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3D Seismic Velocity Structures Associated with BSRs and Gas Hydrate Accumulations on Joetsu Knoll in the Japan Sea

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Characteristics of BSRs

In the eastern margin of Japan Sea, gas hydrates in shallow sediments are characterized by blanking or gas chimney associated to mounds and pockmarks on the seabed. SadoW 3D seismic survey was conducted by METI offshore Niigata in 2008. 3D seismic data on Joetsu Knoll shows aligned BSR bumps on the ridge characterized by structural and velocity pull-ups associated to seabed morphology initiated mainly by large-scale methane seepage.

In this area, multiple BSRs are commonly observed. BSR map was illustrated for the shallowest. For BSR identification, we prepared the curves of seabed depth vs. thickness of BGHS below seabed as a function of geothermal gradients with seabed temperatures. Estimated BGHS is governed by several unknown factors. BSR shows acoustic impedance change and corresponds to BGHZ or top of free gas. Free gas exists if mass fraction of upward flux of gas exceeds its solubility in liquid. Once fraction is less than its solubility, separation of BGHZ and BGHS occurs.

On the ridge of Joetsu Knoll, aligned BSR bumps are conspicuous and have upward correspondence to mounds and adjacent pockmarks on the seabed, some of which appear to be related to subvertical faults interpreted as venting passes, which show blanking. Pull-up effects of higher velocity above them exaggerate relief of bumps. Along 2D sliced lines, acoustic velocity is estimated by continuous velocity analysis. Zone of higher velocity more than approx. 1700m/s spreads above BSR, which sandwiches relatively lower velocity zone. Below BSR bumps, two types of spreading of lower velocity zones is prominent, i.e., downward and horizontal on strong reflectors.

Blanking has multifold background; intense gas hydrates formation, free gas venting passes and other seismic wave attenuation/scattering phenomena. Important point is that apparent amplitude features are dependent on the frequency bands of respective surveys. It has not been commonly mentioned that amplitude behaviors alone could not rule out others as possible origins. Velocity information is important to reason probable origins. Lower velocities just above BSR show velocity smearing related to resolution limit of the current velocity analysis. Note short scale complex subsurface structure deteriorates the accuracy of velocity estimate in conventional velocity analysis. This shortcoming shall be overcome by more advanced approaches for fine and accurate mapping. Velocity evaluations by FWI as an example are taken for some velocity model inversion.

Seismic line along LWD locations

GR14 LWD survey was conducted in 2014 by METI. On L18_Line 6 of METI SK13 AUV/SBP survey, a 2D sliced seismic line is taken along the line of GR14 sites D1-1 and D10-1 from 3D seismic data and velocity structure map is generated. At site D1-1 for LWD1410, seismic blanking is prominent above and below BSR. Just below BSR, lower velocity compartment is striking and prominent blanking zone above BSR shows higher velocity. At site D10-1 for LWD1409, above and below BSR there are no prominent seismic blanking zones. Just above BSR, laterally spreading higher velocity is prominent.

Synthetic seismograms are computed by invariant imbedding method and compared with seismic data. Its frequency band of synthetics with Ricker wavelet source is adjusted to that of seismic data and amplitude of seismic data is adjusted to synthetic seismogram. Synthetic seismograms of LWD sonic show relatively higher amplitudes in later phases are partly caused by assumed density models and/or possible attenuation mechanism for seismic data. LWD resistivity converted to TWT indicates that estimated BGHZ does not correspond to BSR, which suggests higher LWD sonic velocities and/or probable frequency effects under the assumption of no separation of BGHZ and BSR in these locations and no specific site locality.

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Keywords: Gas Hydrate, Blanking, Gas Chimney, FWI, Joetsu Knoll, SadoW 3D Seismic Survey