Press Releases

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Methane Hydrates of Microbial Origin Found in Submarine Mud Volcano

Overview
An international research team led by Drs. Akira Ijiri and Fumio Inagaki at the Japan Agency for Marine-Earth Science and Technology (JAMSTEC: president, Asahiko Taira) has revealed that microbially produced methane hydrates exist 590 m beneath the summit of an active submarine mud volcano in the Kumano forearc basin of the Nankai Trough, off Japan's Kii Peninsula.

Submarine mud volcanoes are formed by the upward intrusion of deformable lower-density materials from several kilometers below the seabed. This process transports deep-sourced fluids, elements, and hydrocarbons to the seafloor, supporting chemosynthetic benthic life including microbial communities that mediate the anaerobic oxidation of methane with sulfate reduction. However, the biogeochemical and microbiological characteristics of deep submarine mud volcanoes have remained largely unknown.

During research cruises by the deep-sea drilling vessel D/V *Chikyu* in 2009 and 2012, scientists drilled 200 m into the summit of a highly active submarine mud volcano in the Kumano forearc basin and obtained core samples. Their analyses of deep biosphere and carbon cycling in this setting, using geochemical and geophysical data with microbiological methods, estimated that methane hydrate could exist as deep as 590 m below the summit (112–160 m above the seafloor). The amount of methane was estimated as 3.2 billion m^3, ten times larger than expected in a single mud volcano. In addition, more than 90% of the methane appears to be microbial in origin and was produced in sediments 400–700 m below the seafloor, the mud volcano's source layer. In this environment, low-salinity water derived from clay mineral dehydration is supplied from an old accretionary prism through a mega-splay fault; this fluid seems to promote microbial activities such as hydrogenotrophic methanogenesis.

These results indicate that the production and migration of fluid in an oceanic plate subduction zone is strongly related to the production of natural gas by microorganisms living in the deep subseafloor. These findings are highly important for a better understanding of biogenic gas resource generation under the seafloor as well as the relationship between earth dynamics and the deep biosphere.

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Title: Deep-biosphere methane production stimulated by geofluids in the Nankai accretionary complex

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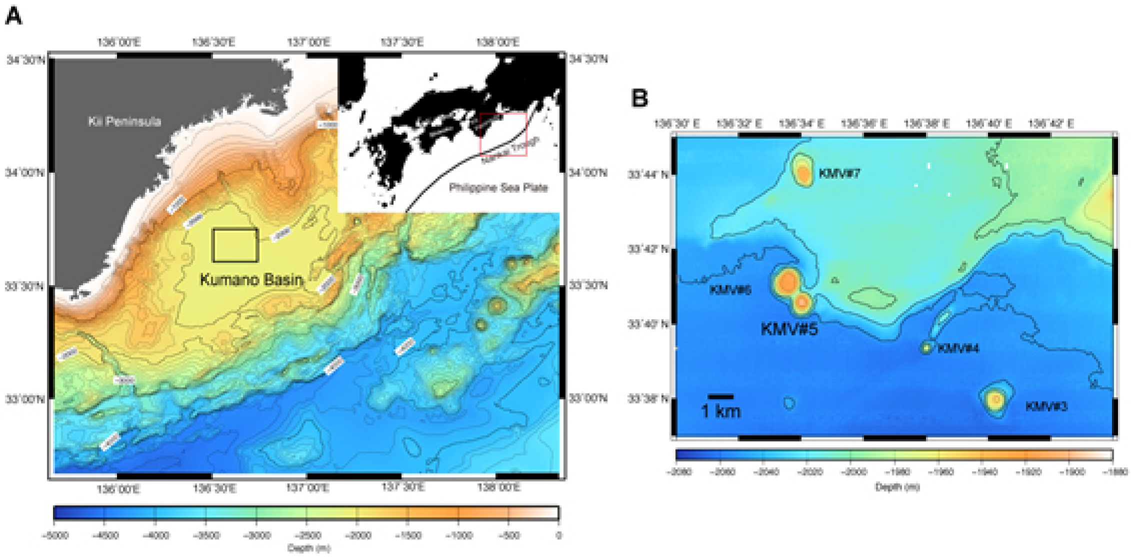

Figure 1. Location of the mud volcano (KMV#5) drilled in this study. (A) General location of the Kumano forearc basin. (B) Specific locations of KMV#3–KMV#7. KMV#5 is among most active of the 13 or more mud volcanoes observed in the Kumano basin.

