

Surface deformation of a mud volcano in azerbaijan 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 Azerbaijan by L-band InSAR and to estimate its source modeling.

Azerbaijan, 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.

キーワード：泥火山、合成開口レーダ

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

種子島沖海底泥火山群の間隙水の化学組成鉛直プロファイルから見積もられた泥火山の活動状況

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

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海底泥火山は、高間隙水圧をもった堆積物が泥ダイアピルとして上昇し海底に噴出した小丘で世界各地の大陸縁辺域で発見されている。種子島沖には数多くの泥火山様マウンドが密集しており、同海域における詳細な地形調査から、第一泥火山 (MV#1; 3053°N, 13146°E; 水深 1540 m) と第14泥火山 (MV#14; 3011°N, 13123°E; 水深1700 m) にて、比較的最近のものと考えられる山頂付近から流れ出ている泥質流体の噴出痕が確認されている。我々は2015年の白鳳丸によるKH-15-2航海において、自航式サンプル採取システム(NSS)を用いてMV#1とMV#14の山頂で柱状堆積物試料 (MV#1 コア長: 361cm; MV#14 コア長: 311cm) を採取し、間隙水の化学組成と鉛直プロファイルから間隙水の起源と泥火山の活動状態を見積もった。

MV#1の間隙水の塩化物イオン(Cl⁻)濃度は、海底近くの554 mMから海底下250 cmの220 mMまでほぼ直線的に下がり、250cmからコア最深部まではおよそ220 mMと一定の値を示した。間隙水の酸素・水素安定同位体比は、Cl⁻濃度の低下と共に、酸素同位体比は高く、水素同位体比は低くなる直線関係を示した。これは海底下深部の高温下 (60~160C) での粘土鉱物の脱水反応により排出された水が海底面近くまで供給され、海水と混合しているためであると考えられる。一方、MV#14ではCl⁻濃度の低下は海底付近の556 mMからコア最深部 (293cmbsf) の490 mMまでと小さく、MV#14はMV#1に比べて深部からの低塩濃度水の影響が小さいことが示唆される。またMV#14の間隙水の酸素・水素安定同位体比とCl⁻濃度のプロットは、MV#1と同じ直線上にのることから、MV#14とMV#1に供給される水の起源は同じであると考えられる。

このCl⁻濃度プロファイルの違いを定量的に評価するため、非定常次元移流拡散方程式を用いた数値解析を行った。MV#1のコアボトムのコア濃度が深部間隙水中の値を代表していると仮定し、泥火山噴出直後の初期状態として海底直下から深部までこのCl⁻濃度を与えた。間隙水の移流速度と噴出後の経過時間を未知パラメータとし、これらの様々な組み合わせについてCl⁻濃度の深度プロファイルを計算し、測定したCl⁻濃度と比較することで移流速度と移流・拡散時間を見積もった。この結果、MV#1では、移流速度が10~15 mm/yで、泥の海底面への噴出から100~200年経過しており、MV#14では移流がほとんどなく (<0.1 mm/y) 泥の噴出から8000~10000年程度経過していることが見積もられた。また予察的な石灰質ナノ化石分析の結果、MV#14から得られた堆積物中には全て第三紀と第四紀の化石が混合して存在しており、海底下約50cmまでは、第四紀の化石が優先的であった。このことは、泥火山の噴出により海底下深部から第三紀の堆積物が海底表層に運ばれた後、半遠洋性堆積物に覆われたことを示唆し、間隙水のプロファイルから見積もったMV#14の活動状況と調和的である。

キーワード：海底泥火山、間隙水化学組成、石灰質ナノ化石

Keywords: Submarine mud volcano, Porewater chemistry, nannofossils

北部琉球弧喜界島周辺海域に分布する泥火山

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.