Mud diapirism impact in methane hydrate-bearing formation

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By ROV KAIKO's submersible dive in 2003, clastic ejecta with characteristic rock texture was obtained in a submarine mud volcano, the Kumano Knoll No.4, in Kumano Basin in the eastern Nankai Trough. The clastic ejecta is a quartz arenite whose quartz and feldspar grains are tremendously fractured and their fractures are filled with authigenic calcite. The arenite is considered to have been derived from a horizon within the Kumano Basin but not from the underlying old accreted sedimentary body, because the arenite is rich in biotite as well as the Kumano Group on land.

The rock texture indicates the arenite was fractured in vertical deviatoric stress. Judging from the minimum size of the fractured quartz grain (less than 0.5 mm), the arenite likely suffered pressure fracturing in more than 50 MPa (Ham et al., 1990). However, such high confining pressure cannot be considered to happen in usual state of the Kumano Basin formation which is 2,000 m deep and has 1-2 km thick sediments. Accordingly, we considered that the quartz arenite could have been fractured by abnormally high pressure originating in explosive cubical expansion by methane hydrate dissociation due to thermal effect when a mud diapir reaches to the methane hydrate-bearing bed.

The calcite filling in the fractures of the arenite grains has rather higher oxygen and carbon isotope ratios (delta18O=+33.8 permil-SMOW, delta13C=+24.5 permil-PDB) than authigenic calcite in any other clastic ejecta (delta18O=+26.9˜+29.1 permil-SMOW, delta13C=-10.7˜-3.8 permil-PDB). The especially high oxygen isotope ratio of the arenite can be thought to have been from isotope fractionations led by formation of methane hydrate and by temperature decreasing due to endothermal reaction while methane hydrate dissociation. And, the particularly high carbon isotope can be considered to have been caused by concentrated residuals of hydrogenophilic methanogeneration (methanogeneration by CO2 reduction).

And moreover, in the eastern Nankai Trough, it is known that sandy beds well-cemented with highly saturating methane hydrate indicate a very high stiffness and low permeability. So, an abnormally high pressure compartment can be locally created in the methane hydrate formation.

Consequently, the rock texture, oxygen and carbon isotope ratios, and nature of methane hydrate-bearing sediments all support the idea that the quartz arenite was fractured in abnormally high pressure in methane hydrate formation.