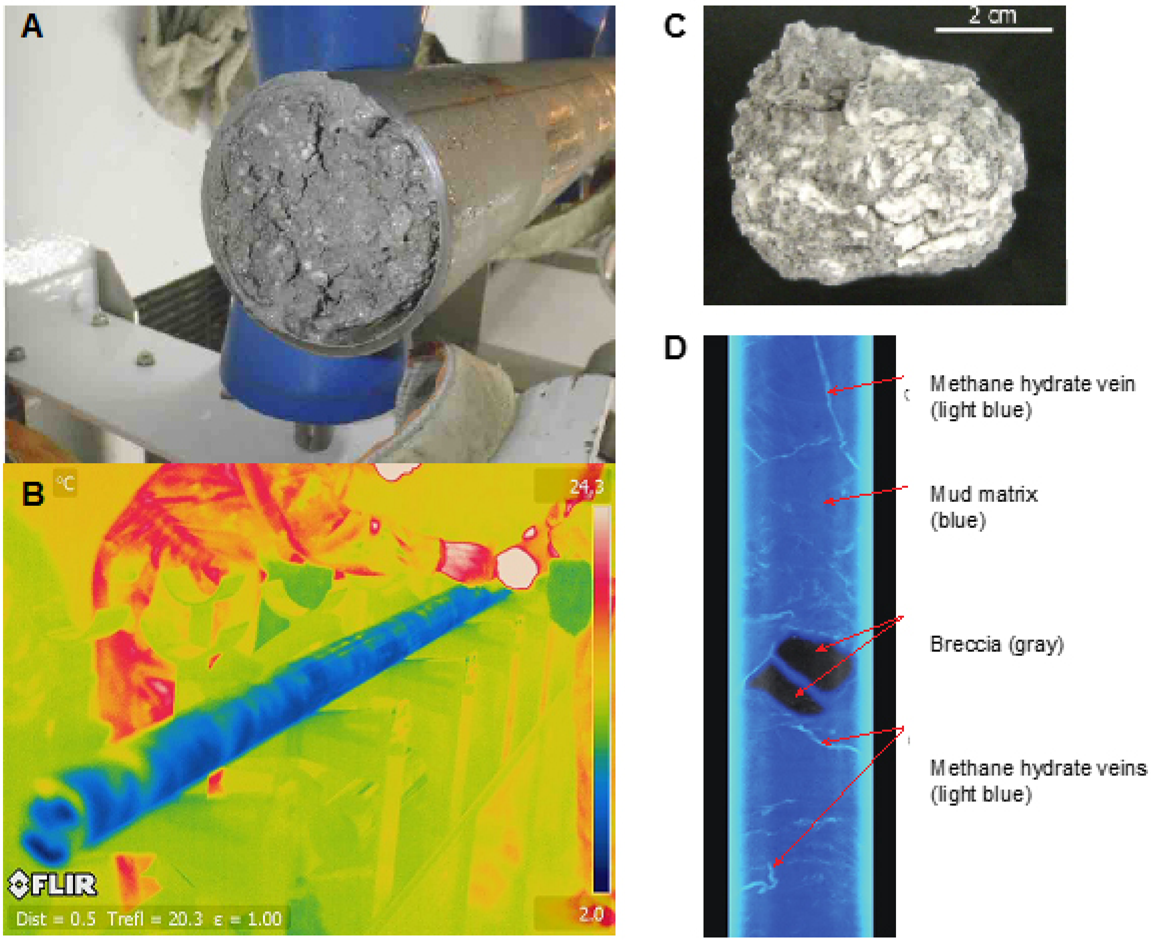

Figure 2. Methane hydrate observed in the KMV#5 sediment core. (A) Photograph of small patchy grains of methane hydrates in the core. (B) Infrared thermal imaging of the core. Hydrate dissociation creates a negative (cold) temperature anomaly that can be rapidly imaged using an IR camera. (C) Photograph of a methane hydrate chunk observed in the sediment core. (D) X-ray image of a core section at full pressure in the Pressure Core Analysis and Transfer System showing mud clasts and methane hydrate veins in a matrix of hemipelagic mud.

