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Methane-induced dolomite "chimneys" on the Kuroshima Knoll, Ryukyu islands, Japan

Rika Takeuchi [a,*], Ryo Matsumoto [a], Shigenori Ogihara [a], Hideaki Machiyama [b]

[a] *Department of Earth and Planetary Science, Graduate School of Science, the University of Tokyo, Japan*
[b] *Deep Sea Research Department, Japan Agency for Marine-Earth Science and Technology, Japan*

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Abstract

The Kuroshima Knoll is about 26 km south of Ishigaki Island in the southern part of the Ryukyu Arc. The area is considered to be the source area of "The 1771 Yaeyama Earthquake Tsunami", which was due to the submarine landslide caused by an earthquake. It has been cleared from some investigations using "Dolphin 3K" and "Shinkai 2000" that there are large-scale dead *Calyptogena* colonies, many gravels of fallen dolomite chimneys and carbonates on the top of the Knoll [Matsumoto, T., Uechi, C., Kimura, M., 1997; Machiyama, H., Matsumoto, T., Matsumoto, R., Hattori, M., Okano, M., Iwase, R., Tomaru, H., 2001b.]. Carbonates of Kuroshima Knoll have various shapes and macroscopic textures. These have been classified into 4 types; shell crust (pavement), chimney, burrow, and nodule. It is clear that all chimney and burrow carbonates are composed of dolomite, while shell curst and nodule are composed of calcite, sometimes both calcite and dolomite. These carbonates are considered to have been formed by cold seep, because they are characterized by the light carbon isotopic ratio (semi-biogenic) and the heavy oxygen isotopic ratio. This suggests that methane hydrate layers develop under this survey area and the water that has the heavy oxygen and the light carbon isotopic ratio is derived from the dissociation of methane hydrate.

Keywords: Methane hydrate; Cold seep; Carbonate; Dolomite chimney

1. Introduction

Methane hydrate is one of the biggest reservoirs in the carbon cycle, because it has approximately 3000 times of atomospheric methane volume, and the estimated total amount of carbon in the world's methane hydrates is about 10^4 Gt (Kvenvolden, 1988). Methane hydrate is commonly stable under conditions of high pressure and low temperature environments. Temperature and pressure fluctuations throughout the Earth's history have apparently favored periodic methane release, and hence affect the carbon cycling and Greenhouse Warming on Earth cite. The formation and dissociation of methane hydrate, therefore, has important meaning to the understanding of global environmental changes.

Submarine cold seeps have been reported at many sites all over the world. Cold seeps play an important role in authigenic carbonate precipitation, because the methane in seep water is oxidized by sulfate within sediments to increase dissolved bicarbonate and alkalinity. Carbonate minerals can provide chemical information about long-term variations in interstitial water at cold seep sites. Some methane hydrate sites are associated with authigenic carbonates, e.g. Hydrate Ridge offshore Oregon, the Gulf of Mexico, the Gulf of Cadiz (Greinert et al., 2001; Pinheiro et al., 2003; Sassen et al.,

* Corresponding author. Science Bd. #1, 7-3-1 Hongo, Bunkyo-ku Tokyo, 113-0033, Japan. Tel.: +81 3 5841 4021; fax: +81 3 5841 4555.
E-mail address: lika@eps.s.u-tokyo.ac.jp (R. Takeuchi).

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2004). The presence of authigenic carbonates on the methane hydrate sites indicates that methane-rich fluids related to methane hydrate feed them. If authigenic carbonate precipitation occurs following to methane hydrate dissociation, they should reflect methane hydrate characteristics. Thus, authigenic carbonates may provide a clue to evaluating the role of methane hydrate in geological history.

The Kuroshima Knoll is located off the Ishigaki Island, the southern Ryukyu Arc, Japan (Fig. 1). A number of active methane gas venting and seep sites, large chemosynthetic communities, and carbonate rocks have been discovered atop the knoll at the water depth of 650–800 m by several surveys using JAMSTEC Deep-tow camera system, ROV "Dolphin-3K", and manned submersible "Shinkai 2000" (e.g., Matsumoto et al., 1998; Machiyama et al., 2001a,b). Furthermore, huge numbers of dead *Calyptogena* shells have also been found atop the knoll. It is clear that the Kuroshima Knoll is not only modern seep site but also past cold seep site. Methane hydrate, which may be thin (from 0 to 70 m thick), can exist theoretically at the Kuroshima Knoll, though no obvious BSR was reported. Since methane hydrate is very sensitive to the change of the pressure and temperature condition, subtle changes would cause dissociation of methane hydrate. The purpose of this paper is to investigate the mechanism of carbonates precipitation at active cold seep on the Kuroshima Knoll, and to discuss the evidence of past methane hydrate dissociation.

