China Geology 9 (2026) 652−658

China Geology

Journal homepage: http://chinageology.cgs.cn
https://www.sciencedirect.com/journal/china-geology

Review Article

Fluid invasion-induced geological risks during drilling in marine natural gas hydrate reservoirs: A mini review

Lin Dong[a], Yan-long Li[a], Neng-you Wu[a, b,*]

[a] *Laoshan Laboratory*, *Qingdao* 266237, *China*
[b] *Key Laboratory of Gas Hydrate*, *Ministry of Natural Resources*, *Qingdao Institute of Marine Geology*, *China Geological Survey*, *Qingdao* 266237, *China*

A R T I C L E I N F O

Article history:
Received 8 February 2024
Received in revised form 8 April 2025
Accepted 27 April 2025
Available online 20 May 2025

Keywords:
Natural gas hydrate
Geological risk
Drilling fluid invasion
Hydrate dissociation
Risk control
Invasion mechanism
Influencing factor
Drilling process

A B S T R A C T

Geological risks are the main obstacles encountered during drilling in marine natural gas hydrate reservoirs. This review aims to provide a primary insight into the geological risks in the process of drilling in marine hydrate reservoirs. Different geological risks and their characteristics will be analyzed, together with a discussion of possible influencing factors. Geological risks occurring in the marine natural gas drilling process have a close association with uncontrollable drilling fluid invasion and hydrate dissociation. Finally, the mechanisms of drilling risks and control strategies for safe drilling are highlighted. Results can give a reference to drilling risk prediction and control for drilling in marine natural gas hydrate reservoirs efficiently.

©2026 China Geology Editorial Office.

1. Introduction

Natural gas hydrate is considered to be a promising energy resource due to its wide distribution and large reserve characteristics (Chong ZR et al., 2016; Dong L et al., 2024c). These ice-like crystalline compounds exist in marine sediments and permafrost regions under high-pressure and low-temperature conditions (Gajanayake SM et al., 2023; Li YL et al., 2023). Driven by the demands of exploration and production, operations of drilling in marine natural gas hydrate reservoirs have been conducted worldwide for pressurized coring, seismic surveys, logging, gas extraction (Merey S, 2016). Exploration and geophysical drilling of hydrate reservoirs is the basis for drilling operations and the premise of hydrate development in safety and efficiency.

Compared with traditional oil and gas reservoirs, marine natural gas hydrate development faces increased challenges triggered by the special geomechanical characteristics of formation (Merey S, 2019; Dong L et al., 2024b). Hydrate reservoirs have the features of shallow burial, weak cementation, and relatively low strength (Dong L et al., 2020; Li YL et al., 2024). Drilling fluid shall invade into the near-wellbore formation, which may further trigger geological risks during drilling (Dong L et al., 2024a). Geological risks exposed in the previous drilling include but are not limited to wellbore failure and wellbore instability (Gizatullin R et al., 2023). These risks limit the drilling efficiency and increase the cost, which is unfavorable for the safe and efficient development of hydrate reservoirs.

Driven by the survey and development demand, drilling operations in the marine natural gas hydrate reservoirs have been conducted in the USA, Japan, China, India, and South Korea (Ruppel CD and Waite WF, 2020; Pratama MA et al., 2023). Drilling activities have achieved the targets of identifying hydrate presence, pressure coring, and gas extraction (Dong L et al., 2022b). Meanwhile, numerous laboratory tests and numerical simulations have been conducted to investigate drilling-related geological risks (Sahu C et al., 2020; Hu QB et al., 2023). However, there is still a gap between drilling operations and theoretical analyses. Because of the complexity of invasion mechanisms and inadequate fundamental research, theoretical studies are unable to provide effective guidance on drilling practices.

First author: *E-mail address*: donglinupc@163.com (Lin Dong).

* Corresponding author: *E-mail address*: wuny@ms.giec.ac.cn (Neng-you Wu).

Literary editor: Xi-jie Chen
doi:10.31035/cg2024021
2096-5192/© 2026 China Geology Editorial Office.

Copyright © 2026 Editorial Office of China Geology. Publishing services by Elsevier B.V. on behalf of KeAi Communications Co. Ltd.
This is an open access article under the CC BY-NC-ND License (http://creativecommons.org/licenses/by-nc-nd/4.0/).

