Marine and Petroleum Geology 35 (2012) 75–90

Contents lists available at SciVerse ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Mass-transport deposits and gas hydrate occurrences in the Ulleung Basin, East Sea – Part 2: Gas hydrate content and fracture-induced anisotropy

M. Riedel [a,*], J.-J. Bahk [b], N.A. Scholz [c], B.-J. Ryu [b], D.-G. Yoo [b], W. Kim [b], G.Y. Kim [b]

[a] Natural Resources Canada, Geological Survey of Canada-Pacific, Sidney Subdivision, 9860 West Saanich Road, Sidney, BC, V8L4B2, Canada
[b] Korea Institute of Geoscience and Mineral Resources (KIGAM), Daejeon, South Korea
[c] School of Earth and Ocean Science, University of Victoria, Canada

ARTICLE INFO

Article history:
Received 6 September 2011
Received in revised form
11 November 2011
Accepted 14 March 2012
Available online 28 March 2012

Keywords:
Mass-transport deposits
Gas hydrate
Fracture anisotropy
Seismic facies mapping

ABSTRACT

Mass-transport-deposits (MTDs) and hemipelagic mud interbedded with sandy turbidites are the main sedimentary facies in the Ulleung Basin, East Sea, offshore Korea. The MTDs show similar seismic reflection characteristics to gas-hydrate-bearing sediments such as regional seismic blanking (absence of internal reflectivity) and a polarity reversed base-reflection identical to the bottom-simulating reflector (BSR). Drilling in 2007 in the Ulleung Basin recovered sediments within the MTDs that exhibit elevated electrical resistivity and P-wave velocity, similar to gas hydrate-bearing sediments. In contrast, hemipelagic mud intercalated with sandy turbidites has much higher porosity and correspondingly lower electrical resistivity and P-wave velocity.

At drill-site UBGH1-4 the bottom half of one prominent MTD unit shows two bands of parallel fractures on the resistivity log-images indicating a common dip-azimuth direction of about $\sim 230^\circ$ (strike of $\sim 140^\circ$). This strike-direction is perpendicular to the seismically defined flow-path of the MTD to the north-east. At Site UBGH1-14, the log-data suggest two zones with preferred fracture orientations (top: $\sim 250^\circ$, bottom: $\sim 130^\circ$), indicating flow-directions to the north-east for the top zone, and north-west for the bottom zone. The fracture patterns may indicate post-depositional sedimentation that gave rise to a preferred fracturing possibly linked to dewatering pathways. Alternatively, fractures may be related to the formation of pressure-ridges common within MTD units.

For the interval of observed MTD units, the resistivity and P-wave velocity log-data yield gas hydrate concentrations up to $\sim 10\%$ at Site UBGH1-4 and $\sim 25\%$ at Site UBGH1-14 calculated using traditional isotropic theories such as Archie's law or effective medium modeling. However, accounting for anisotropic effects in the calculation to honor observed fracture patterns, the gas hydrate concentration is overall reduced to less than 5%. In contrast, gas hydrate was recovered at Site UBGH1-4 near the base of gas hydrate stability zone (GHSZ). Log-data predict gas hydrate concentrations of 10–15% over an interval of 25 m above the base of GHSZ. The sediments of this interval are comprised of the hemipelagic mud and interbedded thin sandy turbidites, which did contain pore-filling gas hydrate as identified from pore-water freshening and core infra-red imaging. Seismically, this unit reveals a coherent parallel bedding character but has overall faint reflection amplitude. This gas-hydrate-bearing interval can be best mapped using a combination of regular seismic amplitude and seismic attributes such as Shale indicator, Parallel-bedding indicator, and Thin-bed indicator.

Crown Copyright © 2012 Published by Elsevier Ltd. All rights reserved.

