Progress Report
Agency: DOE NETL
Project title: Integrating Natural Gas Hydrates in the Global Carbon Cycle
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Executive Summary

During this quarter, we have addressed two specific aspects towards the improvement of our two-dimensional model for modeling the formation and stability of methane hydrates under the seafloor. We have made further general progress in making our code more robust, and exploring the effects of varying the various parameters in the model. Furthermore, we presented our work at the NETL meeting at Georgia Tech a couple of weeks ago and at the AGU meeting in San Francisco in December.

The two specific aspects towards the improvement of our model are as follows. (A) First, we have explored the possibility of adding a highly-permeable wedge within the passive margin, by varying the river velocity used in the simulation. This addition of a highly-permeable wedge has not yet been completely successful, due to the thin computational layers that result at the unconformity that develops when the river velocities are varied. (B) Second, we have developed sedimentation schemes that give approximately the correct spatiotemporal profiles of the accumulation of both sediments and organic matter along the passive margin off the East coast of the U.S.

Approach

A) We have explored the possibility of adding a highly-permeable wedge within the passive margin, by varying the river velocity used in the simulation.
    a. We added the capability to simulate the emergence of high-permeability layers of sediment due to the deposition of large-grain sediments. The variation of the river velocities was the technique we used for depositing large-grain sediments in the bottom set of the passive margin.
    b. This addition of a highly-permeable wedge has not yet been completely successful, due to the thin computational layers that result at the unconformity that develops when the river velocities are varied and the sedimentation rate becomes nearly zero in the topset of the margin. For the time being, this model enhancement will be put on hold.
B) We have developed sedimentation schemes that give approximately the correct spatiotemporal profiles of the accumulation of both sediments and organic matter along the passive margin off the East coast of the U.S.
    a. We investigated the impact of using a non-constant value for the organic carbon fraction of the sediments. The spatial profiles of particulate organic matter (POC) at the seafloor were put into a lookup table that depends on water depth, based upon the work of Mayer (2002) and of Hedges and Keil (1995). This results in a distribution of POC that is:

i. near zero at shallow depths,
ii. reaches a maximum at ~1-2km depth, of about 3% POC, and
iii. goes down to <0.5% POC in the deep bottom set of the passive margin.

b. The result of using this distribution of POC is that most of the hydrate (>50% pore-volume fraction of hydrate) is produced in the sediments below the margin where the sea depth is ~1-2km, whereas there are lesser amounts of hydrate (<10%) develop below the bottom-set where the sea depths are greater than 2-3km.
c. We also further developed a sedimentation model, based upon Pirmez *et al.* (1998), which gives these passive-margin physical properties, which are consistent with those of the U.S. East coast margin near Blake Ridge:
    i. a sharply-oblique foreset slope,
    ii. A depocenter sedimentation rate near the foreset of ~20 cm/kyr, and
    iii. A bottomset sedimentation rate of ~10 cm/kyr.

Future

The next steps for this project include:

1) Further improvement in the vertical resolution of the 1D version of our model for model comparison purposes;
2) Understanding fluid flow when flow velocities are measured after subtracting the co-moving sedimentation velocity of the solid material.
    a. The goal here is to add anisotropic permeabilities with the horizontal permeability ~100x greater than the vertical permeability, in this co-moving frame of reference.
    b. Positive co-moving vertical fluid flow may allow dissolved CH_4 to escape from the seafloor, in addition to the CH_4 that escapes in gaseous form (i.e., bubbles).
3) Adding a radioactive Iodine-129 tracer in order to understand better the evolution of pore-water age and its relation to the respiration of organic carbon. (Fehn, Snyder & Egeberg, 2000). This will be useful for the 'Understanding fluid flow' item above.
4) Adding a formation factor to the model of diffusive transport.
5) Adding deep CO_2 silicate-weathering reactions, in order to get the calcium levels to go up, and also in order to be more realistic geochemically. The addition of the deep CO_2 silicate-weathering reactions has been inspired by CO_2 sequestration papers by: Matter & Kelemen, 2009; Xu, Apps & Pruess, 2004.