This review provides a more comprehensive insight into the hydrate-related drilling risks and further research is summarized, focusing on risk characteristics and adverse effects on the hydrate drilling process. Key influencing factors are discussed in detail, which are followed by the mechanism analysis. After that, control strategies are proposed based on investigating correlations among drilling fluid invasion, hydrate dissociation, and geological risks. Finally, gaps between the laboratory investigation and engineering applications are pointed out and studied to find corresponding suggestions for future research.

2. Drilling fluid invasion

Drilling fluid invasion is one of the most common problems during drilling gas hydrate reservoirs. The drilling fluid will invade into the formation once the borehole pressure exceeds the pore pressure (Zhong RZ et al., 2022). Variations induced by invaded fluid can lead to changes in pore pressure and temperature, resulting in hydrate dissociation in near-wellbore regions (Dong L et al., 2022b). Furthermore, the alteration of pore structures caused by hydrate dissociation can increase the permeability of the dissociation area, which can promote the process of drilling fluid invasion.

The variation of formation properties is the primary factor for the log responses. Invaded drilling fluid can increase the water saturation in pores and cause hydrate dissociation, affecting the logging data quality, wrong depth investigation, as well as noises (Chen J et al., 2021). It may result in multiple logging interpretations and even wrong analysis, which further impacts the logging data of profile accuracy and reliability (Ning FL et al., 2013b). Besides, it affects the wellbore failure by promoting hydrate dissociation and altering stress states, which is unfavorable for realizing safety and high-efficiency drilling, as depicted in Fig. 1.

3. Geological risks induced by drilling fluid invasion

Due to changes in temperature and pore pressure induced by the invaded drilling fluid, hydrate dissociates and releases gas and water during the drilling process. It will cause large-scale deformation of formation, resulting in wellbore instability, casing failure, and formation subsidence (McConnell DR et al., 2012). Typical drilling hazards involve wellbore instability, inefficient cuttings removal, blockage, pipe stuck/bending, gas leakage, equipment damage, explosion (see Table 1), which can lead to damage and even destruction of submarine cables, optical cables, subsea pipelines, as well as platforms (Peng XB et al., 2022).

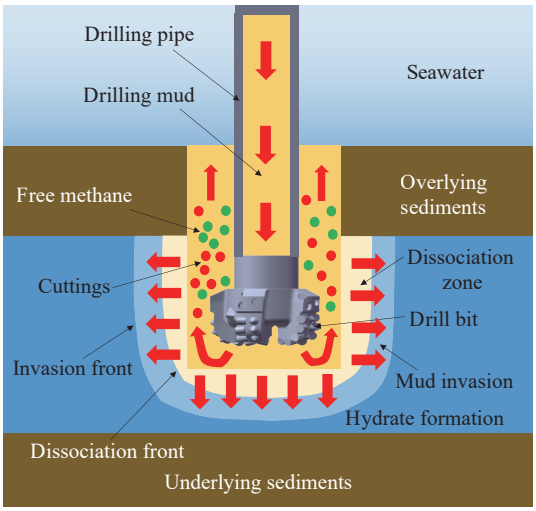

Fig. 1. Marine gas hydrate reservoir drilling (after Dong L et al., 2023b).

3.1. Wellbore instability

Driven by the difference between the drilling fluid and pore pressure, drilling fluid will invade into the hydrate formation and change the physical properties of near-wellbore regions. The invaded drilling fluid can alter pore pressure and lead to hydrate dissociation, as illustrated in Fig. 2. Meanwhile, stress release occurs during the drilling process after the original state of balance is destroyed (Sun JX et al., 2018). That may cause wellbore instability during drilling

Table 1. Typical hydrate drilling hazards.

Voyage	Location	Problems
ODP-160 (Merey S, 2020)	Eastern Mediterranean Sea	Wellbore instability, pipe stuck
ODP-164 (Paull CK et al., 1997)	Blake Ridge, US	Wellbore instability, pipe bending
OPD-204 (Goldberg D and Janik A, 2009)	South Hydrate Ridge, US	Wellbore instability, stuck
JIP-I (Ruppel C, 2008)	Gulf of Mexico, US	Wellbore instability, annulus blockage, hydraulic erosion
JIP-2 (Frye MC et al., 2010)	Gulf of Mexico, US	Wellbore instability, borehole solid settlement, gas leakage, explosion
IODP-311 (Kim JH and Lee YJ, 2009)	North Hydrate Ridge, US	Pipe stuck, equipment damage
GMGS2 (Wei JG et al., 2018)	South China Sea, China	Gas leakage, wellbore instability
NGHP-02 (Motghare PD and Musale A, 2017)	Eastern Continental Margin, India	Wellbore instability, pipe stuck, gas plume, blockage