Cold seep carbonates have various shapes. A key distinguishing feature of these carbonates is "carbonate chimney," and many carbonate chimneys have been reported, e.g. Oregon margin (Ritger et al., 1987), North Sea (Hovland et al., 1987), southern New Zealand (Orpin, 1997), Gulf of Cadiz (Díaz-del-Río et al., 2003), South China Sea (Chen et al., 2005). Carbonate chimneys basically have a cylindrical shape with a vent hole at the center, and occasionally they protrude from the seafloor, just like black smokers at hydrothermal sites. A mechanism of chimney formation has been explored at several seep sites, but interpretations are diverse and it hasn't been inconclusive. Some authors suggest that chimneys form above the seafloor (Ritger et al., 1987; Kulm and Suess, 1990), and to the contrary, other authors suggest that they were formed below the seafloor (Orpin, 1997). Furthermore, carbonate chimneys have various mineralogic compositions, such as calcite, aragonite, and dolomite (Ritger et al., 1987; Takeuchi et al., 2001; Díaz-

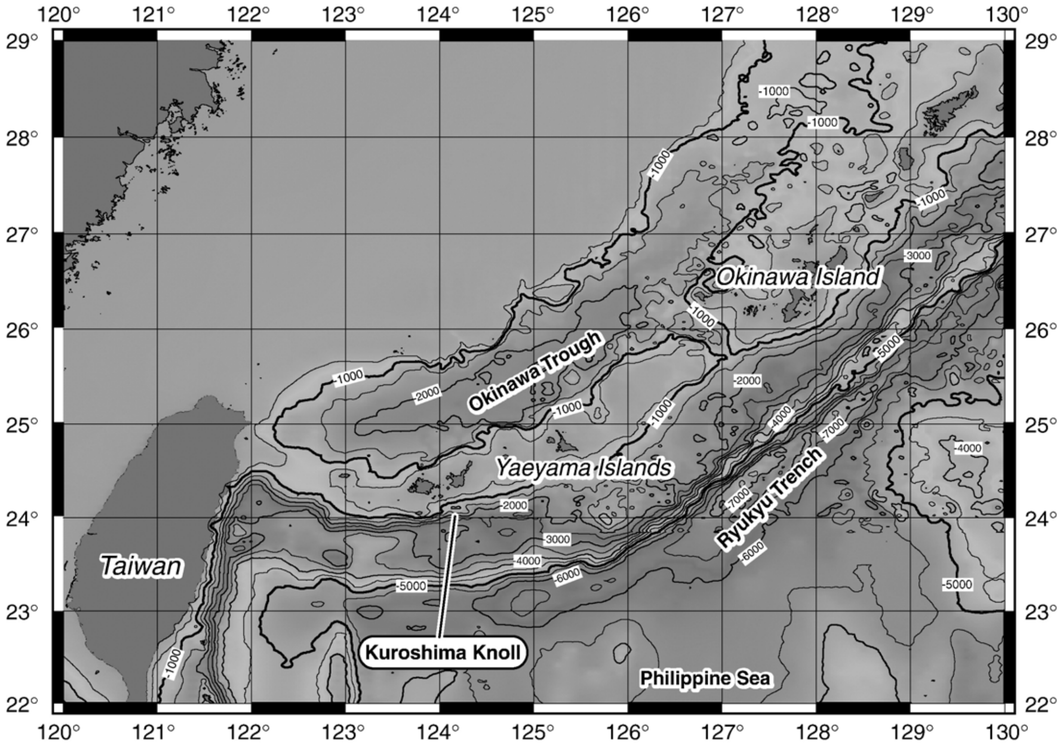

Fig. 1. Location map of the Kuroshima Knoll. The Kuroshima Knoll is about 26 km to the south of Ishigaki Island and is located on the north of the Ryukyu Trench. The top part of the knoll ranges in depth from 800 to 630 m, and the foot part reaches 2400 m deep. The Kuroshima Knoll is considered to be the source area of "The 1771 Yaeyama Earthquake Tsunami", which was due to the landslide caused by an earthquake (Matsumoto et al., 1997).