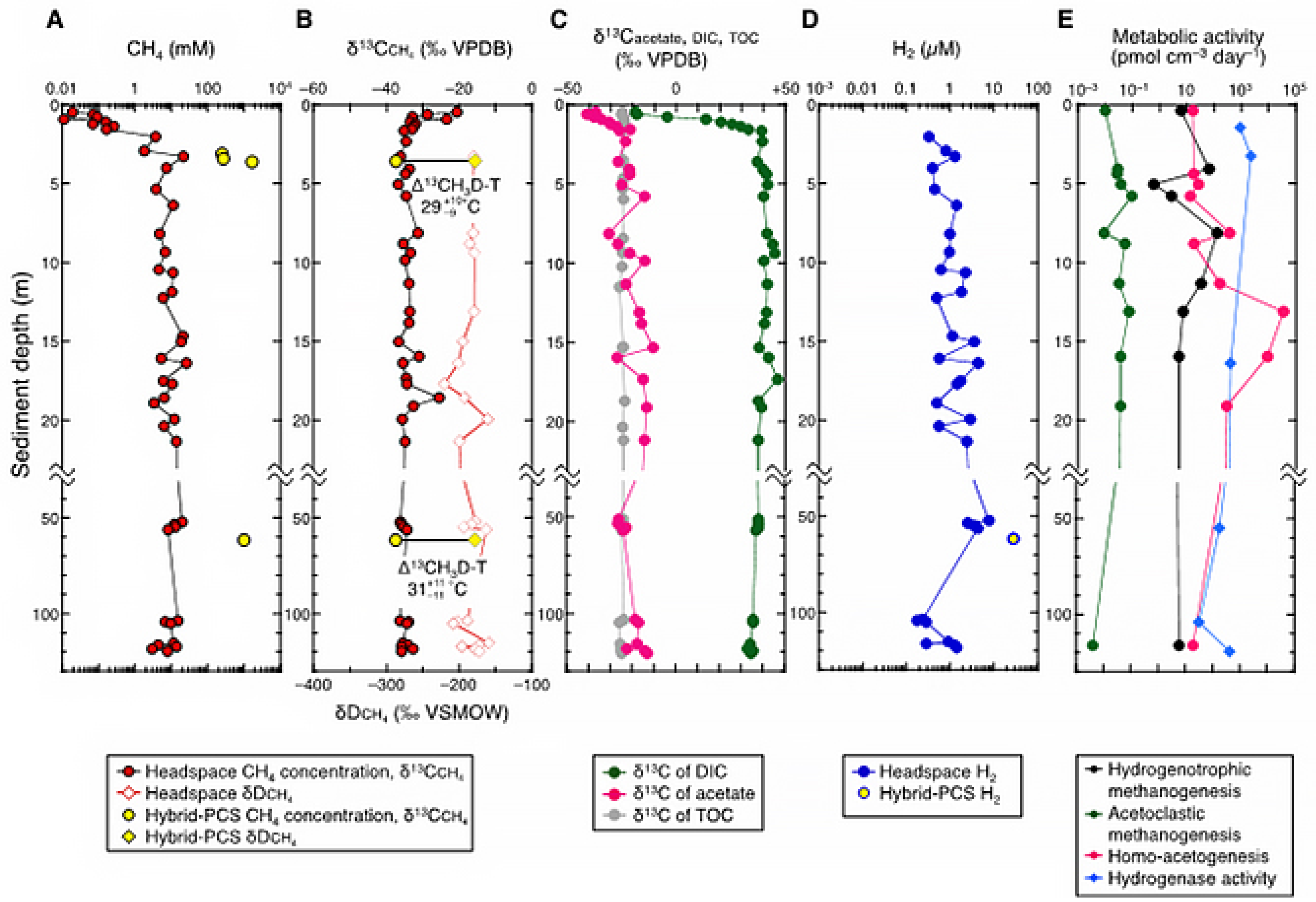

Figure 3. Vertical profiles of biogeochemical data from sediment cores. (A) Methane concentrations; values measured using the pressure core sample (PCS) were over 100 mM, higher than the in-situ solubility. (B) Stable carbon and hydrogen isotopic compositions of methane. (C) Stable carbon isotopic compositions of acetate, dissolved inorganic carbon (DIC), and total organic carbon (TOC). DIC is highly enriched in ^{13}C. (D) Concentration of H_2, generally several tens of μm, four orders of magnitude higher than those in ordinary marine sediments (several nM). (E) Potential metabolic activities. High activity of hydrogenotrophic methanogenesis was observed.

