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Environmentally Friendly CO_2 Storage in Hydrate Reservoirs Benefits From Associated Spontaneous Methane Production

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Abstract

Magnetic Resonance Images (MRI) of core plug experiments shows that CO_2 storage in gas hydrates in porous rock results in spontaneous production of methane, with no associated water production. Exposing methane hydrate to liquid CO_2 causes methane production from the hydrate that indicates an exchange of methane molecules with CO_2 molecules within the hydrate; without addition of heat. Thermodynamic simulations based on Phase Field theory support this assumption and predict similar methane production rates observed in several reproduced experiments. 3D-visualizations of the formation of hydrates in the porous rock and the methane production improve the interpretation of the experiments. Sequestering a greenhouse gas while simultaneously producing the freed natural gas may offer access to the significant amount of energy bound in hydrates and may offer an attractive potential for CO_2 storage. Relative to the potential danger of catastrophic dissociation of hydrate structures, and corresponding collapse of geological formations, the increased thermodynamic stability of the CO_2 hydrate relative to the natural gas hydrate is also a positive issue related to the combined CO_2 storage and gas exploitation strategy.

Introduction

Storage of CO_2 in natural gas hydrate reservoirs by replacing the CH_4 in the hydrate with CO_2 may have some significant attractive potential as this would provide free natural gas and establish a thermodynamically more stable hydrate accumulation. From an energy perspective natural gas hydrates may represent an enormous energy potential as the total energy corresponding to natural gas entrapped in hydrate reservoirs might be more than twice the energy of all known energy sources of coal, oil and gas [1]. The abundance and locations of the natural gas hydrate reserves covers all continents. The source of the methane can be either the microbial degradation of organic matter in shallower sediments or deeper-seated thermogenic methane accumulations. Thermodynamic stability of the hydrate is sensitive to local temperature and pressure but all components in the hydrate have to be in equilibrium with the surroundings if the hydrate is to be thermodynamically stable. Natural gas hydrate accumulations are therefore rarely in a state of complete stability in a strict thermodynamic sense. More typically the hydrate is trapped between clay layers or other structures of low permeability that keeps the system in a state of very slow dynamics. Gas hydrate exposed towards the seafloor will dissociate more rapidly due to very low content of hydrocarbons in the surroundings, as can be observed many places around the world. Even though some of the released methane will be consumed by biological and chemical ecosystems the net flux of methane reaching the surface represents an environmental concern since methane is a more aggressive (~ 25 times) greenhouse gas than CO_2. Although different ecosystems (biological, inorganic, organic) will consume some of the released methane the total flux of methane leaking to the atmosphere is a concern. However, a more serious concern is related to the stability of these hydrate formations. Changes in local conditions of temperature, pressure or surrounding fluids or minerals changes the dynamics of the system and might eventually lead to catastrophic dissociation and subsequent tsunami. The Storegga slide offshore Norway was created by several catastrophic hydrate dissociations. The largest of these is estimated to have occurred 7000 years ago and is believed to have created a massive tsunami [2]. The environmental disaster related to such enormous amounts of released methane to the atmosphere will have dramatic effects on the greenhouse scenario. The replacement of natural gas hydrate with CO_2 hydrate will increase the stability of hydrate formations. The hydrate content in the Storegga area is still significant and estimated to be in the order of 10^{12} m^3 distributed over 4000 km^2. Hydrocarbon exploitation in hydrate regions adds some additional concerns. Drilling operations produce heat and potential risk of local hydrate dissociation. Installation of bottom constructions and equipment in these regions may therefore represent a hazard with a variety of possible disastrous results as discussed by Yahushev & Collett [3].