High-resolution seismic images of gas hydrate-bearing sediments in the Sea of Okhotsk

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1. Introduction

Gas hydrate-related features appear to be completely different images with respect to frequency [1,2]. For example, the bottom simulating reflectors (BSRs) occur as a sharp and strong reflector parallel to the seafloor on multichannel seismic profiles using low frequency seismic sources like airgun, whereas the BSR is not distinct or appears as diffuse high-amplitude reflections (HARs) around the base of the hydrate stability zone (BHSZ) on the profiles using high frequency sources like sparker or 3.5 kHz sub-bottom profiler. With the high-resolution seismic images obtained during the Leg 1 (cruise LV31) of the CHAOS project (2003) (Fig. 1), we examined gas hydrate- related features in gas hydrate-bearing sediments in the Sea of Okhotsk in this study.

2. The BSR

On all seismic profiles acquired using sparker (200-1200 kHz) during the CHAOS Leg1, the BSRs are generally not visible. The sharp and continuous reflector like the BSR occurs in the local area at the sub-bottom depth of 180 ms beneath the water depth of 1000-1050 ms in TWTT on the profile LV31-32-SA (Fig. 2).

3. The high-amplitude reflections (HAR) around the BHSZ

Instead, all profiles of Leg 1 reveal the HARs at the sub-bottom depth of 150-200 ms below the seafloor (Fig. 2). The HARs generally mimic the seafloor, and their depths coincide nearly with the BSR depths that are clearly defined on the nearby low frequency seismic profiles obtained by POI during KOMAX Project in 1999 [A. Obzhirov, personal communication]. Similar HARs were shown on several high-resolution seismic profiles of other study areas (i.e.

in Fig. 6 of Vanneste et al. (2001) and as ER in Figs. 4, 5 and 6 of Vanneste et al (2003)) [1,3]. The HARs are thought to be related to free gas present in pore space of the sediments beneath the hydrate stability zone [4].

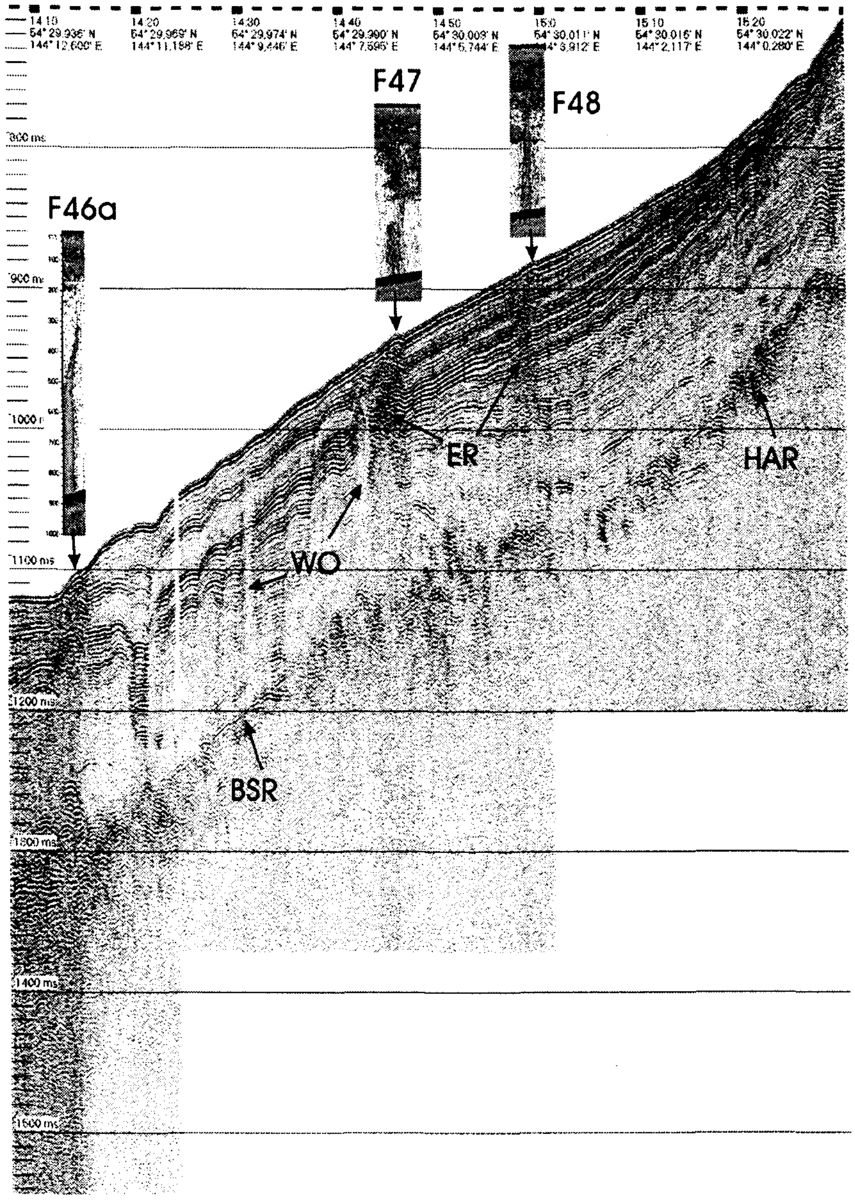

Fig. 2. High-resolution seismic profile of LV31-32. F46a, F47, and F48 (color insets) are gas flares. BSR: bottom simulating reflector, ER: enhanced reflection, HAR: high-amplitude reflectors, WO: wipe-out.

4. Wipeouts and enhanced reflection zones of the acoustic chimneys

All seismic profiles show many narrow near-vertical zones (acoustic chimneys) which seem to extend from HARs at the BHSZ near the seafloor or occasionally to intersect the seafloor. Most chimneys are associated with the bathymetric expressions. The chimneys show two different seismic reflection characteristics: (1) Some chimneys appear relatively narrower and white-colored vertical zone of little to no coherently reflected energy (wipeout: WO) as shown on profile LV31-21-2-SA. (2) Others show relatively wider and diffuse dark-color (enhanced reflection: ER) vertical zone as shown in profile LV31-32-SA (Fig. 2). Occasionally, some WO chimneys are converted to the ER chimneys near seafloor.

Wood et al. (2002) interpreted the WO chimney as gas chimney associated with upward heat and fluid flux, in which the seismic energy can be absorbed by gas [2]. But there are no velocity anomalies (like velocity pull-down) below the WO chimneys on the profile (Fig. 2), so the WO chimneys would be caused by amplitude blanking due to a saturation of gas hydrate.

The exact geological cause of the ER chimneys is ambiguous. The reflection pattern of the ERZ chimney is somewhat similar with that of the HAR at the BHSZ on the profiles. One possible interpretation is that the ER chimney could also be caused by free gas provided from a circuit (for example, faults) in the chimney along which heat and fluid flux migrates upward. Diffuse or alterative saturation of gas/gas hydrate would cause to enhance reflection of the sediments in/around the chimney.

We suggest that the occurrence of two different seismic reflections in the chimneys, the WO and the ERZ, could be controlled by certain parameters (concentration, physical properties etc) of gas/gas hydrates in the chimney.

5. Gas chimneys in sub-seafloor and gas flares in seawater

A lot of gas emanation sites from sub-seafloor into seawater, where gas bubbles form gas flares, have been discovered at the Sakhalin margin. The gas flares were also well detected during hydroacoustic survey (using mainly 12 and 19.7 kHz) of the CHAOS project.

With high-resolution acoustic and hydroacoustic profiles that were obtained on the same survey tracks, we examined the relationship between gas chimneys and gas flares. As shown on profile LV31-32-SA (Fig. 2), gas flares in the study area are very closely correlated with topographic expression above the ER chimneys. So it is noted that the ER chimneys are more strong active circuits of gas migration from sub-surface into the seafloor.

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