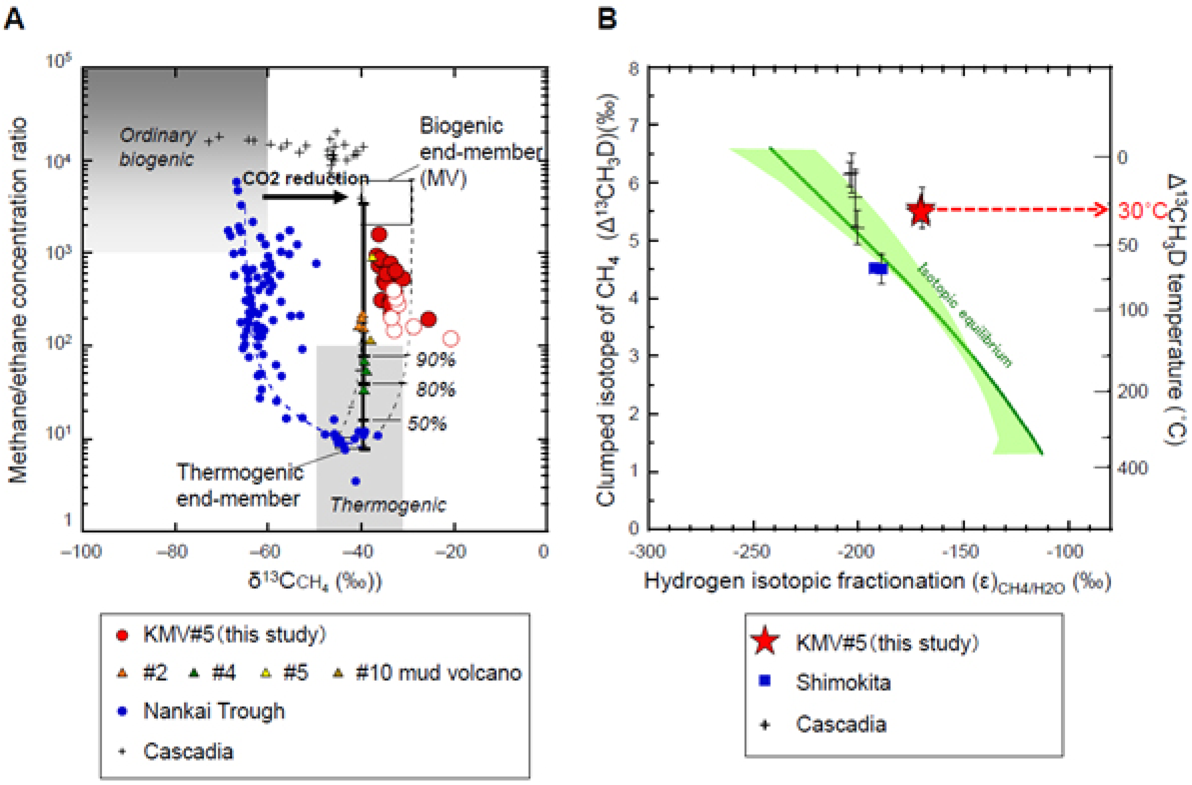

Figure 4. (A) Carbon isotopic composition of methane versus methane/ethane concentration ratio. Methane in KMV#5 was enriched in ^{13}C compared to observations elsewhere in the Nankai Trough because the lighter ^{12}C in DIC is preferentially consumed by microorganisms during hydrogenotrophic methanogenesis, leaving the residual DIC pool enriched in ^{13}C. As more DIC converts to CH_4, both the accumulated methane and remaining DIC pools become increasingly ^{13}C-enriched. (B) Clumped isotopologues of methane from KMV#5 and other locations. The apparent equilibrium temperature based on the clumped isotopologue was ~30 °C.

