Gas hydrate on the continental margin

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ABSTRACT

Because the stability of gas hydrate is constrained mainly by the temperature and pressure condition, gas hydrate on the continental margins had dissociated in response to the global climate changes during the earth's history. Marine gas hydrate hosts isotopically light carbon as gas (mostly methane) and heavy oxygen as water, dissociation of gas hydrate liberates these isotopes into the environment, resulting in the formation of carbonate with light C and heavy O. These carbonates are often found in ocean drilling cores, regarded as a clue for reconstructing the past climate changes. Massive gas hydrate dissociation can take place at present, subsequent ocean anoxia, green house gas release, landslide etc. are hazardous for current human life. Therefore, ocean drilling should aim to the understanding of the behavior of gas hydrate system through the earth's history including the future, targeting the gas hydrate area as a key role for the environmental change. To assess the ongoing behavior of gas hydrate, long-term borehole monitoring is effective as well as deep drilling/coring down to the base of gas hydrate stability.

Tectonic and climate processes, that are ones of the key topics of recent earth sciences, constrain significantly the stability of marine gas hydrate. There have been closely related two major aspects resulting from massive dissociation of gas hydrates in the continental margins; seafloor instability causing a slope failure, and massive release of methane into the marine/atmosphere environments.

Marine gas hydrates generally fill pore spaces and impart mechanical strength of host sediments. Slight change in pressure and/or temperature of seafloor can rapidly and widely dissociate gas hydrates because of their sensitivity to the stability condition of pressure and temperature. The decomposition of gas hydrate-cemented sediment releases hydrocarbon gases, mostly methane in natural environment, to the ocean and atmosphere, which may reduce the slope stability and result in slope failure, slumping, and landslide (Bünz et al., 2003). Furthermore, methane has a strong potential of global warming about 20 times larger than the same volume of carbon dioxide. The global warming caused by gas hydrate dissociation can increase global temperature and thus induce further gas hydrate dissociation, triggering catastrophic chain reactions (Kennett et al., 2002).

Release of huge amount of methane is also hazardous to the global system. Seawater and possibly atmosphere become anoxic after a massive dissociation of gas hydrates because of increased amount of methane that is strongly reductive carbon, and may cause mass extinction. Recent studies have revealed that there are some lines of evidence of catastrophic climate changes due to the gas hydrate dissociations. Matsumoto (1995) and Dickens et al. (1995) pointed out the methane release from gas hydrate during the latest Paleocene thermal maximum (LPTM) by $\delta^{13}C$ anomalies in carbonates. A 1.12×10^{18} g of methane releasing due to hydrate dissociation with $\delta^{13}C$ of -60 ‰ over 10^4 years is well consistent with the geological records (Dickens et al., 1997). Hesselbo et al. (2000) also considered the possibility of methane hydrate dissociation during a Jurassic anoxic event on the basis of $\delta^{13}C$ anomalies in carbonates. Kennett et al. (2000) discussed the methane release due to hydrate dissociation during Quaternary interstadials using planktonic $\delta^{18}O$ and $\delta^{13}C$ anomalies in the Santa Barbara Basin, and concluded that gas hydrate stability was modulated by intermediate-water temperature changes induced by switches in thermocline circulation. Bratton (1999) examined clathrate eustasy that is a mechanism of gas hydrates controlling sea level. Sea level rise associated with thermal expansion can be offset by a decrease of hydrate volume due to their dissociation, and this may explain anomalous sea level falls during ice-free periods such as the early Eocene, the Cretaceous, and the Devonian.