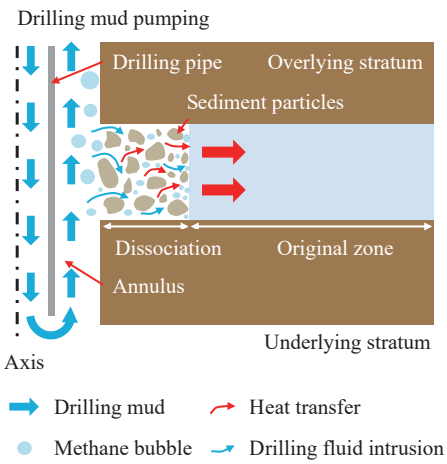

Fig. 2. Wellbore instability related to hydrate dissociation (after Yan CL et al., 2020).

hydrate reservoirs, which must be emphasized in further field operations (Li QC et al., 2022).

Additionally, drilling fluid invasion and induced hydrate dissociation make the phenomenon of wellbore instability appear more likely (Liu C et al., 2022). On the one hand, hydrate dissociation can lead to cementation damage and destruction, causing an obvious decrease in the formation strength (Gao YH et al., 2016). On the other hand, produced gas and water will increase the pore pressure and further decrease the effective stress, resulting in the wellbore failure (Sun X et al., 2019).

3.2. Gas kick

The leak of gas produced from hydrate dissociation may appear in harsh environments and special conditions where reservoir fracture and damaged casing exist (Liao YQ et al., 2022). The leaked gas flows towards the sea surface, causing drilling platforms and other floating equipment under extreme conditions. Furthermore, the gas may also corrode drilling equipment, resulting in safety problems, and increasing cost (Gizatullin R et al., 2023).

3.3. Submarine landslides

Various large-scale landslides are observed in the Storegga area (Paull CK et al., 2007), Beaufort Sea (Kayen RE and Lee HJ, 1991), Hinlopen-Yermak Megaslide (Geissler WH et al., 2016), as well as Amazon Fan (Maslin M et al., 1998), which are largely attributed to massive hydrate dissociation. Generally, the presence of submarine landslides connected with hydrate dissociation must satisfy three basic requirements: Wide distribution of hydrate in formation, unstable region on the side slope, and high pore pressure (Wan YZ et al., 2023). Based on numerical simulations, Tan L et al. (2021) stated that it usually occurs on the subsea slopes with a gradient of less than 5 degrees during hydrate production.

Under some special conditions, improper drilling operations may lead to massive dissociation during drilling hydrate reservoirs, which can decrease the stability of seabed formation, further leading to the occurrence of submarine landslides (McConnell DR et al., 2012; Song BJ et al., 2019), as displayed in Fig. 3. On the one hand, uncontrolled dissociation of hydrate occurring in the drilling process can result in a marked reduction in formation strength (Dong L et al., 2022a). On the other hand, high hydrate-saturated sands may lead to apparent free gas accumulation, further causing potential serious drilling-induced geological risks.

In addition, landslides can destroy drilling tools, oil pipelines, as well as subsea cables, and even lead to disasters under unfavorable conditions (Sun WT et al., 2021). Note that its frequency is quite low and difficult to observe in the field during drilling hydrate formation at present. Nonetheless, it remains an important case to study for further geohazard control because of its great potential danger to the drilling process of gas hydrate.

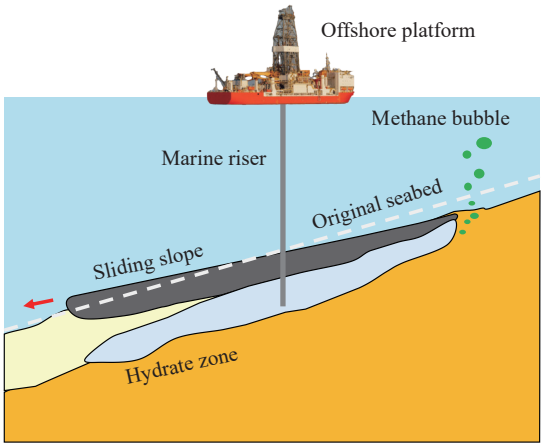

Fig. 3. Illustration of seabed landslides related to natural gas hydrate (after Yan CL et al., 2020).