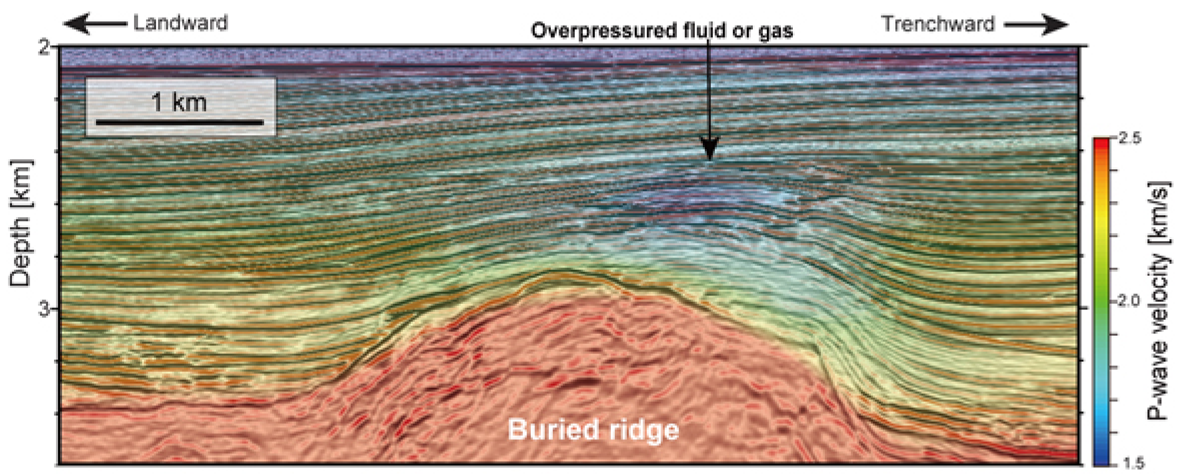

Figure 5. P-wave velocity predicted by 3D-tomography inversion during 3D-prestack depth migration based on data from Tsuji et al. (2015). The overpressure zone (fluid- or gas-accumulation zone) is identified as a low-amplitude and low-velocity zone at 400–700 mbsf in the forearc basin sequence. The low-velocity zone, which is located above the ridge due to the mega-splay fault displacement, suggests that the overpressured fluids are moving upward along the interpreted ancient mega-splay faults. The mud volcanoes are located along the northern extension of the mega-splay faults.

