedetta et al. (2014) also detected the ground deformation of this mud volcano, using ENVISAT/ASAR C-band SAR data, spanning from 2003 to 2005, only along descending path; InSAR observes the surface from nearly the north to the south in a slant direction along this path. Although the ground displacement at the mud volcano was 20 cm in Line of Sight (LOS) for the two years, subsequent displacements were not clear. However, the results of our study, using ALOS data from ascending path that is opposite look direction from the previous study and ALOS-2 data for ascending and descending paths, indicated more active and larger horizontal displacements. The cumulative LOS displacement is up to nearly 300 cm for five years by ALOS and 100 cm for two years by ALOS-2. Thus we performed the source modeling to explain the displacement, assuming an elastic half-space. The modeling showed this deformation consists of normal slip and tensile opening components.

Keywords: Mud volcano, SAR

Evidence for widespread mud diapirs in norther Kumano Basin, Nankai Trough forearc basin

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Although mud volcanoes (MV) have been studied in Kumano Basin for almost 20 years, the roots of the MVs have received little attention. Morita et al. (2004) published a seismic line across the basin showing mud diapirs sourcing the MVs, but the extent of these diapirs has remained underappreciated. We present JAMSTEC 2D seismic lines across and along the basin axis showing that much of the northern part of the basin is underlain by mud diapirs. The diapirs feed at least 11 MVs in the northern part of the basin, all of which have been surveyed with multibeam bathymetry, high-resolution sonar and sampling. The diapirs range in diameter from 4-6 km and have seismic expression to at least 2-3 km below the seafloor. Older sedimentary layers are tilted upward adjacent to the diapirs and have internal onlap features that indicate several stages of uplift. Bottom simulating reflections (BSRs) that cross-cut the sediment and diapirs are locally disrupted under the MVs, indicating upward migration of fluids through the methane hydrate layers to the surface. Morita et al. (2004) report that mudstone fragments carried to the surface by the MVs range in age from 18.2-13.6 Ma (late Early Miocene –early Middle Miocene), indicating that the mud diapirs, which probably originate within the underlying accretionary prism, passed through the older layers of the forearc basin.
Reference: Morita, S., J. Ashi, K. Aoike, and S. Kuramoto (2004), Evolution of Kumano basin and sources of clastic ejecta and pore fluid in Kumano mud volcanoes, Eastern Nanaki Trough, In: Proceedings of the International Symposium on Methane Hydrates and Fluid Flow in Upper Accretionary Prisms, Engineering Geology Laboratory, Department of Civil & Earth Resources Engineering, Kyoto University, Kyoto, pp. 92–99.

Keywords: mud volcano, Nankai Trough, accretionary prism

Deep-seated mud volcanoes and their impact on seismicity at Nankai (landward of the NanTroSEIZE drilling transect)

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Sediments in subduction zone forearcs experience major and progressive compositional changes as a function of depth and distance to the trench when they are buried through accretion or underthrusting. Fluids primarily exit the system along fault pathways, thereby reducing the stress state along the plate boundary and allowing aseismic slippage. However, little is known about the abundance or role of water within the region of the seismogenic zone itself, and whether such waters leave the system via landward-dipping reverse faults in the frontal or distal portion of the forearc wedge.

In this study, we sampled the sub-seafloor of the Kumano forearc basin of the Nankai accretionary complex, Japan, along the landward extension of the IODP NanTroSEIZE drilling transect. During R/V SONNE cruise SO222 in June 2012 we collected 450 pore fluid samples from 6 sea floor drill rig cores (up to 35 m depth) and 26 gravity cores (up to 8 m depth) at 13 mud volcanoes and additional background sites, all located some 120 km behind the deformation front (and about 50 km landward of the end of the IODP drillings). The data set was complemented by further sampling during R/V SONNE cruise SO251 in october 2016. The material was analysed for major and minor elements and isotopes of H, O, B, Li and Sr. Mud volcano fluids were strongly freshened, with Cl^- as low as 20% of the sea water value, Mg is completely depleted in the most altered samples, and B and Li^+ are enriched to values rarely seen in this environment. B peaks at 16 mM in the most altered samples with B/Cl reaching 200x the seawater value, possibly the highest ever recorded in seafloor pore fluids. Similarly Li/Cl peaks at 50x the seawater value.