3.4. Flow blockage in drilling fluid

Generally, invaded drilling fluid can cause hydrate dissociation once formation pressure and temperature alter and reach the equilibrium conditions (Koh CR et al., 2012). After that, the produced gas is released and flows into the drilling fluid. Furthermore, released gas is prone to reform hydrate in the drilling fluid and gradually aggregate in the wellbore and annulus, blocking the channels of the drilling fluid circulating flow (Gizatullin R et al., 2023). Reformed hydrates in the wellbore will cause blockages, resulting in wellbore and annulus plugging (Zhao JF et al., 2023).

4. Influencing factors

4.1. Hydrate saturation

Physical properties are the base of deformation and failure analysis in drilling hydrate, including hydrate distribution, sediment type, permeability, pressure, and temperature (Ning FL et al., 2013a). Wherein the hydrate saturation has a close association with the strength and stiffness of hydrate reservoirs (Zeng ZY et al., 2023). More specifically, the strength reduction of HBS induced by the hydrate dissociation can reach 3.71 MPa with a maximum gap up to 63.63% (Song YC et al., 2019). The fall may be more significant with various original hydrate saturation and stress states (Dong L et al., 2024d). The higher the hydrate saturation, the better the mechanical strength (Lijith KP et al., 2019). Once the temperature reaches the phase equilibrium temperature, hydrate will dissociate, further leading to a decrease in reservoir strength (Hou XK et al., 2022). It may cause wellbore instability, subsidence, and even submarine landslides.

Released natural gas from the dissociated hydrate can flow into the pipelines (McConnell DR et al., 2012). After that, reformed hydrate often occurs under specific conditions, which may plug the drilling pipes (Zhao JF et al., 2023). This condition is more prone to appear in drilling the free gas layer. Generally, hydrate dissociates and reforms in the drilling pipes, which can further lead to well leakage and blowout, causing damage, and wellbore instability.

4.2. Permeability

The drilling fluid invasion process is affected by the permeability of hydrate sediments. High permeability can bring in larger volumes of invaded drilling fluid with high velocity during drilling hydrate reservoirs (Dong L et al., 2022b). Wei J et al. (2019) pointed out that the drilling fluid rapidly invaded the high-permeability hydrate sediments and further accelerated the heat transfer process. Huang TJ et al. (2020b) also verified that the velocity of drilling fluid invasion accelerates due to the high permeability. Drilling-related risks are easier to appear, which may result in severe geological disasters.

Additionally, hydrate dissociation induced by high-temperature fluid invasion changes the effective porosity, thereby altering the invasion process. Hydrate dissociation can increase the permeability and in turn promote the invasion process (Dong L et al., 2022b). Besides, the process of heat and mass transfer is improved greatly in high-permeability formation, promoting the hydrate dissociation in the invaded formation (Dong L et al., 2023a). Therefore, drilling the high-permeability hydrate reservoirs should focus on uncontrollable hydrate dissociation and thereby rapid drilling fluid invasion.

4.3. Pressure and temperature of drilling fluid

Invasion characteristics of drilling fluid primarily depend on the drilling fluid pressure and temperature, which further affect the hydrate dissociation and even drilling-induced geological risks (Ning FL et al., 2013b). The higher pressure of drilling fluid can bring in a larger volume of invaded drilling fluid in the formation with high invasion velocity. Meanwhile, the higher the temperature of invaded drilling fluid can accelerate the process of hydrate dissociation (Hannegan DM, 2005). Gao YH et al. (2019) showed that high-temperature drilling fluid can induce hydrate dissociation through heat and mass transfer. Wei J et al. (2019) stated that proper high drilling fluid density is favorable for preventing hydrate dissociation. Zheng MM et al. (2020) found that high-density and low-temperature of drilling fluid is beneficial for field drilling. Under certain conditions, massive hydrate dissociation occurs induced by the invaded drilling fluid with high pressure and temperature, which can cause wellbore instability, subsidence, and even landslides (Najjarpour M et al., 2021). In addition, released gas from the hydrate dissociation may flow into the drilling pipes, leading to block and blowout.