1. Introduction

As part of the Korean gas hydrate program, systematic regional 2-D reflection seismic data were acquired across the Ulleung Basin, East Sea (Fig. 1) to characterize the depositional environment and to map gas hydrate accumulations mainly by identifying the bottom-simulating reflector (BSR) (e.g. Ryu et al., 2009; Lee et al., 2005; Park et al., 2008). Additionally, a 3-D seismic data set was acquired in the south-eastern region of the Ulleung Basin thought to potentially contain gas hydrate based on initial interpretations of the BSR occurrence and wide-spread seismic characteristics including seismic blanking and elevated interval velocities. The Ulleung Basin Gas Hydrate Drilling Expedition 1 (UBGH1) in 2007 (see Fig. 1 for location of drill sites) was conducted to verify the presence of gas hydrate in the basin and consisted of a logging-

* Corresponding author. Tel.: +1 250 363 6422.
E-mail address: mriedel@nrcan.gc.ca (M. Riedel).

0264-8172/$ – see front matter Crown Copyright © 2012 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.marpetgeo.2012.03.005

while-drilling (LWD) operation at five sites (UBGH1-1, UBGH1-4, UBGH1-9, UBGH1-10, and UBGH1-14) followed by a coring operation at three of those sites (UBGH1-4, UBGH1-9, and UBGH1-10). Additional wire-line logging and vertical seismic profiling was conducted at Site UBGH1-9. Drilling and coring at Site UBGH1-4 encountered gas hydrates within sandy turbidites near the base of the gas hydrate stability zone (GHSZ). The other two sites of UBGH1 with coring-operations were located within prominent cold-vent features (also referred to as seismic chimneys), and gas hydrate was recovered in massive form as vein- and fracture-fill (Kim et al., 2011; Bahk et al., 2011). Linkages between fracture-formation and gas hydrate occurrences within these type of chimney structures have been investigated also as part of other drilling campaigns off India (e.g. Riedel et al., 2010a; Holland et al., 2008), the northern Cascadia margin (Riedel et al., 2006), as well as in the Gulf of Mexico (e.g. Cook et al., 2008). Especially in the fracture systems drilled offshore India, a high degree of anisotropy has been found to alter the log-measurements of electrical resistivity and P-wave velocity (e.g. Cook and Goldberg, 2008) due to the alignment of the logging tools in the borehole with the almost vertical fracture-planes. As a result, the gas hydrate concentrations inferred from traditional techniques such as Archie's-law (Archie, 1942; Collett and Ladd, 2000) are skewed to unrealistically high values when compared to results from pressure-coring or pore-water freshening (Lee and Collett, 2009).

At Sites UBGH1-4 and UBGH1-14 the LWD-data show several depth intervals with prominent strata-bound fractures, but these sites are not within chimney structures. In this study, we use the LWD borehole images of resistivity to delineate fracture-orientation and combine these results with seismic data to understand linkages between the depositional environments of mass-transport deposits (MTDs) and gas hydrate formation. This study is linked to the companion paper by Scholz et al. who used seismic attributes to define seismic characteristics and flow-direction of a MTD encountered at Site UBGH1-4. Understanding the sedimentary processes (e.g. deposition of MTDs, hemipelagites, and turbidites) in the Ulleung Basin and associated sediment types (sand or clay) is an important component of the gas hydrate petroleum system and helps in the prediction of appropriate porous media that are known as preferred hosts for gas hydrates.

2. Geologic setting, sedimentation patterns and general gas hydrate occurrence-regimes

The Ulleung Basin is a continental back-arc basin and lies on the eastern margin of the Eurasian Plate, separated from the Pacific by the Japanese Islands. The East Sea containing the Ulleung, Japan, and Yamato basins originates in the Oligocene with an extensional phase extending to the middle Miocene (32–10 Ma). Crustal thinning and seafloor spreading was followed by convergence linked to a change of the direction of plate motion in the late Miocene as part of the subduction along the Japanese Island arc as well as back-arc closure and crustal shortening (Lee and Suk, 1998). The East Sea is still in the state of compressive deformation today. Lee et al. (2001) mention two distinct phases of different sedimentation patterns consisting of mainly MTDs during the late Neogene and extensive turbidite and hemipelagic sedimentation since the Pleistocene. Uplift and deformation in the south and southeast of the basin due to back-arc closure are seen as causes for the enormous volumes of sediments found in the basin (Lee et al., 2001).

