Characteristics of BSRs in South Shetland Continental Margin, Antarctica

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Introduction

Bottom Simulating Reflector (BSR), which has strong reflectivity and reverse polarity in the seismic profiles, indicates the gas hydrate stability zone. BSR is one of the strong evidences supporting for the existence of gas hydrate and free gas, which is located in under the BSR (Shipley et al., 1979). There are some seismic evidences on the continental slope of the South Shetland continental margin, Antarctic Peninsula (Jin et al., 2003; Lodolo et al., 1993; Tinivella et al., 2002). Because any gas hydrates have not been recovered yet in this region, a lot more seismic data is required to investigate the distributions and the characteristics of buried gas hydrates and free gas.

Purpose of this study is to find the distributions of buried gas hydrate and investigate the relationship between seafloor topography and free gas distribution with BSR reflection coefficients. We conducted 2D and pseudo-3D seismic survey using a multi-channel seismic system on the South Shetland continental margin during the 2005-09 austral summer (Fig. 2). We tried to define the distribution of BSRs using 2D seismic profiles from Korea Seismic Line 2005-08 (KSL05-08) and Antarctic Data Library System (SDLS) data. And we investigate the characteristics of free gas distribution with bathymetry calculating BSR reflection coefficients using pseudo-3D seismic data, KSL09.

Tectonic Setting and Study Area

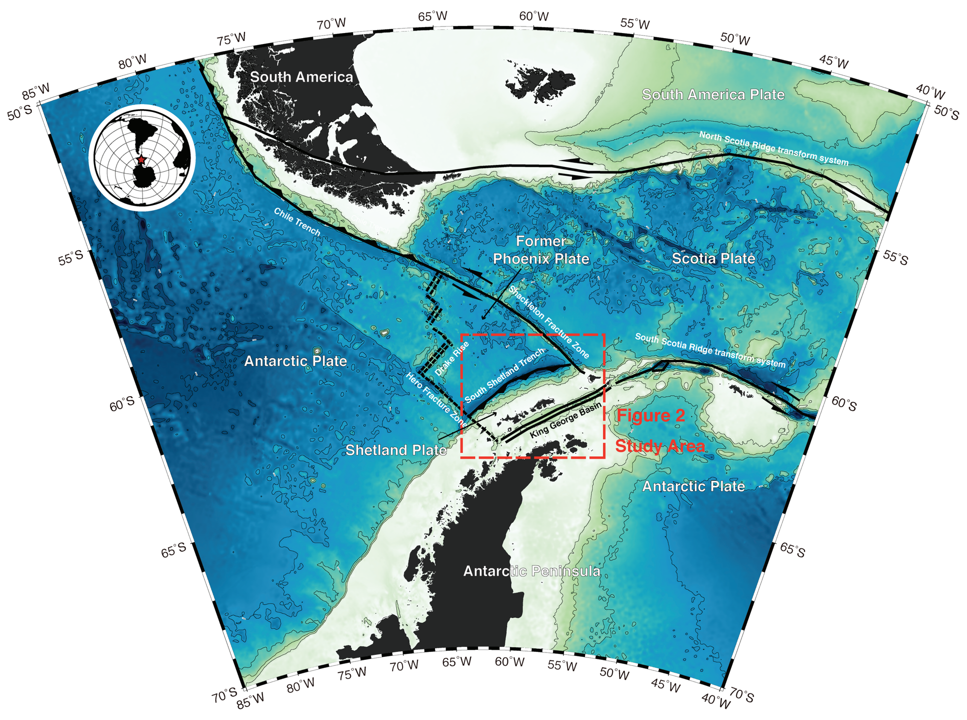

Figure 1. Regional map showing the tectonic setting of the region between South America and Antarctic Peninsula. Developed after Klepeis and Lawver (1996).

There are many tectonic structures, which are the trench, the passive margin, the fracture zone, the extinct spreading ridges and a back-arc in the region between South America and Antarctic Peninsula. The subduction of the former Phoenix Plate almost stopped after the cessation of spreading in Drake Passage at about 3.3 Ma (Barker, 1982; Jin et al., 2009; Kim, 2005; Larter et al., 1997). Study area is located on the continental slope of the South Shetland continental margin, Antarctic Peninsula.

