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Evaluation of gas production potential from gas hydrate deposits in National Petroleum Reserve Alaska using numerical simulations

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ABSTRACT

An evaluation of the gas production potential of Sunlight Peak gas hydrate accumulation in the eastern portion of the National Petroleum Reserve Alaska (NPRA) of Alaska North Slope (ANS) is conducted using numerical simulations, as part of the U.S. Geological Survey (USGS) gas hydrate Life Cycle Assessment program. A field scale reservoir model for Sunlight Peak is developed using Advanced Processes & Thermal Reservoir Simulator (STARS) that approximates the production design and response of this gas hydrate field. The reservoir characterization is based on available structural maps and the seismic-derived hydrate saturation map of the study region. A 3D reservoir model, with heterogeneous distribution of the reservoir properties (such as porosity, permeability and vertical hydrate saturation), is developed by correlating the data from the Mount Elbert well logs. Production simulations showed that the Sunlight Peak prospect has the potential of producing 1.53×10^9 ST m^3 of gas in 30 years by depressurization with a peak production rate of around 19.4×10^4 ST m^3/day through a single horizontal well. To determine the effect of uncertainty in reservoir properties on the gas production, an uncertainty analysis is carried out. It is observed that for the range of data considered, the overall cumulative production from the Sunlight Peak will always be within the range of ±4.6% error from the overall mean value of 1.43×10^9 ST m^3. A sensitivity analysis study showed that the proximity of the reservoir from the base of permafrost and the base of hydrate stability zone (BHSZ) has significant effect on gas production rates. The gas production rates decrease with the increase in the depth of the permafrost and the depth of BHSZ. From the overall analysis of the results it is concluded that Sunlight Peak gas hydrate accumulation behaves differently than other Class III reservoirs (Class III reservoirs are composed of a single layer of hydrate with no underlying zone of mobile fluids) due to its smaller thickness and high angle of dip.

1. Introduction

Gas hydrates are crystalline solids composed of gas molecules trapped inside the water cavities formed by hydrogen-bonded water molecules (Sloan and Koh, 2007). They are found all over the world, specifically off the coasts on the continental margins and in permafrost regions where the pressure-temperature conditions are suitable for hydrate formation and sufficient amount of hydrate-forming gas is available (Giavarini and Hester, 2011). Hydrates are a vast source of natural gas with an estimated amount of 20,000 trillion cubic meters of gas in permafrost and oceanic hydrate deposits, which are almost two orders of magnitude higher than the conventional natural gas resources (Collett et al., 2009). The large volume of gas content and the wide distribution of hydrate deposits all over the globe make gas hydrate a potential energy resource.

Natural gas can be technically recovered from the gas hydrate deposits by breaking the thermodynamic equilibrium of the three phase water-hydrate-gas system to dissociate hydrate into gas and water. The known methods of hydrate decomposition are depressurization, thermal stimulation, inhibitor stimulation and gas exchange, amongst which depressurization is considered as the most economically promising method for the production of natural gas

Abbrevations: BHSZ, base of hydrate stability zone.

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from in-situ gas hydrates (Collett et al., 2009). The short term field tests such as thermal stimulation test in 2002 and depressurization tests in 2007 and 2008 at the Mallik gas hydrate site in Canada (Dallimore et al., 2012; Hancock et al., 2005; Kurihara et al., 2011) and the pressure transient tests at the Mount Elbert site in Alaska North Slope (ANS) in 2007 (Hunter et al., 2011) were conducted with the motive of studying the gas hydrate dissociation process, calibration of numerical models and gathering wireline log, core and formation pressure test data. In 2013, the first field trial test of gas production from marine methane hydrate deposits was conducted in the area of Eastern Nankai Trough off the Pacific coast of Japan using depressurization method (Yamamoto et al., 2014). The method of gas exchange was first evaluated in 2012 through the field trial test at Prudhoe Bay L-Pad unit in ANS, where the mixture of CO_2 and N_2 was injected through the Ignik Sukimi well for 14 days and the gas was produced by depressurization (Schoderbek et al., 2012, 2013). In absence of any field test and laboratory experiment, numerical simulation is a powerful and low-cost tool to predict the behavior of hydrate reservoir and estimate its production potential. It can also be used to history match the existing production data. Various numerical simulation studies have been conducted, such as long term production modeling of the Mount Elbert gas hydrate deposit (Anderson et al., 2011; Myshakin et al., 2011), marine hydrate sediments at the Walker Ridge site in the Gulf of Mexico (Gaddipati and Anderson, 2012), gas hydrate deposits in Qilian Mountain Permafrost region of China (Zhao et al., 2013), and the Prudhoe Bay Unit L-Pad site in ANS (Myshakin et al., 2016; Moridis et al., 2011).