4.4. Drilling fluid additives

To inhibit unexpected hydrate dissociation, researchers add the hydrate dissociation inhibitors into drilling fluid for risk prevention (Gulbrandsen AC and Svartaas TM, 2017). Chemical reagents can increase the phase equilibrium temperature to prevent hydrate dissociation, which has excellent performance in drilling hydrate. Zhang HW et al. (2017) investigated the effect of thermodynamics hydrate inhibitors based on tests, indicating that the boost effects of salt-type inhibitors are markedly stronger than alcohol-type inhibitors. Li QC et al. (2022) found that the increase of stabilizer concentration in drilling fluid can inhibit hydrate dissociation more effectively than hydrate saturation. Shao ZH et al. (2023) carried out NMR-based experiments of fluid invasion to hydrate sediments. Results indicated that the invasion area is reduced with the presence of a hydrate dissociation inhibitor.

In addition, additives for drilling hydrate can also help to carry cutting and pervert circulation loss (Yin FL et al., 2023). Hydrate reformation often occurs during drilling fluid circulation within the wellbore, which should be controlled by adding the hydrate inhibitor (Yang MJ et al., 2019). Thus, proper application of the drilling fluid additives in hydrate drilling is necessary for drilling risk control.

4.5. Drilling period

The increasing drilling period can enlarge the invaded drilling fluid volume and invaded depth. Wei J et al. (2019) stated that shortening well-drilling time can restrain temperature growth and limit the expansion of hydrate dissociation areas. Huang TJ et al. (2020a) conducted tests of drilling fluid invasion into hydrate-bearing sediments, showing that longer drilling time resulted in a larger volume of invaded fluid. Dong L et al. (2022b) indicated that the shorter drilling duration contributed to the preventing invasion of the drilling fluid with high temperature, decreasing the hydrate dissociation. In this regard, the longer drilling period may bring in the geological risks related to the drilling process. On the one hand, shortening drilling time can decrease the drilling cost; on the other hand, it helps to control the drilling risks (Zhou SW et al., 2018).

Currently, realizing this target needs to apply new drilling technology as well as corresponding drilling strategy. Dong L et al. (2022b) suggested that new technology can accelerate the drilling process, which is favorable for reducing drilling risks. For example, riserless drilling technology can improve drilling efficiency, which has been applied in drilling hydrate (Zhou SW et al., 2018).

5. Risk control measurement

5.1. Drilling fluid invasion mechanisms

Drilling fluid invasion is a multi-field coupled process, including multiphase flow, heat and mass transfer, phase change, as well as solid deformation (Wu NY et al., 2021; Wan YZ et al., 2023). Wherein, drilling fluid invasion and hydrate dissociation are the key parts. The invasion of high-temperature drilling fluid can promote hydrate dissociation, which in turn accelerates the invasion velocity by altering the pore structures (Zhao YP et al., 2023). Meanwhile, hydrate dissociation will decrease the strength and stiffness of hydrate reservoirs, unfavorable for maintaining reservoir stability (Zhang M et al., 2021). To describe this process accurately, the model establishment must consider this complicated process and further characterize invasion behaviors accurately, as shown in Fig. 4.

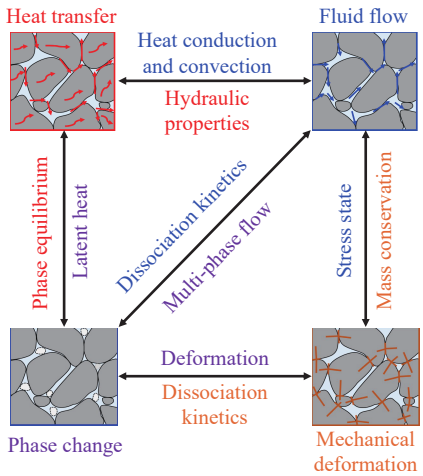

Fig. 4. Control mechanisms of drilling hydrate reservoirs (after Dong et al., 2023b).

Currently, laboratory tests on drilling fluid invasion are limited to a certain degree due to complex downhole conditions and low-precision measurements. Invasion characteristics of drilling fluid and formation responses differ from actual work conditions, resulting in an insufficient understanding of the invasion mechanisms. Besides, method selection as well as plan establishment require precise descriptions of invasion behaviors and control mechanisms during the drilling process. Therefore, control of drilling-related geological risks needs to deeply understand the invasion properties and influencing mechanisms of drilling fluid.