Korea Seismic Line 2005 - 2009 and Gas Hydrate Distributions

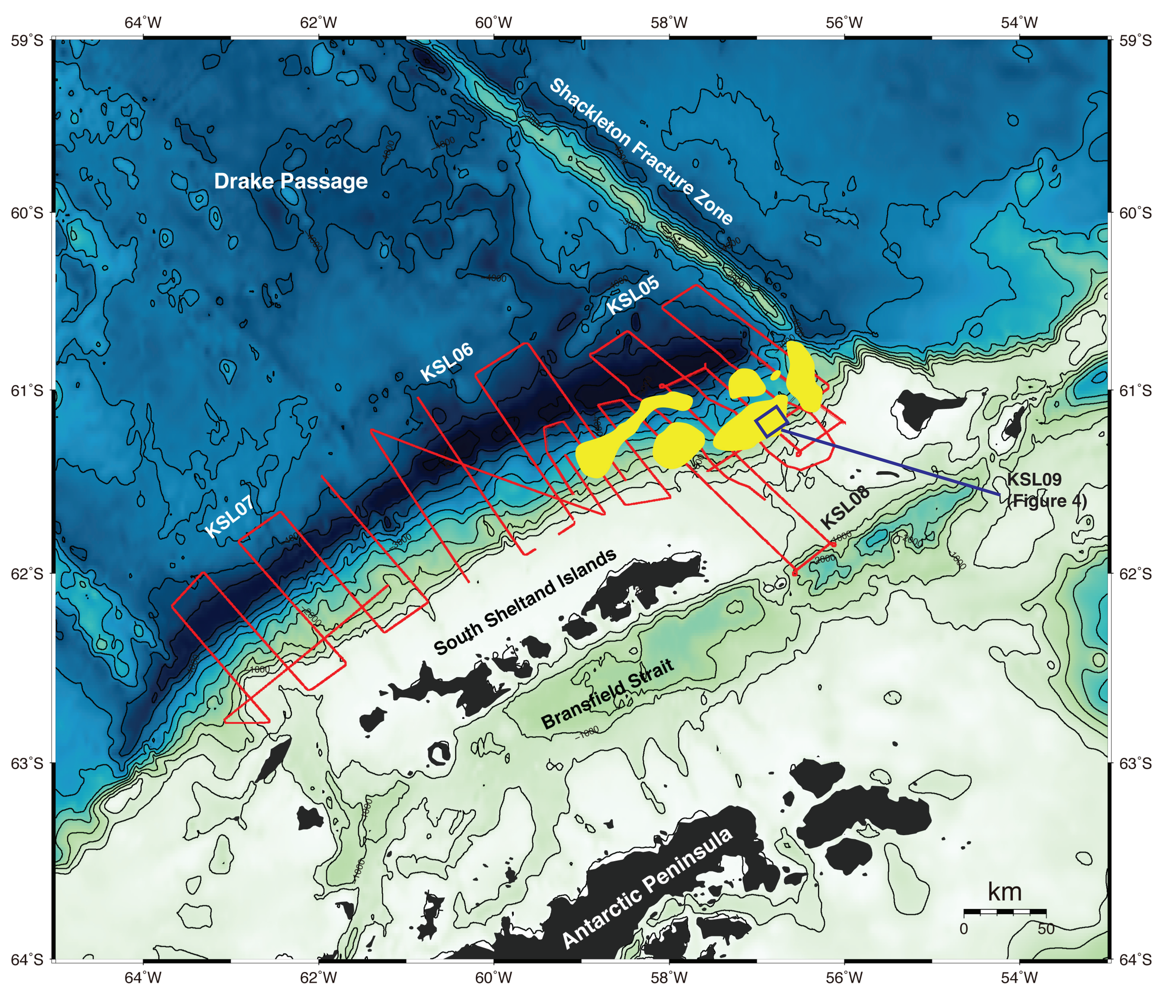

Figure 2. Track chart of Korea Seismic Line 2005 - 2009 (KSL05 - 09). Solid red line is the seismic survey lines. Purple open box is location of KSL09. Yellow region indicate buried gas hydrate.