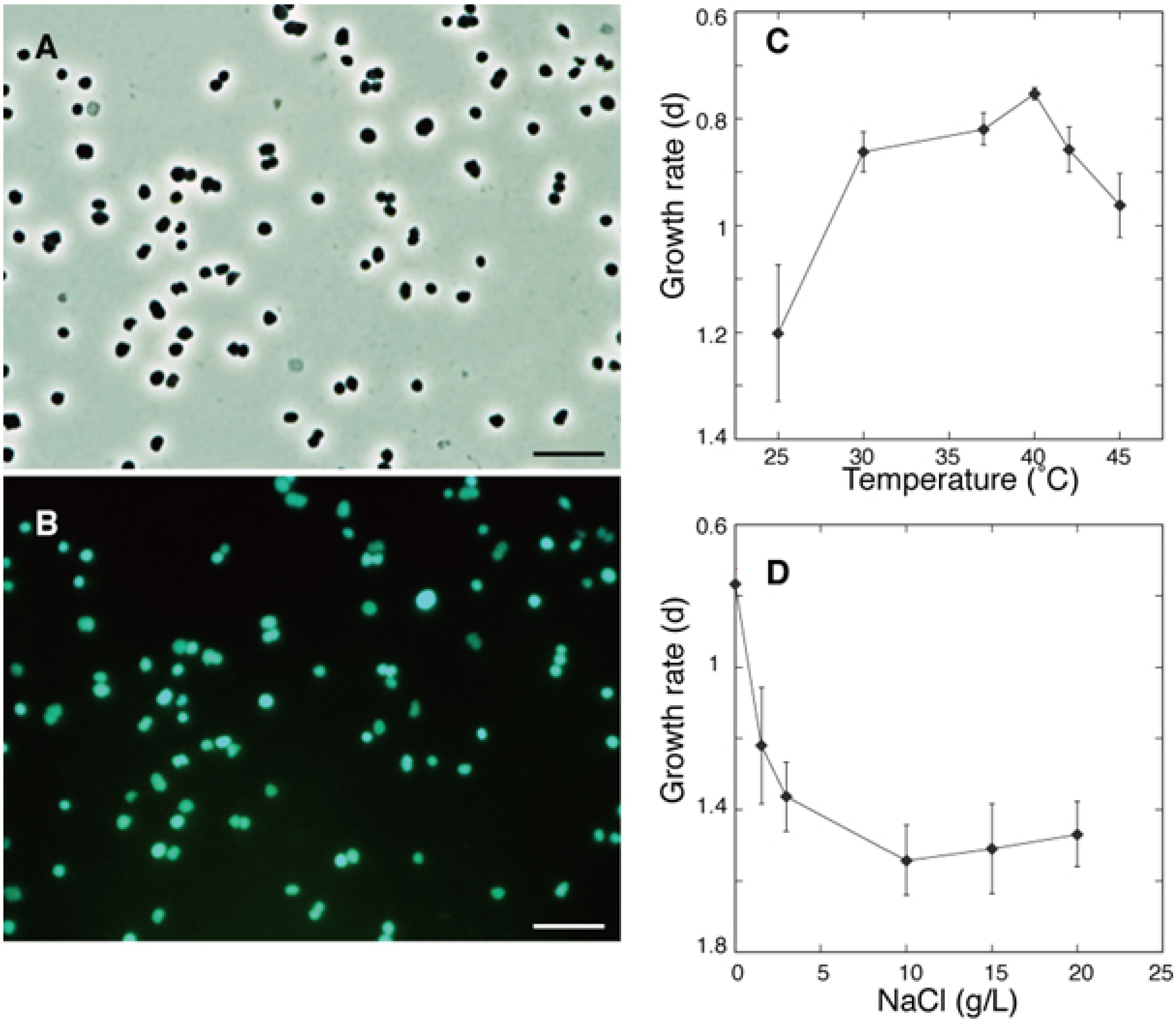

Figure 6. Characteristics of the isolated methanogenic archaeon strain 1H1 from the KMV#5 core. (A-B) Photomicrographs of strain 1H1 grown on H_2/CO_2 medium. Shown are (A) a phase-contrast micrograph and (B) a fluorescence micrograph of the same field. Bars represent 10 μm. (C-D) Effect of (C) temperature and (D) NaCl concentration on the specific growth rate of strain 1H1 on H_2/CO_2 medium; this preferentially grows under very low-salinity conditions.

