

## Geologic factors to control the behavior of subsurface gas hydrates in the eastern Nankai Trough, off central Japan

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In January to May 2004, METI/JOGMEC-MH21 conducted the drilling of the METI Tokai-oki to Kumanonada wells including drillings, loggings and long-term borehole temperature monitoring by DTS/FBG. Gas hydrate study on the active margin would offer clues to the dynamics of gas hydrate by potentially revealing the response of gas hydrates to changing P-T conditions, caused by geologically controlled factors.

High resolution geochemical study of the interstitial waters and sediments was conducted at Dai-ichi Tenryu site, 30km south-west off Tokai area where the double BSRs were recognized, and Dai-ni Atsumi site located on the northern flank of the Daini-Atsumi Knoll. Gas hydrates are mostly concentrated in sandstone layers of alternating turbidite beds of very fine to medium sandstone and clay/siltstone. Pore-saturations of gas hydrates are estimated to be 65 to 80 % at Dai-ichi Tenryu site, and to be 20 to 80 % at Dai-ni Atsumi site, from the chloride anomaly of the interstitial water.

$\text{Cl}^-$ -baselines (the original in situ  $\text{Cl}^-$  concentration) at both sites show contrasting and characteristic patterns, which have been never observed before.  $\text{Cl}^-$ -baseline at Dai-ichi Tenryu site gently increased from seawater value (560 mmol/L) to 700 mmol/L at 100 mbsf. Below 100 mbsf, the  $\text{Cl}^-$ -baseline anomalously enriched (600-880 mmol/L).  $\text{Cl}^-$ -baseline at Dai-ni Atsumi site was observed to be kept at around the seawater value down to 250 mbsf. At the depth of 250 mbsf, they show the slightly lower value (ca. 500 mmol/L), then rise to 681 mmol/L at 295.8 mbsf. At 295.8 mbsf,  $\text{Cl}^-$ -baseline was sharply folded back, and radically decreased down to 335 mbsf. Below 335 mbsf,  $\text{Cl}^-$  concentrations were radically restored to the seawater value. Besides, the behavior of all ion species is almost harmonized with  $\text{Cl}^-$ . Oxygen isotopic composition from sandy sediments shows high value (up to 2 in permil SMOW), while it from muddy sediments shows relatively low value at both sites. Thus, oxygen isotope composition of the interstitial water seem to show symmetrical pattern mirror image similar to  $\text{Cl}^-$  concentration. During gas-hydrate formation, the ambient interstitial water becomes enriched in salts and light oxygen. Oppositely, gas-hydrate dissociation shifts the baseline of ion concentration lower and the baseline of oxygen isotopic composition higher. The fluctuation of oxygen and  $\text{Cl}^-$ -baseline can be mostly explained by dilution/enrichment mechanism caused by gas-hydrate formation and dissociation.

The formation and dissociation history of gas hydrate at two sites is summarized as follows: (1) Sea level had fallen toward the Last Glacial Maximum, and the BGHS moved upward. Methane and heavy oxygen enriched water moved upward as a response to gas-hydrate dissociation: (2) Released methane was again trapped above the new BGHS, and gas hydrates have been concentrated within sandy sediments. The upper BSR in the Dai-ichi Tenryu Knoll area was formed at this time. In the Dai-ni Atsumi Knoll area, released methane would be partly oxidized by sedimentary oxides and hydroxides causing an increase in alkalinity, then carbonates with heavy oxygen were precipitated: (3) the BGHS has migrated downward following the transgression over the last 18000 yr. In the Dai-ni Atsumi area, the relic-BSR corresponding to the upper BSR in the Dai-ichi Tenryu Knoll area would disappear by rapid accumulation of gas hydrate by high methane flux, whereas in the Dai-ichi Tenryu Knoll area, it would remain long after the BGHS migration due to lower methane supply. Eustatic sea-level change has brought the hydrostatic pressure change, and gas hydrate stability zone would also change. However, the amount of additional gas hydrate accumulation would obliterate or facilitate the development of the relic BSR behind.