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GRAIN SCALE MODELING OF COUPLED FLOW AND MECHANICS: IMPLICATIONS FOR METHANE HYDRATE IN OCEAN SEDIMENTS

*** Antone K. Jain[1] and Ruben Juanes[2]**

[1] Department of Civil and Environmental Engineering
Massachusetts Institute of Technology
77 Massachusetts Ave, Room 48-114
Cambridge, MA 02139, USA
Email: akjain@mit.edu

[2] Department of Civil and Environmental Engineering
Massachusetts Institute of Technology
77 Massachusetts Ave, Room 48-319
Cambridge, MA 02139, USA
Email: juanes@mit.edu

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ABSTRACT

Methane hydrates are crystalline ice-like compounds, composed of methane molecules caged in a lattice of water molecules. Hydrates form naturally at high pressures and low temperatures, like those typical of most of the ocean floor, or below permafrost. It is believed that an enormous pool of carbon exists in the form of methane gas and methane hydrate in the ocean floor along the continental margins (some estimates of the size of this reservoir suggest that the amount of energy is of the order of all other fossil fuels combined). It also seems likely that this pool of carbon plays an important role in the global carbon cycle, and in massive submarine landslides.

Our research is aimed at testing the following hypothesis: the coupling between drainage and fracturing, both induced by pore pressure, determines whether methane gas entering the hydrate stability zone (HSZ) is converted completely to hydrate. Here we present a discrete element method (DEM) to model the strong coupling that takes place between the pore fluids and the mechanical behavior of the sediment.

In a discrete element method, each element or grain is an individual entity, identified by its size, mass and moments of inertia. The movement of a grain is dictated by the net force and moment acting on it. For systems in which the pore pressure is negligible, the interactions between particles are limited to grain contacts. Here, in contrast, we account rigorously for the presence of one or more fluids in the pore space by incorporating two additional sets of forces: one set due to pore fluid pressures, and another due to surface tension between fluids. We demonstrate the ability of DEM to reproduce core-scale behavior, as measured by triaxial laboratory experiments. The proposed methodology elucidates the depositional environments (grain size, depth, earth stresses) under which migration of methane gas by fracturing of the sediment is favored over capillary invasion. This determines the distribution of methane gas and hydrate which, in turn, has direct implications on the likelihood that gas and hydrate will co-exist, and on the overall size of the energy resource.

References

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