In 2002, the U.S. Geological Survey (USGS) started an assessment to conduct a geology-based analysis of the occurrences of gas hydrates within ANS (U.S. Geological Survey Alaska Gas Hydrate Assessment Team, 2013). As a result of this assessment, many potential gas hydrate prospects were identified in the eastern portion of the National Petroleum Reserve Alaska (NPRA). Gas from NPRA gas hydrate deposits could be used in pressurizing nearby oil fields or possibly supplementing the export of conventional gas in the near future (Wilson et al., 2011). A regional ANS Index map (Fig. 1) shows the location of the NPRA study area relative to the Tarn and Eileen accumulations. Amongst the identified prospects, Sunlight Peak is one of the most promising prospects in NPRA with relatively large area and proximity to the base of the hydrate stability zone (BHSZ) (U.S. Geological Survey Alaska Gas Hydrate Assessment Team, 2013). No well logs are available for this location and no numerical studies were conducted previously to characterize the reservoir and predict the gas production for any of the hydrate prospects in NPRA region. In this work, new efforts are made to investigate the gas production potential of Sunlight Peak gas hydrate deposit and study the evolution of reservoir properties with time, using numerical simulation technique.

The Sunlight Peak gas hydrate accumulation is divided into different sub-sections by regional faults as shown in Fig. 2. Assuming that the faults are non-conducting in terms of mass and heat flow, three major sub-sections which are bounded by faults are modeled separately as Model 1, Model 2 and Model 3. The overall production potential of Sunlight Peak gas hydrate accumulation is estimated to be the sum of the productions from these three individual accumulations. The depressurization method is used for gas recovery by maintaining a constant bottom-hole pressure of 2.8 MPa. This paper explains the methodology and simulation results for only Model 1 because a similar approach is used for the other two models.

2. Numerical reservoir model

2.1. Numerical modeling with CMG STARS

The numerical modeling and simulations in this study are carried out using Advanced Processes and Thermal Reservoir Simulator (STARS), which is a commercial reservoir simulator developed by the Computer Modeling Group (CMG) to model three phase multi-component fluid flow and heat transfer in porous and fractured media (CMG STARS, 2016). STARS is primarily designed for

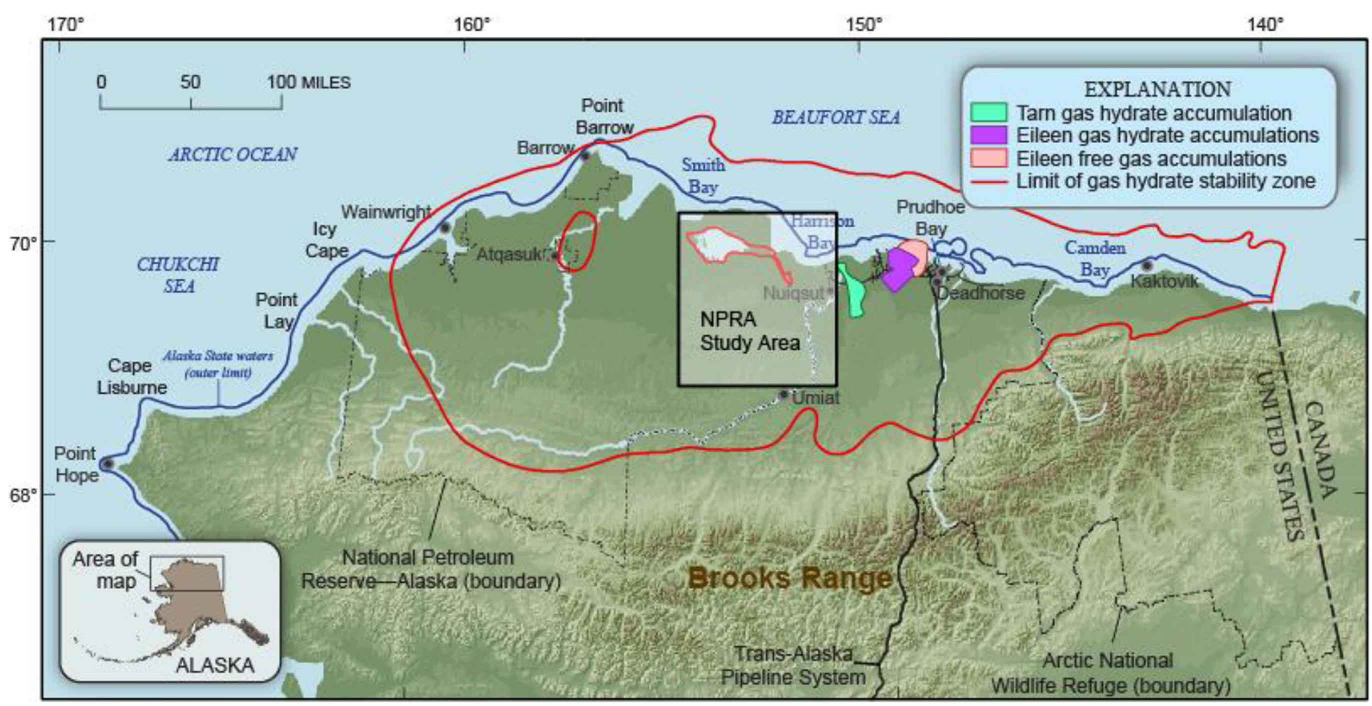

Fig. 1. Index map showing the NPRA Study Area.