An important issue of the research focused on marine gas hydrate system is that these events can take place near future in relatively short time compared to other geological events because of the strong instability of gas hydrates against the pressure and temperature. The drilling research is useful to observe present condition of sub-seafloor gas hydrates, observation/monitoring of the gas hydrate and the related-phenomena, however, must be conducted to investigate and expect behavior of gas hydrate system. Here we propose the development of observation system on gas hydrates, e.g. monitoring of geochemical and geophysical changes of pore water, gas, and sediment in borehole as well as the P-T conditions. Fluid and gas expulsion from the seafloor is also an important proxy of sub-seafloor gas hydrates and is a direct input of methane and fresh water into marine/atmospheric environments. Monitoring of the flux and geochemistry of fluid and gas from the seafloor should be carried out together with the deep observations to investigate the entire nature of marine gas hydrate system and assess the potential geohazards such as landslides and global environment changes. This research integrates the environmental change models induced by gas hydrate dissociation in the past with that may occur in the future.

Western margin of the Pacific Ocean, including Nankai Trough, Japan Sea, South China Sea, Okhotsk Sea, and Bering Sea, is proposed for this integrated gas hydrate studies because of the ubiquitous presence of gas hydrates and gas hydrate-related phenomena, e.g. gas seepage on the seafloor, and BSR and gas charged sediment structure on seismic records, in different geological settings (Fig. 1). Both pore space-filling and massive/nodular gas hydrates occur in backarc and forearc locations where subduction-induced geological activities such as accretion, thrust/fault, and earthquakes have been developed. The spacious investigation in this region is, therefore, feasible for the comparison of factors controlling gas hydrate behavior among occurrences, geological settings, and geological activities through the earth's history.

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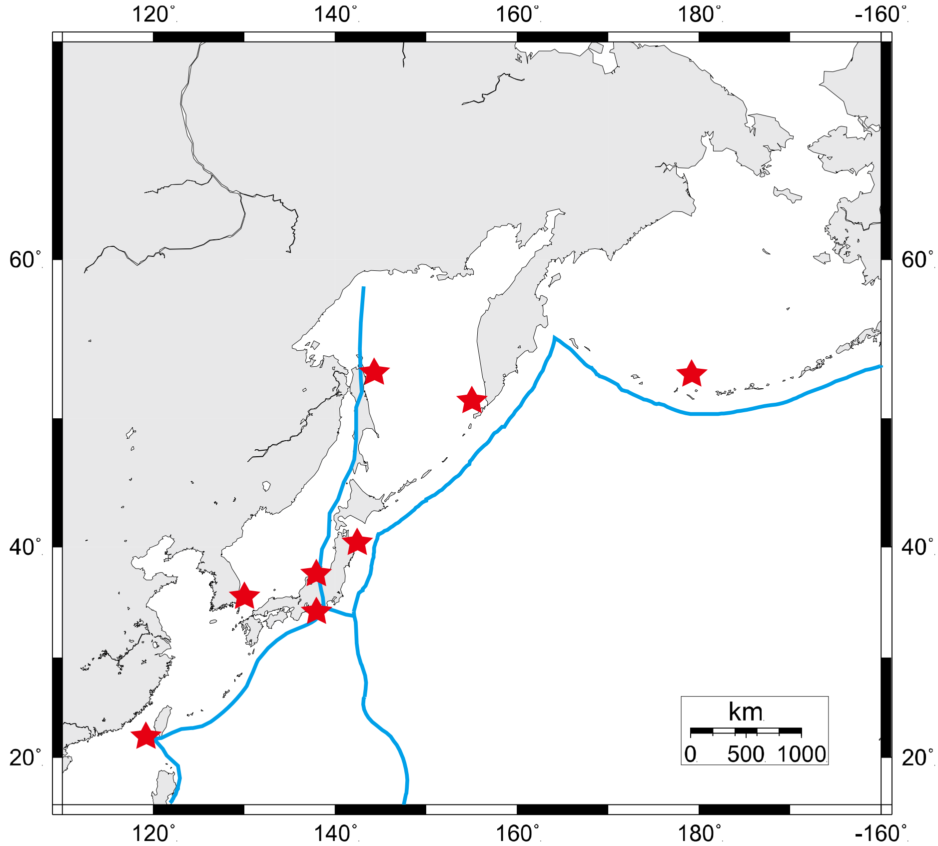

Fig. 1: Western margin of the Pacific Ocean. Stars represent locations where gas hydrates were collected or gas hydrate-related phenomena were observed.