Korea Seismic Line 2005 - 2008 (KSL05 - 08) crossed the South Shetland Trench (SST) and the continental slope. KSL09 was located in northeastern part of the continental slope. We calculated the area of the gas hydrates that was based on exrapolation and interpolation method of the connection of seismic line segment which has strong BSRs (Figure 3). The area of gas hydrates estimated to be about 3,600 km^2. To estimate total volume of buried gas hydrate, we applied a degree of saturation as 6.3 % which is from Jin et al (2003). Estimated volume of methane gas in the layer of gas hydrate was about 6.3X10^{10} m^3.

BSRs in Seismic Section

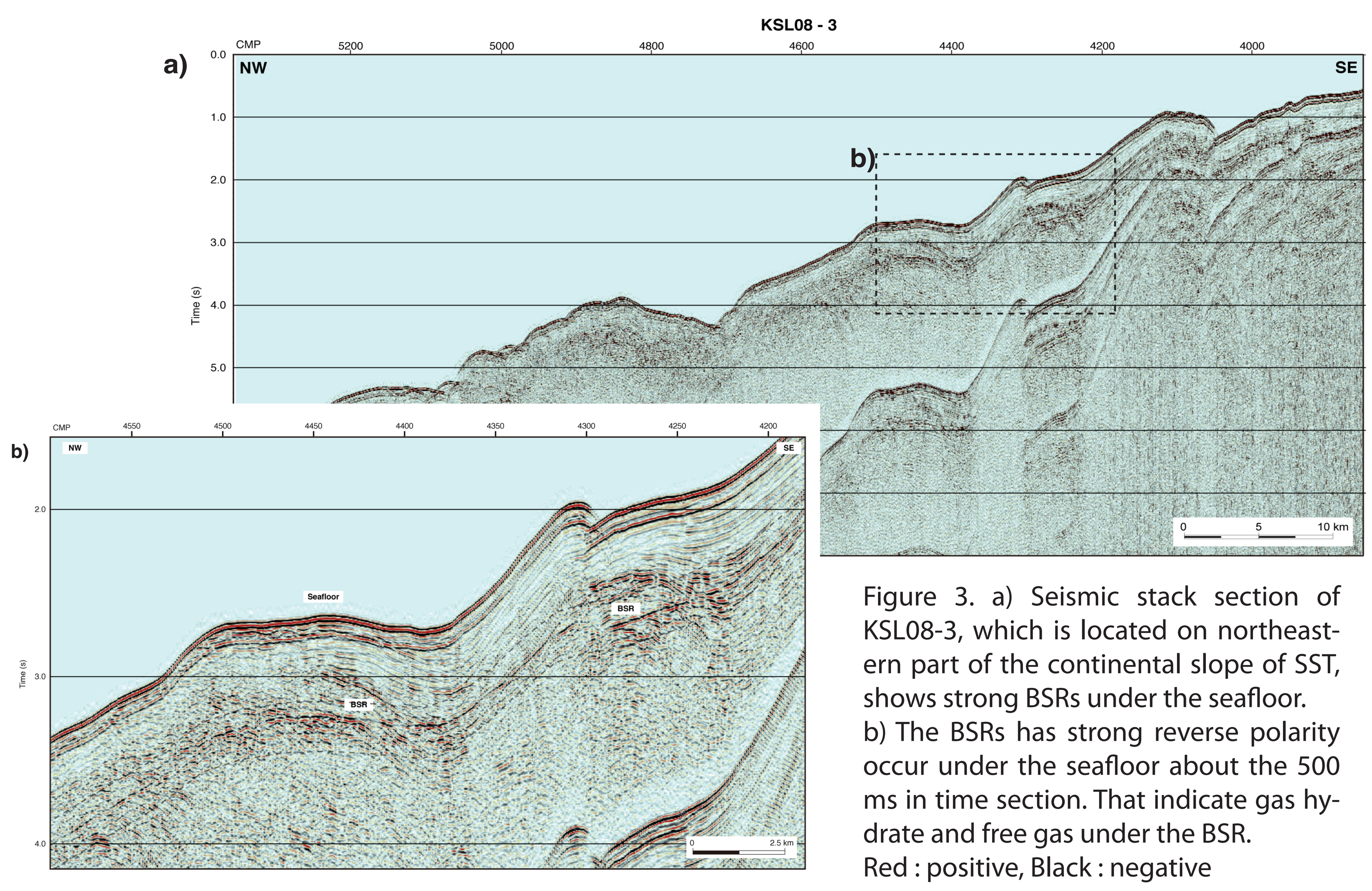

Figure 3. a) Seismic stack section of KSL08-3, which is located on northeastern part of the continental slope of SST, shows strong BSRs under the seafloor.
b) The BSRs has strong reverse polarity occur under the seafloor about the 500 ms in time section. That indicate gas hydrate and free gas under the BSR.
Red : positive, Black : negative

BSR Reflection Coefficient and Seafloor Topography in KSL09

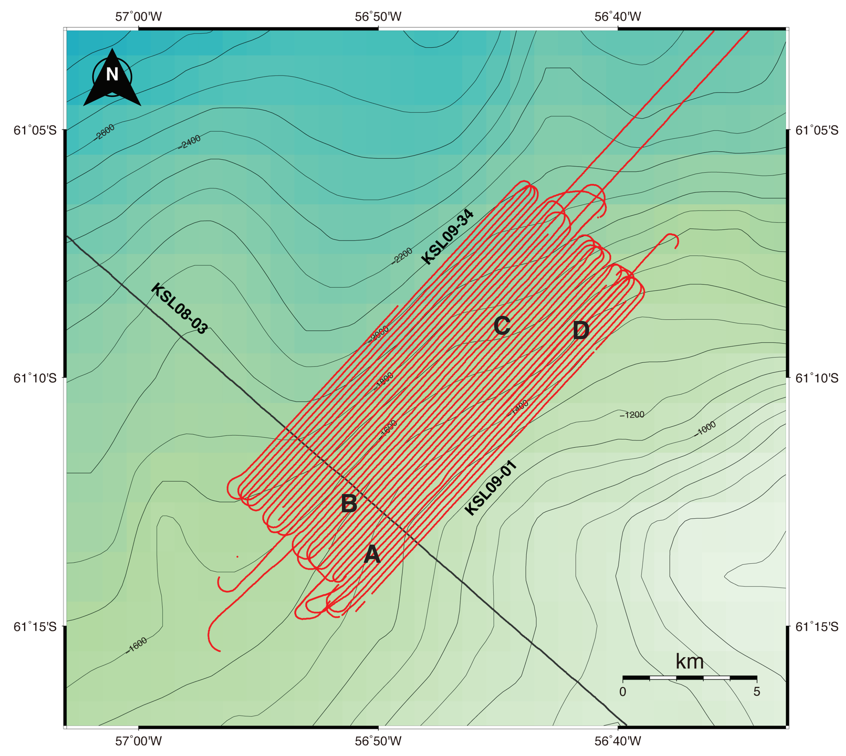

Figure 4. Track chart of Korea Seismic Line 2009 (KSL09). KSL09 consist of the 34 lines and each line has 200m intervals.

