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BSRs and Associated Reflections as an Indicator of Gas Hydrate and Free Gas Accumulation: An Example of Accretionary Prism and Forearc Basin System along the Nankai Trough, off Central Japan

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Abstract: Multi-channel seismic data obtained from the Nankai accretionary prism and forearc basin system has been studied to elucidate the migration and accumulation process of gas to the BGHS and examine the distribution pattern of BSRs and characteristic reflections associated with them.

BSRs are distributed widely in the Nankai accretionary prism and associated forearc basins (33,000 km^2) and 90 % of them have migration and recycling origins. The widest distribution of the BSRs can be seen at the prism. A correlation between the BSR distributions and prism size shows that the BSRs tend to be more well-developed in a prism of large size. This suggests that a large prism may produce much amount of gas-bearing fluids that migrate to the BGHS and form the BSRs (tectonic control). In the forearc basins, the BSRs are identified at topographic highs, anticlines and basin margins (structural control).

The upward migration of gas-bearing fluids is carried out through permeable sand layers and as a result, the distribution of BSRs is confined to alternating beds of sand and mud facies (sedimentary control). However, if there is enough time for upward migration and accumulation of gas to the BGHS, the BSRs can be generated widely in low-permeable mud facies (time control).

Those results imply that structural, tectonic, sedimentary and time controls are primary factors to decide the distribution of BSRs in the Nankai Trough area.

Keywords: BSR, gas hydrate, methane hydrate, fluid migration, seismic, accretionary prism, forearc basin, Nankai Trough

1. Introduction

Bottom simulating reflections (BSRs) are widely recognized in seismic profiles around the Japanese island-arc system and their total distribution area is 44,000 km^2. This BSR distribution is highly heterogeneous and 75 % of them are recognized at well-developed present accretionary prism (the Nankai accretionary prism) and forearc basins (the Enshu Trough, the Kumano Basin, the Muroto Basin, the Tosa Basin and the Hyuga Basin) along the Nankai Trough (Baba and Yamada, 2000). The Nankai accretionary prism has developed as a large accretionary wedge since the Miocene (e.g. Shipboard Scientific Party, 1991) due to the NNW-directed subduction of the Philippine Sea Plate (Seno and Maruyama, 1984). Most accreted sediments are coarse terrestrial clastics which are derived from the Japan island-arc system. The segment of the Philippine Sea Plate subducting at the Nankai is called 'Shikoku Basin', a former back-arc basin of the Izu-Bonin arc, thus the heat flow at Nankai is exceptionally high (Yamano et al., 2003). The forearc basins have been formed between the older accreted belt of the Japanese island-arc and the Nankai accretionary prism, and subsequently filled with sediments of submarine fan systems (Fig. 1).

It is commonly believed that BSRs are resulted from a change in P-wave velocity; from high-velocity sediments containing gas hydrates to lower velocity sediments containing a small amount of free gas (e.g. Yuan et al., 1999; Ecker et al., 1998). Therefore, BSRs are regarded as an indicator of hydrate-bearing sediments that can be a seal to the free gas underneath.

Two models for the gas hydrate accumulation have been proposed. In the first, gas hydrates are generated in-situ from organic carbon contained in the sediments of a gas hydrate zone (Claypool and Kaplan, 1974) whereas in the second, gas hydrates are derived from upward migrating fluids containing light hydrocarbons (Hyndman and Davis, 1992). In addition to these models, the gas hydrates are re-concentrated by "hydrate recycling" (e.g. Paull et al., 1994; von Heune and Pecher, 1999) in which gas hydrates form again from upflow of dissociation gas derived from pre-existing gas hydrates when the base of the gas hydrate stability field (BGHS) moves upward by tectonic uplift or with burial.

In this study, we try to elucidate an accumulation process of gas hydrates in the Nankai accretionary prism