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Methane gas likely spewing into the oceans at a rate much faster than previously believed

PROBLEM

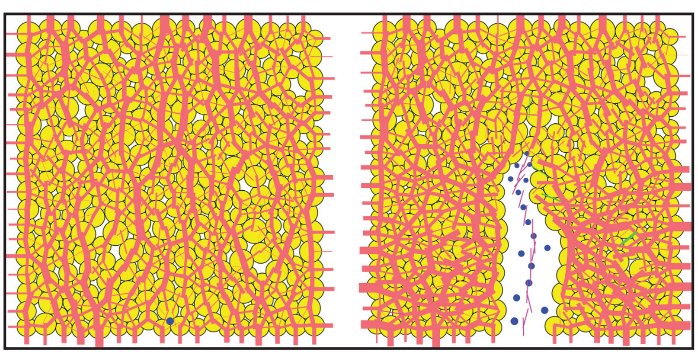
Among the many potential dangers of global warming is the possibility that an additional increase in atmospheric temperatures will initiate the release of methane gas that has been trapped underground as a hydrate in some arctic regions and under the ocean floors. If released, this gas would speed up global warming by trapping the Earth's heat radiation about 20 times more efficiently than does carbon dioxide. The release of subsurface methane into the ocean also has been associated with climate change of the past and future.

APPROACH

Professor Ruben Juanes and recent graduate Antone Jain developed a discrete element model that couples multiphase fluid flow with sediment mechanics to simulate at the grain scale the upward migration of hydrate gas in brine-saturated deformable media. Their model accounts for the presence of two fluids (water and gas) in a pore space by incorporating the forces acting on grains due to pore fluid pressures as well as the surface tension between fluids. The model elucidates the two ways that gas migration may take place: by capillary invasion in a rigid-like medium and by initiation and propagation of a fracture. The researchers find that grain size is the key controlling factor: coarse-grain sediments favor capillary invasion, while fracturing dominates in fine-grain media.

FINDINGS

Jain and Juanes' model elucidates how underground methane in frozen regions would escape and concludes that methane trapped under the ocean may already be escaping through vents in the sea floor at a rate faster than previously believed.



The image at left shows underground methane gas as it begins to invade fine-grain sediment (shown in yellow) by creating a fracture. In the image at right, the blue circles represent pore spaces where the gas has invaded. Graphic / Ruben Juanes

In the hydrate phase, a methane gas molecule is locked inside a crystalline cage of frozen water molecules. These hydrates exist as a layer in underground rock and sub-floor oceanic sediments called the hydrate stability zone or HSZ. Beneath the HSZ, where the temperatures are higher, methane is found primarily in the gas phase mixed with water and sediment. If atmospheric temperatures rise, the HSZ will shift upward, leaving in its stead a layer of methane gas that has been freed from the hydrate cages. Pressure in that new layer of free gas would build, forcing the gas to shoot up through the HSZ to the surface through existing veins and by opening up cornflake-shaped fractures in the sediment.

Using this model and seismic data and core samples from a hydrate-bearing area of ocean floor off the coast of Oregon, Jain and Juanes found that methane gas is very likely spewing out of vents in the sea floor at flow rates up to 1 million times faster than if it were migrating as a dissolved substance in water making its way through the oceanic sediment — a process previously thought to dominate methane transport.

IMPACT

The results indicate that scientists may be greatly underestimating the methane fluxes presently occurring in the ocean and from underground into Earth's atmosphere, which could have implications for our understanding of the Earth's carbon cycle and global warming. The research also explains the short-term consequences of injecting carbon dioxide into the ocean's subsurface. Juanes and Jain conclude that while some of the carbon dioxide would remain trapped as a hydrate, much would likely spew up through fractures.

MORE

This model provides a physical explanation for the recent striking discovery by the National Oceanic and Atmospheric Administration of a short-lived plume 1,400 meters high at the seafloor off the Northern California Margin.

A paper by Jain and Juanes, the ARCO Assistant Professor in Energy Studies, appeared in the Journal of Geophysical Research online Aug. 29.

The Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology is dedicated to balancing the built environment with the natural world. In our research, we seek to understand natural systems, to foster the intelligent use of resources and to design sustainable infrastructure systems.

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