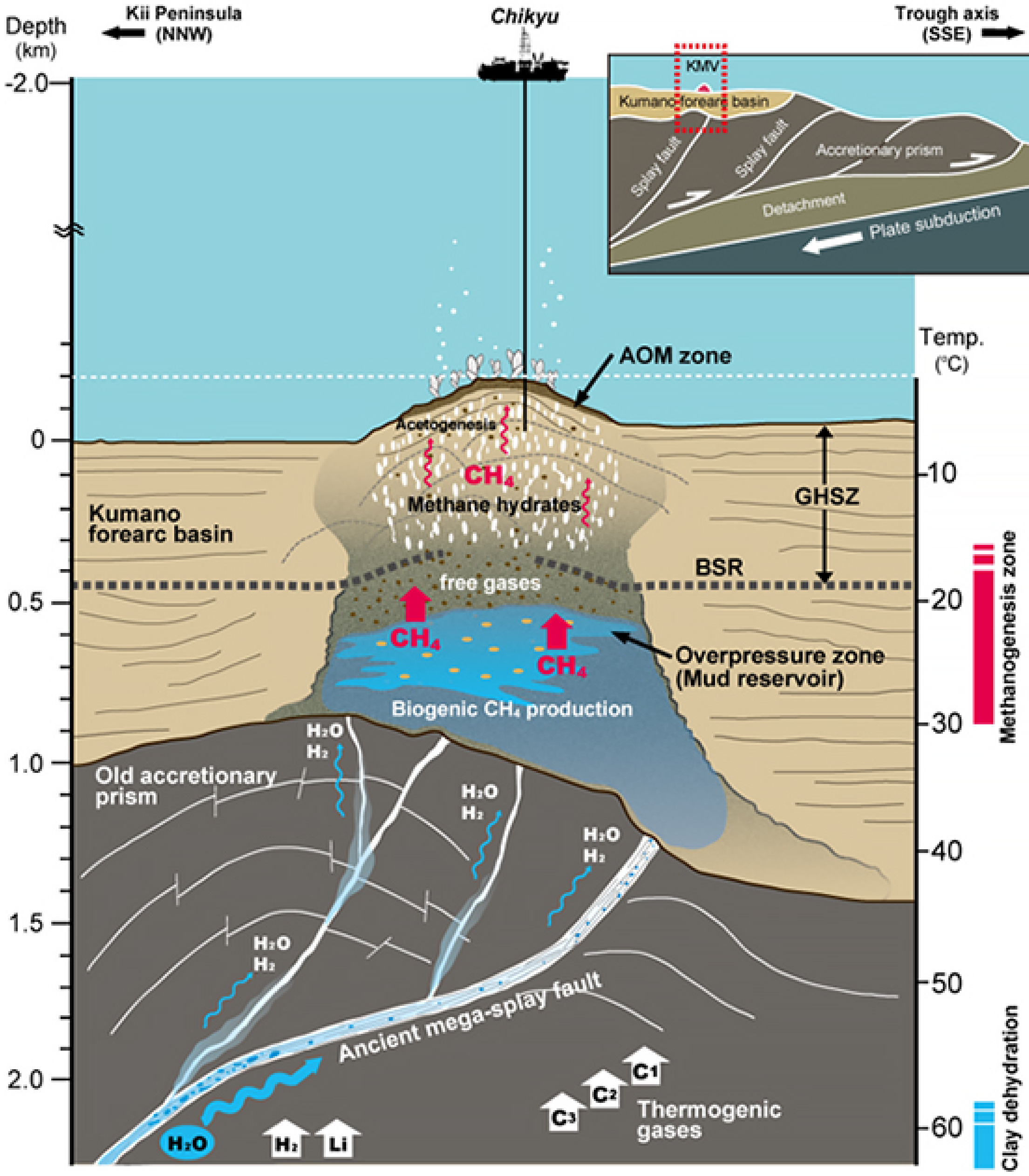

Figure 7. Schematic figure illustrating methanogenesis in the deep mud volcano sediments associated with fluid migration via the mega-splay fault.

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