5.2. Prevention of hydrate dissociation

Methods for preventing hydrate dissociation during drilling hydrate have been conducted and discussed in detail, such as shortening the drilling period, increasing the drilling fluid density, lowering the temperature, and using inhibitors (Dong L et al., 2022b). Low temperature and high pressure of drilling fluid are unfavorable for hydrate dissociation, which contributes to narrowing the number of challenges and risks in further development (Huang TJ et al., 2020b). Likewise, hydrate dissociation inhibitors can serve a similar purpose. Differently, shortening the drilling period can reduce the invasion depth and volume of the drilling fluid to reduce the geological risks (Freij AE et al., 2007).

These operational strategies are applicable to the prevention and control of drilling-related risks, some of which have been used in hydrate exploitation (Zhao X et al., 2019). However, there remains a need to build an effective prevention and control system for drilling risks, which can offer proper drilling operations to deal with the risks. Meanwhile, early warning and control operations should be carried out before drilling risks occur, which needs a system to predict and adjust drilling conditions.

6. Conclusions

(i) Drilling in marine gas hydrate reservoirs is an integral part of the hydrate development, which is related to the drilling fluid invasion, wellbore instability, blowout, flow blockage, gas kick, subsidence, and even landslides. These drilling-related risks will increase the drilling period as well as cost, limiting the safe and efficient development of natural gas hydrate.

(ii) The main reasons for drilling-related risks are drilling fluid invasion and hydrate dissociation. Wherein massive dissociation of hydrate can lead to large-scale deformation and even geological disasters, such as subsidence and landslides. Thus, the control of these risks should prevent drilling fluid invasion and inhibit hydrate dissociation.

(iii) Currently, risk control of drilling hydrates should pay attention to two aspects. It's the foundation to propose a drilling fluid invasion model for characterizing the invasion process accurately. Besides, selecting proper measurements to present hydrate dissociation is an efficient approach to control the risks.

CRediT authorship contribution statement

Lin Dong wrote the entire paper, Lin Dong and Yan-long Li conducted analyses and constructed the figures, Neng-you Wu carried out the project. All authors were involved in revising the manuscript and approved the submitted version.

Declaration of competing interest

The authors declare no conflicts of interest.

Acknowledgment

This research was jointly supported by the National Natural Science Foundation of China (42506223, U25A20798), and National Key Research and Development Program of China (2022YFC2806405).

References

Chen J, Hu GW, Bu QT, Liu CL, Dong L, Wan YZ, Mao PX, Guo Y, Wang ZH. 2021. Elastic wave velocities of hydrate-bearing sands containing methane gas bubbles: Insights from CT-acoustic observation and theoretical analysis. Journal of Natural Gas Science and Engineering, 88, 103844. doi: 10.1016/j.jngse.2021.103844.

Chong ZR, Yang SHB, Babu P, Linga P, Li XS. 2016. Review of natural gas hydrates as an energy resource: Prospects and challenges. Applied Energy, 162, 1633–1652. doi: 10.1016/j.apenergy.2014.12.061.

Dong L, Li YL, Liao HL, Liu CL, Chen Q, Hu GW, Liu LL, Meng QG. 2020. Strength estimation for hydrate-bearing sediments based on triaxial shearing tests. Journal of Petroleum Science and Engineering, 184, 106478. doi: 10.1016/j.petrol.2019.106478.

Dong L, Liao HL, Li YL, Meng QG, Hu GW, Wang JT, Wu NY. 2022a. Analysis of the mechanical properties of the reconstituted hydrate-bearing clayey-silt samples from the South China Sea. Journal of Marine Science and Engineering, 10, 831. doi: 10.3390/jmse10060831.

Dong L, Wan YZ, Li YL, Liao HL, Liu CL, Wu NY, Leonenko Y. 2022b. 3D numerical simulation on drilling fluid invasion into natural gas hydrate reservoirs. Energy, 241, 122932. doi: 10.1016/j.energy.2021.122932.

Dong L, Li YL, Wu NY, Wan YZ, Liao HL, Wang HJ, Zhang YJ, Ji YK, Hu GW, Leonenko Y. 2023a. Numerical simulation of gas extraction

performance from hydrate reservoirs using double-well systems. Energy, 265, 126382. doi: 10.1016/j.energy.2022.126382.

