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Evaluation of gas production from Qilian Mountain permafrost hydrate deposits in two-spot horizontal well system

Bo Li [a,b,c], Xiao-Sen Li [a,b,*], Gang Li [a,b], Zhao-Yang Chen [a,b]

[a] Key Laboratory of Renewable Energy and Gas Hydrate, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangzhou 510640, PR China
[b] Guangzhou Center for Gas Hydrate Research, Chinese Academy of Sciences, Guangzhou 510640, PR China
[c] University of Chinese Academy of Sciences, Beijing 100083, PR China

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ABSTRACT

In 2008–2009, gas hydrate deposits were confirmed to exist in the Qinghai–Tibet Plateau permafrost (QTPP) during the Scientific Drilling Project of Gas Hydrate in Qilian Mountain permafrost. Gas hydrate samples were successfully collected from three drilling sites: DK-1, DK-2, and DK-3. Based on the limited geological data from site measurements, gas was produced from the hydrate deposits of DK-2 zone in a two-spot well system through numerical simulation, and its commercial viability was evaluated. The two wells were placed on the same horizontal plane in the middle of the hydrate-bearing layer (HBL), and the depressurization and thermal stimulation methods were employed simultaneously in this system. Simulation results showed that desirable gas production performance could be obtained under suitable operation conditions when using this kind of well design. During the production process, large amount of free gas accumulated in the vicinity of the injection well until the flow channels between the two wells were gradually opened. It was found that the gas production performance was more favored with larger depressurization driving force, while the heat injection rate should be determined cautiously. Dependences of gas production performance on the various properties of hydrate deposits were also assessed.

1. Introduction

Natural gas hydrates (NGH) are solid crystalline compounds which are formed by gas and water molecules under high pressure and low temperature conditions (Sloan and Koh, 2008). The most common hydrate-forming gas (named guests) is methane, and it has been found to exist widely in the permafrost and deep ocean sediments where the thermodynamic conditions are favorable for stable hydrate formation. As a kind of new and potential energy resource, natural gas hydrates have attracted global attentions, and many scientific drilling projects have been carried out for in-situ gas hydrate exploitation researches (Moridis et al., 2009a).

In 2008–2009, the Scientific Drilling Project of Gas Hydrate was implemented by the China Geological Survey in the Qilian Mountain permafrost (Fig. 1), which is situated in the north of the Qinghai–Tibet Plateau permafrost (QTPP) in China. Four test wells (DK-1, DK-2, DK-3 and DK-4) were completed, and direct evidence of gas hydrate existence was observed in the collected core samples from these wells, as shown in Fig. 2 (Lu et al., 2011; Zhu et al., 2010b). The gas hydrates were found to occur in the pores and/or in the fractures (Wang et al., 2014) of sandstones, oil shale, mudstones and siltstones, which are the main geological composition of the hydrate-bearing cores. Drilling results showed that the hydrate layers in the Qilian Mountain were situated in depths of 133–396 m underground (Zhu et al., 2010a). The annual average temperature of the permafrost ground (T_0) was around −1 to −3 °C. In recent years, the geothermal gradients within the frozen layer (G_1) and below the frozen layer (G_2) of the QTPP were measured to be 0.011–0.033 °C/m and 0.028–0.051 °C/m, respectively (Lu et al., 2009; Wu et al., 2010). So the pressure and temperature were both favorable for the stability of natural gas hydrate in the Qilian Mountain.

There are mainly four kinds of techniques for gas extraction from gas hydrates: depressurization (Jiang et al., 2012; X.S. Li et al., 2012), thermal stimulation (B. Li et al., 2012; Schicks et al., 2013), inhibitor injection (Lee, 2010), and CO_2 replacement (Yuan et al., 2012). Depressurization is usually thought to be the most promising and practical method for hydrate dissociation because of its simplicity for operation. However, the gas production rate is always burdened with the limited sensible heat provided by the hydrate reservoir. X.S. Li et al. (2012) investigated the gas production potential of the hydrate deposits at site DK-3 using depressurization method in a single horizontal well, and found that the gas production rate was within a low level. Similar results were also observed by Zhao et al. (2013) when they employed

* Corresponding author at: Key Laboratory of Renewable Energy and Gas Hydrate, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangzhou 510640, PR China. Tel./fax: +86 20 87057037.
E-mail address: lixs@ms.giec.ac.cn (X.-S. Li).

