Geophysical Research Abstracts, Vol. 9, 05617, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-05617

Methane-hydrate BSRs as indicators of the rates of methane flux in continental margins.

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Bottom-simulating seismic reflectors (BSRs) that are associated with the formation of methane hydrate in continental margins are caused primarily by the reduction of bulk modulus in a zone containing free gas that underlies the hydrate stability field. In cases where methane migrates as free gas through the sediments, the BSR is created at the base of the hydrate stability field, because free gas cannot exist within the hydrate stability field, where it forms hydrate. More generally, methane is advected in solution in pore water, and other processes are needed to raise the concentration of methane above saturation and produce the free-gas zone that causes the BSR. Two processes found to be important were investigated and modelled. The first of these, hydrate recycling, generates gas from the dissociation of hydrate where the base of the hydrate stability field moves upward relative to the matrix of rock containing hydrate, as a consequence of an increase in temperature, uplift of the seabed, a fall in sea level or sedimentation. Secondly, in regions where hydrate is present near, but not necessarily at, the base of the hydrate stability field and the upward fluid flux is low, downward diffusion of methane causes methane concentration to exceed saturation in a thick zone beneath the hydrate stability field, because the methane–water solubility usually decreases downward for several hundred metres below the hydrate stability field. The thickness of free-gas zone is an indicator of fluid flux rate and the concentration of methane in solution. In the end-member situation of the migration of free gas, the free-gas zone can extend as deeply as the source of the gas. Where methane migrates in solution, thick gas zones occur when the rate of fluid flow is low (less than a few tenths of a mm per year). High rates of flow produce thin gas zones. In the absence of hydrate recycling, high rates of fluid flux, but low concentration of methane in solu-

tion, can lead to the occurrence of hydrate in the shallow part of the hydrate stability field without a free-gas zone and, hence no BSR. The models are one-dimensional, so, in nature, the thickness of the free-gas zone can be changed by the lateral flow of gas, once the concentration of gas becomes high enough for it to form a connected fluid. In passive continental margins, where there is generally no net upward fluid flow relative to the seabed, the occurrence of hydrate and BSRs is confined to areas of hydrocarbon production and of localised fluid upflow, such as regions of salt and mud diapirism. In accretionary wedges at active continental margins, the upward net flux caused by tectonically induced dewatering and hydrate recycling driven by tectonic uplift of the seabed combine to create extensive free-gas zones with associated BSRs.