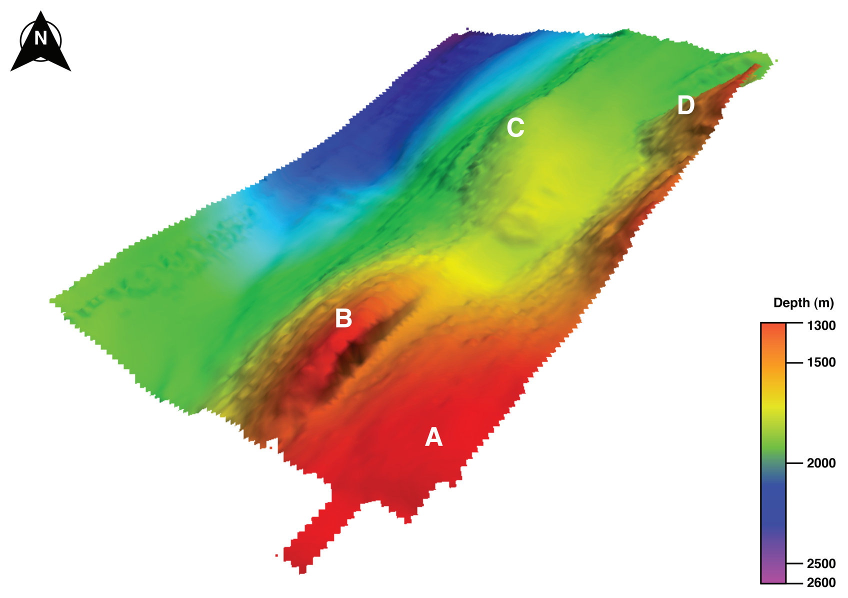

Figure 5. Seafloor topography of KSL09. The dip direction of this region is the northwest. This picture is made by the data set from multibeam (swathe) echosounder.

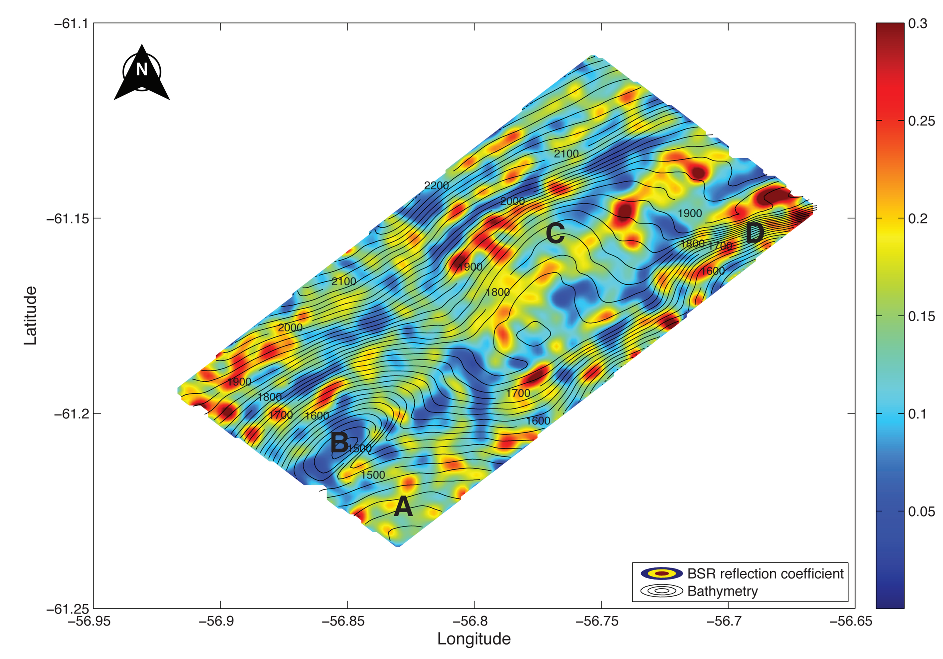

Figure 6. BSR reflection coefficient with seafloor topography. Color contour : BSR reflection coefficient, Black black contour : Seafloor topography

KSL09 was pseudo-3D seismic data that consist of thirty four 2D sesimic lines. We calculated BSR reflection coefficient using KSL09 and compare with seafloor topography. *

To investigate reflection coefficient at the BSR, we picked the value of seafloor reflection amplitude, multiple amplitude and BSR reflection amplitude in the seismic profiles. And then we calculated depth ratio between seafloor and BSR applying the velocity information of this region from Tinivella et al. (2000). We got the BSR reflection coefficients and compared with seafloor topography.