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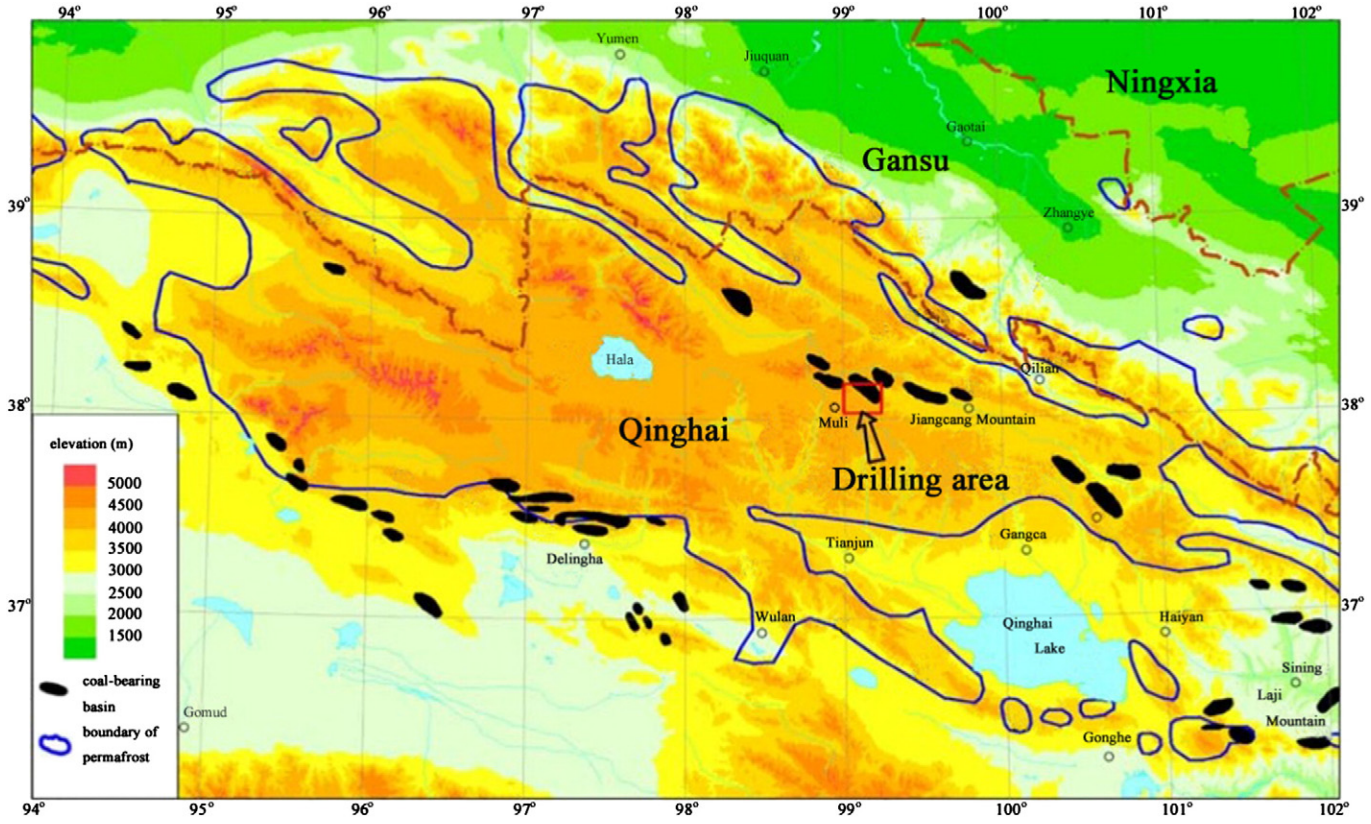

Fig. 1. Location map of the Scientific Drilling Project of Gas Hydrate in Qilian Mountain permafrost.

depressurization in a single vertical well for hydrate dissociation in the Qilian Mountain at DK-3. When the huff and puff method (combining the depressurization with thermal stimulation) was also applied in a single horizontal well by X.S. Li et al. (2012), the gas production performance was enhanced obviously because of the additionally provided heat for promoting the hydrate dissociation.

Generally, previous studies have shown that the single horizontal or vertical well will not be suitable for hydrate exploitation in the Qilian

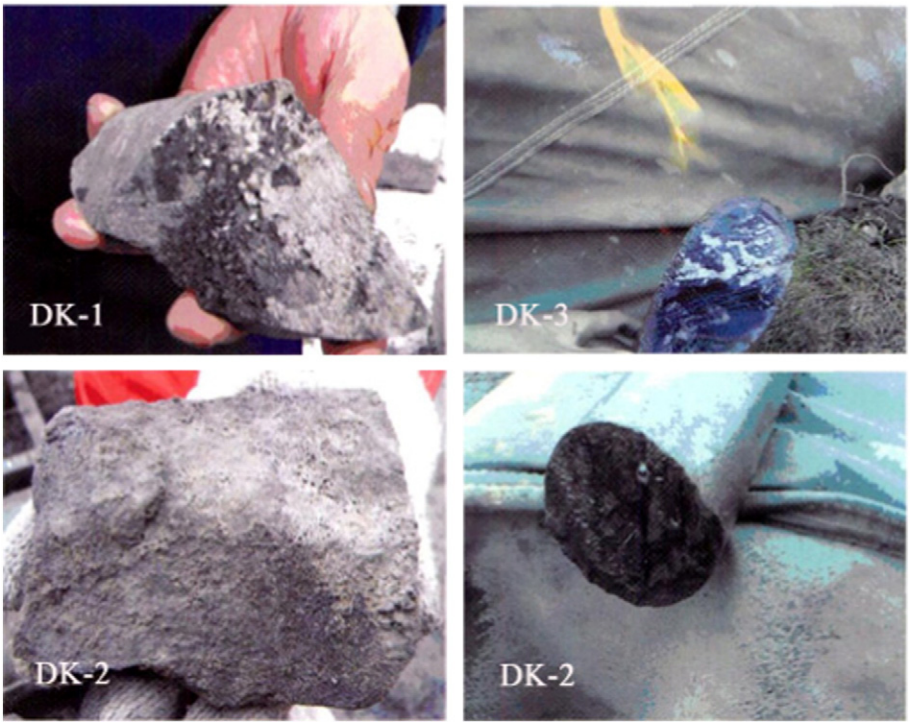

Fig. 2. Gas hydrate-bearing cores from Qilian Mountain permafrost.