**Supplementary Information**

*Sensitivity of SRZ depth*

The sensitivity of our results to changes in SRZ depth was investigated by adding two sets of model simulations; Case B1 with an SRZ depth equal to 2.5 m (default value is 5 m) and Case B2 with an SRZ depth equal to 7.5 m. The AOM rate is kept at $10^{-8}$ mol cm$^{-3}$ day$^{-1}$ (corresponding to Case A4). The interpretation of these results are far from straight forward, because when the SRZ depth is changed, it influences several parameters. Clearly, when increasing the SRZ depth, the AOM capacity increases which should make the microbial filter more effective, but the initial hydrate mass is also altered which affects the amount of over pressure that builds up within the sediments. This in turn effects the vertical CH$_4$ transport in both low permeability sediments (through hydraulic fracture dynamics) and high permeability sediments (through Darcy's law). Also the travel distance from the dissociation front to the seafloor changes, which affects the timing of seafloor CH$_4$ release. It is a complex task to separate these different aspects from the AOM dynamics and therefore, we discuss only the net effect of variations in SRZ depth below.
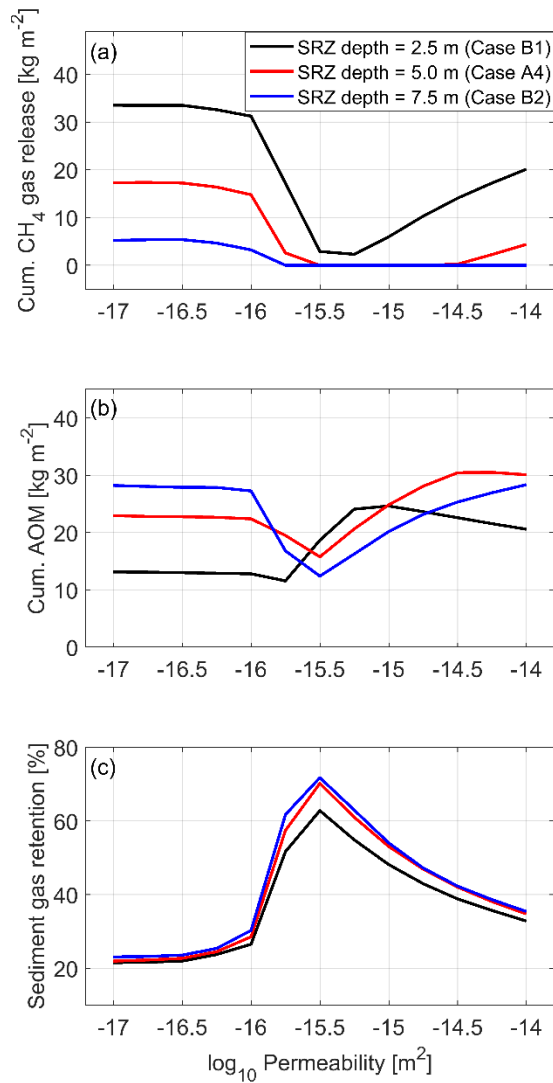
*Figure S1. Sensitivity of the results to changes in SRZ depth. All data are from 200 years into the simulations.*

In terms of CH$_4$ gas escape from the seafloor (Fig. S1a) the trend is quite clear, with fluxes decreasing with increasing SRZ depth. For Case B2 gas is only escaping in the *fracture flow* regime, and the cumulative mass flux is fairly low (~5 kg CH$_4$ m$^{-2}$). In terms of cumulative AOM quantities, the picture is a bit more complex. The clear minimum seen for mid-permeability sediments is not present in the B1 Case. Instead, there is a peak in cumulative AOM for sediments with a permeability of 10$^{-15}$ m$^2$. This is presumably because, with the reduced AOM capacity the microbial filter is most efficient when CH$_4$ percolates slowly through the SRZ, while higher CH$_4$ transport only leads to more gas escaping the microbial filter. The sediment gas retention (Fig. S1c) is surprisingly unresponsive to changes in SRZ depth. The amount of gas still residing within the sediments seems to be a function of the sediment transport capacity alone – if the

CH₄ supplied to the SRZ ends up in the AOM pool or in the ocean is another matter (larger SRZ depth leads to a more effective microbial filter as discussed above).

*Sensitivity of Sh*

The sensitivity of our results to changes in $S_h$ was investigated by adding two sets of model simulations; Case C1 with $S_h$ equal to 2.5% (default value is 5%) and Case C2 with $S_h$ equal to 7.5%. The AOM rate is kept at $10^{-8}$ mol cm$^{-3}$ day$^{-1}$ (corresponding to Case A4). While the AOM capacity stays constant when changing $S_h$, the initial hydrate mass is altered which affects the amount of CH₄ in the system and the amount of over pressure that builds up. This in turn effects the vertical CH₄ transport in both low and high permeability sediments. The net effect of these changes is discussed below.
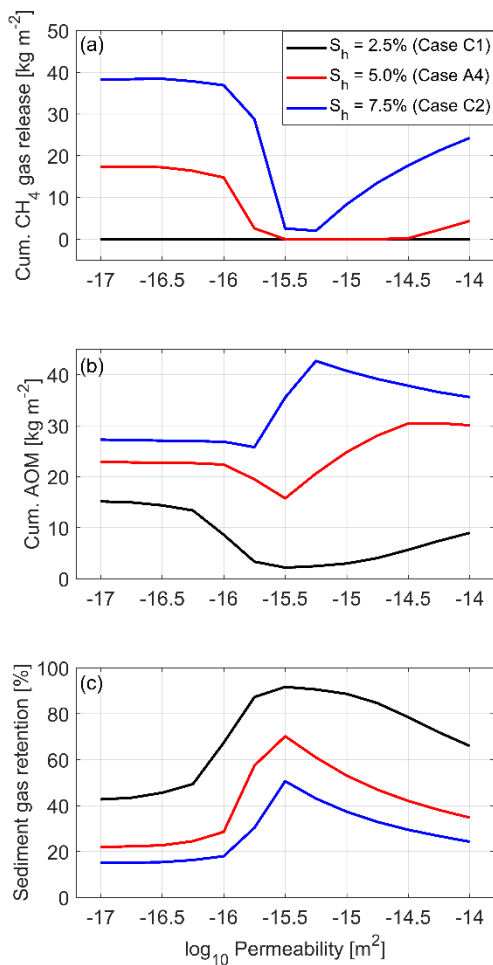
*Figure S2. Sensitivity of the results to changes in initial hydrate saturation. All data are from 200 years into the simulations.*

Naturally, the cumulative CH₄ gas escape quantities increase with increasing Sh (Fig. S2a). The same is true for the cumulative AOM (Fig. S2b), but the picture is somewhat more complex. For Case C1, all the

CH$_4$ that reaches the SRZ is oxidized (as evident from the fact that no gas is escaping the sediments at any permeability, Fig S2a). Looking at Case C2, we note that it has a shape very similar to the corresponding Case B1 curve (Fig. S1b). We interpret the peak in cumulative AOM for sediments with a permeability of $10^{-15.25}$ m$^2$ as a maximum in AOM efficiency, where higher CH$_4$ transport only leads to more gas escaping the microbial filter. As already discussed, the sediment gas retention is mainly a measure of the CH$_4$ transport capacity of sediments. Decreasing S$_h$ leads however to lower over-pressures building up within the sediments which leads to a less effective CH$_4$ transport towards the seafloor and thus higher CH$_4$ gas retention (percentage wise).