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Supplement of

Can anaerobic oxidation of methane prevent seafloor gas escape in a warming climate?

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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 CH₄ 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 CH₄ 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.

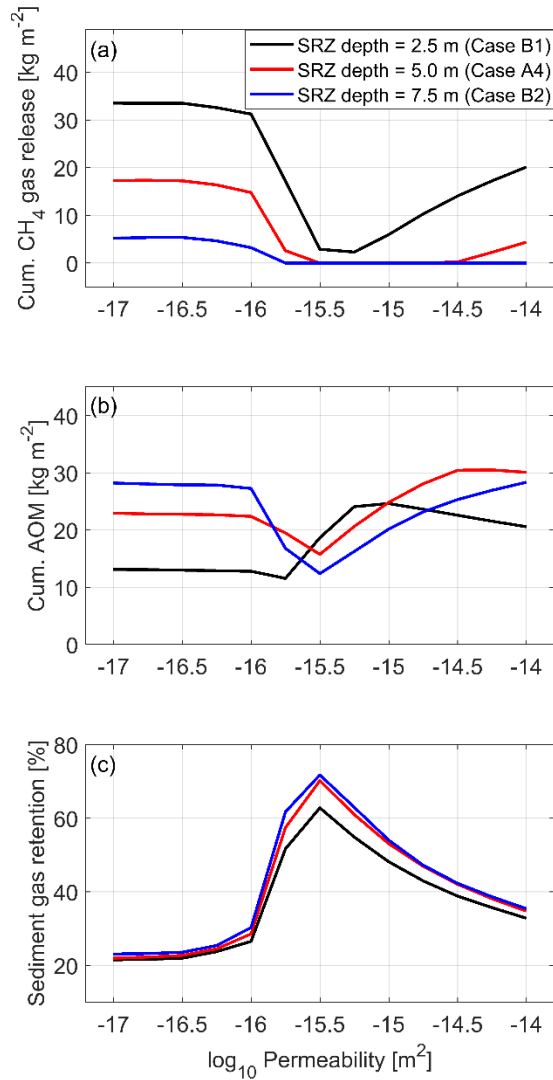


Figure S1. Sensitivity of the results to changes in SRZ depth. All data are from 200 years into the simulations.

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 ($\sim 5 \text{ kg CH}_4 \text{ m}^{-2}$). 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 S_h

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.

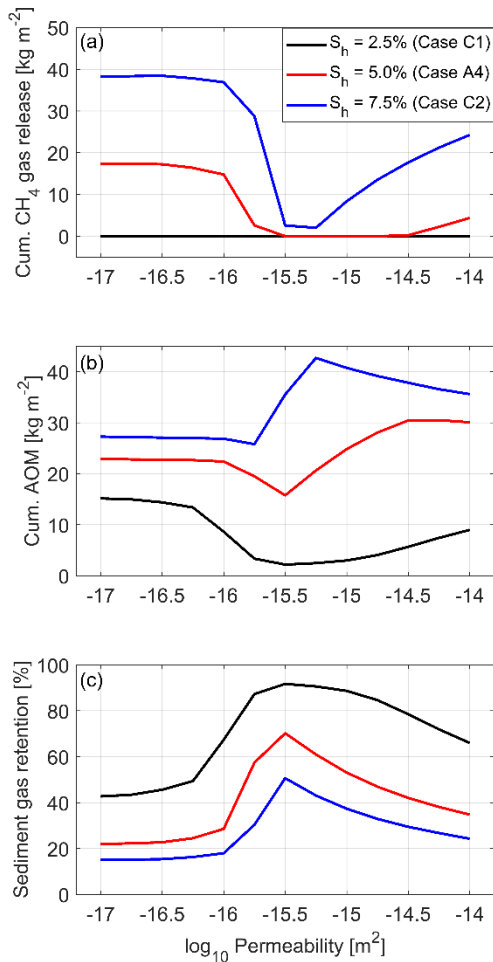


Figure S2. Sensitivity of the results to changes in initial hydrate saturation. All data are from 200 years into the simulations.

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

CH₄ 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 $10^{-15.25} \text{ m}^2$ as a maximum in AOM efficiency, where higher CH₄ transport only leads to more gas escaping the microbial filter. As already discussed, the sediment gas retention is mainly a measure of the CH₄ transport capacity of sediments. Decreasing S_h leads however to lower over-pressures building up within the sediments which leads to a less effective CH₄ transport towards the seafloor and thus higher CH₄ gas retention (percentage wise).

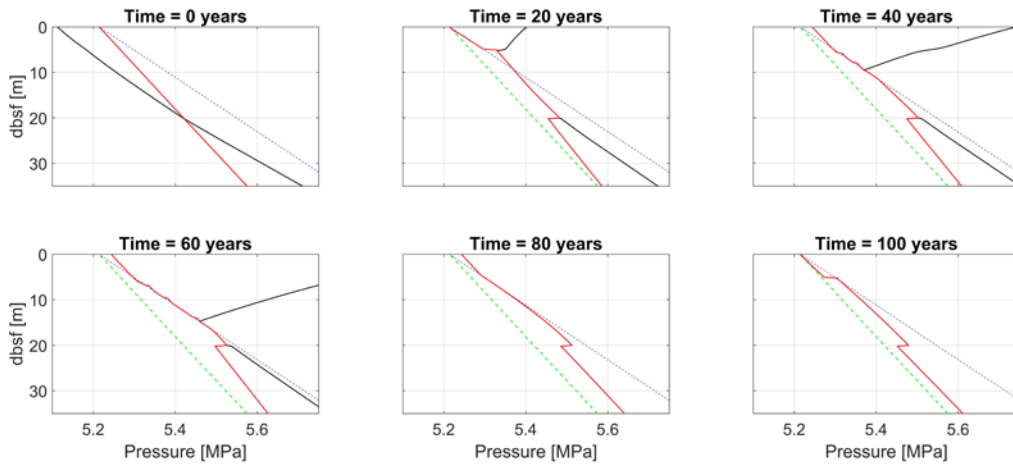


Figure S3. Pressure evolution in Case A4 with sediment intrinsic permeability of 10^{-17} m^2 . In situ pore pressure (red), phase transition boundary (black), initial hydrostatic pressure (dashed green), and critical pressure (dashed blue) as a function of depth at different times. Initially, the GHSZ extends to 20 mbsf as indicated by the intersection between the in situ pressure and phase transition boundary curves. Fractures start forming after 35 years, as pore pressure reaches the critical pressure, which keeps pressure from building up farther. Note the train of fractured zones approaching the seafloor at time equal to 40 and to 60 years (see Fig. 8d for another visual representation of the hydraulic fracture propagation within the sediment column).