The most likely source of pore fluid freshening is mineral dehydration, with complete depletion of Mg and very low Li isotope ratios being typical of hydrothermal systems in igneous rocks. We hence provide the first evidence for water sourced within the subducting ocean crust directly beneath the decollement in the seismogenic zone, which migrates upward through the upper plate wedge and exits through mud volcanoes ca. 15 km above. The presence of water in sufficient quantity to drive mud volcanism in this region coincides with fewer earthquakes in this region of the fault zone.

Keywords: earthquake, mud volcano, Nankai

Estimated activities of submarine mud volcanoes off Tanegashima based on vertical profiles of pore water chemistry

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Submarine mud volcanoes occur along the margins of convergent plates and are formed by the vertical intrusion of low density, deformable sediments from the deep subsurface to the seafloor. Several mud volcanoes have been found at off Tanegashima Island along the northern Ryukyu Trench. Since 2012, we performed an intensive topographic survey of submarine mud-volcanic structures off Tanegashima Island and observed clear mud-flow channels suggestive of the recent mud-volcanic activities at MV#1 (30˚53'N, 131˚46´E; water depth: 1540 m) and MV#14 (30˚11'N, 131˚23'E; water depth: 1700 m) based on the side scan sonar image. During the KH-15-2 cruise in 2015, we obtained two sediment cores from the summit of MV#1 (core length: 361 cm) and MV#14 (core length: 311 cm) using a Navigable Sampling System (NSS). At the MV#1, the chloride (Cl^-) concentration linearly decreased from 550 mM near the sediment surface to 220 mM at 250 cmbsf. Below 248 cm to core bottom, the concentration was constant at ~220 mM. The stable isotopic compositions of pore waters exhibit ^{18}O-enriched and D-depleted isotopic values in proportion to the depletion of the Cl^- concentration, indicating the addition of water from the dehydration of clay minerals that typically occur in the temperature range from 60˚C to 160˚C. In contrast to the MV#1, at the MV#14, the Cl^- concentration only slightly decreased from 556 mM near the sediment surface to 490 mM at core bottom, indicating slow fluid advection. This indicates that the activity of MV#14 is lower than the MV#1. However, the data of stable isotopic compositions of pore water and Cl^- concentrations from MV#1 and MV#14 show same trends, indicating that the end members of fluids derived by clay mineral dehydration are same.
We tried the quantitative evaluation of the difference in the vertical profiles of Cl^- concentrations between MV#1 and MV#14 by using the one-dimensional unsteady advective diffusion model. As the initial state of the Cl^- profile just after the mud eruption, we assumed that the Cl^- concentration in the core bottom at MV#1 represents the original value of the deep sourced fluid, and the Cl^- concentrations were constant from deep to surface immediately after the eruption. We estimated the advection rates of fluids and times after the mud eruption by fitting the numerically simulated depth profiles of Cl^- concentrations to the observed depth profiles. As the result, advection rate and the time after the eruption at MV#1 were calculated to be 10–15 mm/y and 100–200 years, respectively, and those at MV#14 were estimated to be <0.1 mm/y and 8,000–10,000 years, respectively. The preliminary result of the nannofossils observation shows that the Quaternary and the Tertiary species mixed in the sediment sample obtained from MV#14 in which the Quaternary species are dominant in top 50 cm. The nannofossils records suggest that the hemi-pelagic Quaternary sediments have covered on the deep sourced Tertiary sediments which were conveyed to the sea surface from deep sedimentary realm by the mud eruption. The result is consistent with our estimation for the activity of MV#14 based on the Cl^- profile.

Keywords: Submarine mud volcano, Porewater chemistry, nannofossils

Mud volcano distributed around the Kikai-jima Island, northern Ryukyu Arc

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Geological Survey of Japan have carried out research cruises around the Ryukyu Arc since 2008 in order to improve geoinformation of Japan. During three cruises GH14, GK14 and GK15-2 in 2014 and 2015, we found at least eleven mud volcanoes around the Kikai-jima Island of northern Ryukyu Arc using multi-narrow beam survey system. The largest mud volcano with 1-km diameter of the caldera is located at 17 km off SSW of the Kikai-jima Island (water depth: 400 m). Surface deposition collected by a grab sampler from the caldera is composed of grayish silty clay including many subangular pebbles. These pebbles were likely carried from old strata below the sea-floor when the mud volcano erupted in relatively near the past. To investigate erupted ages of the mud volcano may be important for understanding their relation to the fault activity at the forearc region.

