OTC 19489

Feasibility of Monitoring Gas Hydrate Production with Geophysical Methods

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This paper was prepared for presentation at the 2008 Offshore Technology Conference held in Houston, Texas, U.S.A., 5–8 May 2008.

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Abstract

Many studies involving the application of geophysical methods in the field of gas hydrates have focused on determining rock physics relationships for hydrate-bearing sediment with the goal being to delineate the boundaries of gas hydrate accumulations and to estimate the quantities of gas hydrate such accumulations contain using remote sensing techniques. However, the potential for using time-lapse geophysical methods to monitor the evolution of hydrate accumulations during production and thus to manage production has not been investigated. In this work we begin to examine the feasibility of using time-lapse geophysical methods for monitoring changes in hydrate accumulations that are predicted to occur during production of natural gas. This is made possible through the coupled simulation of (1) large-scale production in hydrate accumulations and (2) time-lapse geophysical surveys. We consider a geological system, based on a hydrate accumulation in the Gulf of Mexico, which represents a promising target for production. While the current study focuses on seismic measurements, the approach can easily be extended to consider additional geophysical methods, such as electromagnetic methods. In addition to examining the sensitivity of geophysical attributes and parameters to the changing conditions in hydrate accumulations, we aim to determine optimal sampling strategies (e.g., source frequency, time interval for data acquisition) and measurement configurations (e.g., surface seismic reflection, and vertical seismic profiling), while taking into account uncertainties in rock physics relationships. The numerical simulation tool being developed in this work provides a means for designing cost effective geophysical surveys to track the evolution of hydrate properties. This work also serves as a basis for developing a comprehensive method for monitoring production that integrates multiple types of geophysical and hydrological data. Here we describe the modeling procedure and present some preliminary results.

Introduction

Background. Identifying the extent of gas hydrate accumulations, predicting their behavior, and monitoring their properties is of great importance. Gas hydrates–solid crystalline structures consisting of water and gas molecules (usually methane)–are distributed widely across the earth in permafrost and under the ocean (Sloan, 1998). When conditions in hydrate-bearing sediment (HBS) become thermodynamically unfavorable for gas hydrates (e.g., when the pressure decreases or the temperature increases and moves the system away from the hydrate stability zone), dissociation can occur releasing large amounts of gas and water. Thus gas hydrates are viewed as a promising source of alternative energy (Kvenvolden, 1994; 2002), in hopes that dissociation can be induced in hydrate accumulations in a controlled manner while natural gas is harvested (Makogen, 1997). The presence of HBS also serves as a hazard to hydrocarbon production platforms or infrastructure, the integrity of which is at risk due to ocean floor instabilities arising from dissociation-induced sub-marine landslides or subsidence (Moridis and Kowalsky, 2007).

The use of geophysical methods for identifying hydrate accumulations and quantifying the amount of gas hydrates present in the subsurface has been investigated for many years and appears promising (e.g., Hyndman and Spence, 1992; Yuan et al., 1996; Andreassen et al, 1997; Ecker et al., 1998; Ecker et al., 2000; Gueren et al. 1999). There still remains much uncertainty in seismic (Helgerud et al., 1999; Gueren and Goldberg, 2005) and electrical (Spangenberg, 2001; Sun and Goldberg, 2005) rock physics relationships for HBS. The use of geophysical methods to remotely monitor the state of hydrate accumulations undergoing production (at distant locations where well-logging techniques can not be applied) is only beginning to be examined, which is made possible by recent advances in the ability to model the complex processes that occur in such systems which inevitably involve the nonisothermal, multiphase transport of fluids and gas.