Methane gas likely spewing into the oceans through vents in sea floor

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Scientists worry that rising global temperatures accompanied by melting permafrost in arctic regions will initiate the release of underground methane into the atmosphere. Once released, that methane gas would speed up global warming by trapping the Earth's heat radiation about 20 times more efficiently than does the better-known greenhouse gas, carbon dioxide.

An MIT paper that appeared online Aug. 29 in the Journal of Geophysical Research elucidates how this underground methane in frozen regions would escape and also concludes that methane trapped under the ocean may already be escaping through vents in the sea floor at a much faster rate than previously believed. Some scientists have associated the release, both gradual and fast, of subsurface ocean methane with climate change of the past and future.

"The sediment conditions under which this mechanism for gas migration dominates, such as when you have a very fine-grained mud, are pervasive in much of the ocean as well as in some permafrost regions," said lead author Ruben Juanes, the ARCO Assistant Professor in Energy Studies in the Department of Civil and Environmental Engineering.

"This indicates that we may be greatly underestimating the methane fluxes presently occurring in the ocean and from underground into Earth's atmosphere," said Juanes. "This could have implications for our understanding of the Earth's carbon cycle and global warming."

Above: This video shows underground methane gas invading fine-grain sediment (shown in yellow) by creating a fracture, as predicted by Jain and Juanes' grain scale model. Blue circles represent pore spaces where the gas has invaded. The maroon lines indicate compressive forces between sediment grains. The video shows that the network of compressive forces changes drastically with the evolution of the fracture. The green lines indicate tension between grains, caused by capillary forces that hold the grains together. The network of tension forces also changes with time, as the gas invades the sediment. Video / Ruben Juanes and Antone Jain, MIT.

Methane, the primary component of natural gas, is more abundant in the Earth's atmosphere now than at any time during the past 400,000 years, according to a recent analysis of air bubbles trapped in ice sheets. Over the last two centuries, methane concentrations in the atmosphere have more than doubled. It is estimated that about 60 percent of global methane emissions are tied to human activities like raising livestock and coal-mining, with the rest tied to natural sources such as wetlands, decomposing forests and underground deposits known as methane hydrates.

In the hydrate phase, a methane gas molecule is locked inside a crystalline cage of frozen water molecules. These hydrates exist in a layer of underground rock or oceanic sediments called the hydrate stability zone or HSZ. Methane hydrates will remain stable as long as the external pressure remains high and the temperature low. Beneath the hydrate stability zone, where the temperatures are higher, methane is found primarily in the gas phase mixed with water and sediment.

But the stability of the hydrate stability zone is climate-dependent.

If atmospheric temperatures rise, the hydrate stability zone 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 new fractures in the sediment. A grain-scale computational model developed by Juanes and recent MIT graduate Antone Jain indicates that the gas would tend to open up cornflake-shaped fractures in the sediment, and would flow quickly enough that it could not be trapped into icy hydrate cages en route.

"Previous studies did not take into account the strong interaction between the gas-water surface tension and the sediment mechanics. Our model explains recent experiments of sediment fracturing during gas flow, and predicts that large amounts of free methane gas can bypass the HSZ," said Juanes.

Using their model, as well as seismic data and core samples from a