The seafloor of the Ulleung Basin is fairly smooth in the centre and dips gently from 2000 m water depth to 2500 m in the northeast (Park et al., 2008). Slide and slump deposits occur mainly on the upper steeper slopes of the southern part of the basin whereas debris flows are found at the lower slopes of the basin. As the depositional energy of the mass-transport processes decreases with increasing distance from the source, interbedded turbidites and hemipelagic sediments were deposited further to the northeast of the basin. As the number of mass-transport flows retreated since the late Miocene, a prominent change in sedimentary facies occurred in the central basin, with a transition from high energy MTDs to low-energy turbidites and hemipelagic sediments. The occurrence of clustered chimney-like features with their massive gas hydrate occurrences (as seen e.g. in Site UBGH1-9 and UBGH1-10) in form of vein- and fracture fill is constrained to the northern part of the basin where the upper-most 200–300 m of sediments are mostly comprised of interbedded turbidites and hemipelagic sediments (Horozal et al., 2009; Ryu et al., 2009). More isolated chimney-like features, associated with faults were also found in other parts on the basin (Fig. 1).

Sediments within the gas hydrate stability zone at the southern portion of the basin are dominated by MTDs with some minor events containing hemipelagic and interbedded turbidite sediments. Gas hydrate was encountered here at Site UBGH1-4 within the thin sandy turbidite intercalated with hemipelagic mud. As an example of this change in sedimentation pattern across the basin, seismic line 05GH-43 is shown in Figure 2 crossing the three coring sites UBGH1-4, UBGH1-10, and UBGH1-9 (from south to north). The occurrence of a prominent BSR is apparently limited to the southern portion of the basin. It is difficult to discern it in the northern basin around the chimney features because sedimentary layers of the area are mostly developed parallel to the seafloor. In this northern basin, the depth of BSR is possibly much shallower due to the regional increase in heat flow (Horozal et al., 2009).

3. Data and methods

The seismic data used for this study are explained in the companion paper (Scholz et al). Here, we use the 3-D seismic attributes related to similarity (also referred to as seismic coherence) to define the flow-direction of the MTD intersected at Site UBGH1-4. We also use two crossing 2-D seismic lines at Site UBGH1-14 (~60 km southwest from UBGH1-4) to link observations from log-data to seismic reflections. LWD-data (gamma-ray, bulk-density, porosity, P-wave velocity, as well as electrical resistivity) from Sites UBGH1-04 and UBGH1-14 are shown in Figure 3. Matching characteristic log-trends to seismic reflections was achieved by calculating synthetic seismograms (Fig. 4) from the LWD P-wave velocity and density log and estimating representative wavelets from the seismic data crossing the boreholes. A time-depth curve was defined by tying key-horizons (seafloor, BSR) and integrating over the LWD P-wave velocity log.

We calculate gas hydrate concentrations from electrical resistivity log using the empirical Archie (1942) relation, which assumes that gas hydrate forms within the pore-space of the sediment. The cross-plot between formation factor (measured resistivity normalized by the in situ pore-water resistivity) and porosity defines the required empirical constants in the Archie-calculations as listed in Table 1. Only the assumed non-gas hydrate-bearing zones are used in this analysis (upper 70 mbsf and all data below the GHSZ). At Site UBGH1-4 it is possible to use measured in situ pore-water salinity (which varies from 34 ppt at the seafloor to a slightly increased value around 37 ppt at 125 mbsf before decreasing to 35 ppt) and a measured temperature gradient (~90 °C/km) to define the in situ pore-water resistivity. At Site UBGH1-14, we only have log-data but no core. Thus, we assumed uniform pore-water salinity (seawater-values of ~34 ppt) and a reduced geothermal gradient (~65 °C/km) reflecting the regional trends in the basin (as defined by Horozal et al., 2009). For both sites, two sets of porosity-values are available (neutron-porosity

Download English Version:

https://daneshyari.com/en/article/4695855

Download Persian Version:

https://daneshyari.com/article/4695855

Daneshyari.com