Point A is topographic high has gentle slope (Figure 5). The value of BSR reflection coefficients is in the range of 0.17 to 0.20 at the point A (Figure 6).

Point B has steep slope at the southeatern face that looks like fault or broken slope (Figure 5). At the top of the point B has low BSR reflection coefficients (Figure 6).

Point C is topographic high, which distributed broad area with gentle slope (Figure 5). BSR reflection coefficient is in the range of 0.18 to 0.23 and some abnormal values (Figure 6).

Point D is very steep slope (Figure 5). There is high BSR amplitude at the northeastern slope of slope (Figure 6).

*** Calculation of BSR reflection coefficient**

$$SF_{amp} = Source \times SF_{rc} \quad (1)$$

$$MT_{amp} = Source \times SF_{rc} \times SS_{rc} \times SF_{rc} \times \frac{1}{2} \quad (2)$$

$$\frac{MT_{amp} \times 2}{SF_{amp}} = SS_{rc} \times SF_{rc} \simeq -SF_{rc} \quad (SS_{rc} \simeq -1) \quad (3)$$

$$BSR_{amp} = Source \times (1 - SF_{rc}) \times BSR_{rc} \times (1 + SF_{rc}) \times \frac{1}{D_{ratio}} \quad (4)$$

$$BSR_{rc} = \frac{BSR_{amp} \times D_{ratio}}{SF_{amp}} \times \frac{SF_{rc}}{(1 - SF_{rc}^2)} \quad (5)$$

$SFamp$: Seafloor amplitude
$MTamp$: Multiple amplitude
$SFrc$: Seafloor reflection coefficient
$SSrc$: Seasurface reflection coefficient
$BSRrc$: BSR reflection coefficient
$Dratio$: Depth ratio between seafloor and BSR

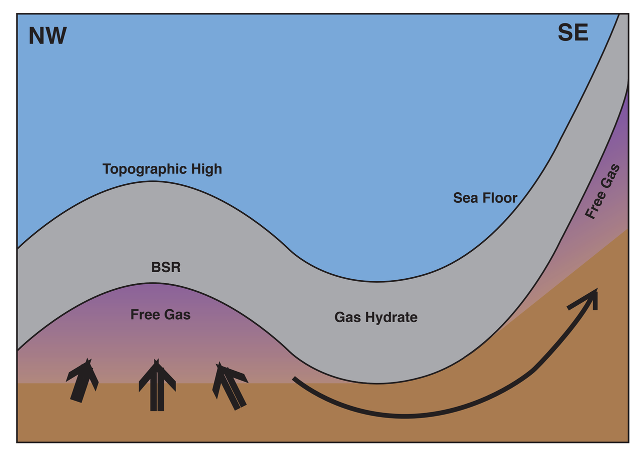

Figure 7. Schematic illustration of free gas concentration and migration under the seafloor topographic high.

Discussion

1. BSRs are mainly distributed on northeastern part of the South Shetland Trench.

Buried gas hydrates are estimated to located on northeastern part of the continental slope of study area, while there are no strong BSRs on the rest of the continental slope. There has been known to stop the subduction at The South Sheltand Trench. But there is a difference of tectonic setting between southwestern and northeastern part of the SST. We roughly guess that this different tectonic environment affects gas hydrate generation. So we need more study about relationship between the generation of gas hydrate and the difference of tectonic environment.

2. Correlation between BSR reflection coefficients and Seafloor topography

First we expected that the concentration of free gas occurs under the seafloor topographic high, since impermeable BSR, which is formed along the seafloor, play a role as cover (Figure 7). Concentrated free gas increses difference of density with gas hydrate layer that cause high BSR reflection coefficients at the topographic high. Fink and Spence (1999) and Lin et al. (2009) showed the correlation between BSR refection coefficient and seafloor topography. KSL09 shows that high BSR amplitude at the topographic highs except point B and several places. We supposed that point B is slipped land, so this unusual structure cause reflection wave scattering or increase permeability of the layer of gas hydrate.

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