Dong L, Wu NY, Leonenko Y, Wan YZ, Liao HL, Hu GW, Li YL. 2023b. A coupled thermal-hydraulic-mechanical model for drilling fluid invasion into hydrate-bearing sediments. Energy, 278, 127785. doi: 10.1016/j.energy.2023.127785.

Dong L, Li YL, Zhang YJ, Hu GW, Liao HL, Chen Q, Wu NY. 2024a. Deformation characteristics of hydrate-bearing sediments. Journal of Ocean University of China, 23, 149–156. doi: 10.1007/s11802-024-5551-y.

Dong L, Liao HL, Li YL, Zhang YJ, Bu QT, Hu GW, Wu NY. 2024b. Estimating mechanical parameters of hydrate-bearing sediments on basis of shear wave velocity under triaxial compression. Journal of Ocean University of China, 23, 1481–1487. doi: 10.1007/s11802-024-5649-2.

Dong L, Wu NY, Leonenko Y, Wan YZ, Zhang YJ, Li YL. 2024c. Numerical analysis on hydrate production performance with multi-well systems: Synergistic effect of adjacent wells and implications on field exploitation. Energy, 290, 130292. doi: 10.1016/j.energy.2024.130292.

Dong L, Wu NY, Liu F, Sun ZW, Qi MH, Hu GW, Li YL. 2024d. Estimation on strength parameters of sediments with hydrate layered distribution based on triaxial shearing tests. Gas Science and Engineering, 123, 205255. doi: 10.1016/j.jgsce.2024.205255.

Freij AR, Tan C, Clennell B, Tohidi Bn, Yang JH. 2007. A wellbore stability model for hydrate bearing sediments. Journal of Petroleum Science and Engineering, 57, 209–220. doi: 10.1016/j.petrol.2005.10.011.

Frye MC, Shedd WW, Godfriaux PD, Dufrene R, Collett TS, Lee MW, Boswell R, Jones E, McConnell DR, Mrozewski S, Guerin G, Cook A. 2010. Gulf of Mexico gas hydrate joint industry project leg II: Results from the Alaminos Canyon 21 Site. Proceedings of the Annual Offshore Technology Conference, Houston, Texas, USA, OTC-20552-MS. doi: 10.4043/20552-ms.

Gajanayake SM, Gamage RP, Li XS, Huppert H. 2023. Natural gas hydrates-Insights into a paradigm-shifting energy resource. Energy Reviews, 2, 100013. doi: 10.1016/j.enrev.2022.100013.

Gao YH, Chen Y, Wang ZY, Chen LT, Zhao XX, Sun BJ. 2019. Experimental study on heat transfer in hydrate-bearing reservoirs during drilling processes. Ocean Engineering, 183, 262–269. doi: 10.1016/j.oceaneng.2019.04.092.

Gao YH, Sun BJ, Xu BY, Wu XR, Chen Y, Zhao XX, Chen LT. 2016. A wellbore/formation-coupled heat-transfer model in deepwater drilling and its application in the prediction of hydrate-reservoir dissociation. SPE Journal, 22, 756–766. doi: 10.2118/184398-PA.

Geissler WH, Gebhardt AC, Gross F, Wollenburg J, Jensen L, Schmidt AMC, Krastel S, Elger J, Osti G. 2016. Arctic megaslide at presumed rest. Scientific Reports, 6, 38529. doi: 10.1038/srep38529.

Gizatullin R, Dvoynikov M, Romanova N, Nikitin V. 2023. Drilling in gas hydrates: Managing gas appearance risks. Energies, 16, 2387. doi: 10.3390/en16052387.

Goldberg D, Janik A. 2009. Stress orientation in gas hydrate-bearing sediments near Hydrate Ridge: Evidence from borehole breakouts observed from logging-while-drilling resistivity images. Proceedings of the Ocean Drilling Program: Scientific Results, 204, 1–14 doi: 10.2973/odp.proc.sr.204.108.2006.

Gulbrandsen AC, Svartaas TM. 2017. Effect of poly vinyl caprolactam concentration on the dissociation temperature for methane hydrates. Energy and Fuels, 31, 8505–8511. doi: 10.1021/acs.energyfuels.6b03487.

Hannegan DM. 2005. Methane hydrate drilling technology. Offshore Technology Conference, Houston, Texas. doi: 10.4043/17448-MS.

Hou XK, Qi SW, Huang XL, