## BSR pull-up phenomena revealed by high-resolution 3D seismic survey in the shallow gas hydrate deposit area off Joetsu, Niigata Prefecture

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Three-dimensional distribution of the bottom simulating reflectors (BSRs) as well as the characterization of gas chimney structures beneath the gas hydrate mounds offshore Joetsu, have been precisely revealed by a high-resolution three-dimensional seismic survey (HR3D).

In the HR3D data, pull-ups of BSR up to 80 msec (TWT) are observed beneath the gas chimney structures, suggesting the existence of high velocity materials deposited between the sea floor and the BSRs. Such high velocity materials, mainly gas hydrates, cause the reduction of travel times to induce shallowing of BSRs in the time domain seismic sections. The observed pull-ups are concordant with the estimated pull-ups based on the LWD p-velocity data and the amount of pull-up seems to be proportional to the concentration of the hydrates in the gas chimneys. Therefore, the distribution of the BSR and the amount of its pull-ups could be used for the provisional evaluation of the hydrate potential.

BSRs are thought to be the base of gas hydrate stability zone (BGHS), but in some cases in this area, there are discrepancies between the BSRs observed in the seismic data and the depths of BGHS which are estimated from the geothermal gradient and the P - T condition in the methane phase diagram. In general, BSRs tend to be shallower than BGHS. Possible causes of this phenomenon are:

(a) Due to the difference in the wavelength and the propagation paths, LWD may have measured higher velocities than the velocities deduced from the HR3D data. This may cause the depth-to-time converted velocity logs to be apparently shallower than the depths in the HR3D sections.

(b) Very local geothermal anomalies near the LWD well sites, such as abnormal high heat flows, high thermal gradients, low thermal conductivities, etc. This could upheave the BGHS to some degree.

(c) BSR tracking errors in the seismic interpretation.

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