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Excess Pore Pressure and Slope Failures Resulting From Gas-Hydrates Dissociation and Dissolution

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Abstract

Parameters affecting gas hydrate formation include temperature, pore pressure, gas chemistry, and pore-water salinity. Any change in the equilibrium of these parameters may result in dissociation (gas-hydrate turns into free gas/water mixture) and/or dissolution (gas-hydrate becomes mixture of water and dissolved gas) of the gas hydrate. While, gas-hydrate dissociation at the base of the Gas Hydrate Occurrence Zone (*GHOZ*) is often considered as a major cause of sediment deformation and submarine slope failures the consequence in terms of pore pressure and sediment deformation of the dissolution of the gas hydrate at the top of the *GHOZ* remains neglected. In this study, we quantify and compare the excess pore pressure resulting from gas hydrate dissociation and dissolution. Based on theoretical development it is demonstrated that excess pore pressure and shear discontinuities generated by hydrate dissociation is unlikely to be a hazardous factor. In natural environment, the excess pore pressure generated by hydrate dissociation is bounded by the gas hydrate stability law inducing for a natural temperature increase a limited amount of excess pore pressure and limited shear discontinuities at the base of the *GHOZ*. On the other hand, we show that under natural temperature changes hydrate dissolution at the top of the gas hydrate stability zone, which can occur at a regional scale, is a hazardous process that can lead to catastrophic landslides.

Introduction

For the last 3 decades, several authors have raised serious concerns regarding the possible link between gas hydrate and submarine slope failures. [McIver](#)¹ was amongst the first authors to speculate about this possible link. In the [McIver](#) conceptual model¹, the excess pore pressure generated by

hydrate dissociation and the sediment shear strength decreases (lost of hydrate playing the role of cementing agent between sediment grains) are the two key factors in the slope failure mechanism. The causal factor of the hydrate dissociation in [McIver](#)¹ model is the continuous sedimentation, which induces the upward migration of the base of the Gas Hydrate Stability Zone (*GHSZ*). Afterwards, [Kvenvolden](#)² has stated that an upward movement of the bottom of the *GHSZ* due to an increase of bottom water temperature may accelerate the process of slope failures associated to hydrate dissociation. Different authors have later developed several other hypotheses and theories supposing all that gas hydrate dissociation may lead to important excess pore pressure and lead to sediment deformations and slope instabilities^{3,4,5,6,7}. In the meantime, many large submarine landslides have been described worldwide in areas where gas hydrate occurrence was proved or suspected^{9,10,11,12,13}. [Paull and co-authors](#)⁶ have proposed that gas-hydrate is the main cause of the increased frequency of sea-floor slumping on continental margins containing gas hydrates during sea-level lowstands. While authors seem to agree about the association between gas-hydrate dissociation and submarine slope failures, few theoretical and mathematical works were developed to define accurately the mechanism associated to the slope failure process. In the last few years, some authors have tried to evaluate using different approaches the excess pore pressure due to hydrate dissociation^{14,15,16,17,18}. On the other hand, almost none or very few theoretical and experimental works were carried out to identify the decrease of the sediment shear strength with hydrate dissociation.

The process of hydrate dissolution and slope failure was described previously by [Sultan and co-authors](#)¹⁶ to illustrate one of the possible triggering mechanisms of the Storegga slide. More recently, it was shown that the excess pore pressure generated by hydrate dissolution seems to be in the same order of magnitude than the one generated by hydrate dissociation under undrained conditions and for a closed system¹⁷. On the other hand, the gas hydrate stability law bounds the amount of the excess pore pressure generated by gas-hydrate dissociation. By considering theoretically the two processes of hydrate dissolution and hydrate dissociation, our work aims to give an answer to the following major question: Under natural sea level and temperature changes as the one occurred since the last deglaciation where is the most hazardous area in the *GHOZ* of submarine slopes?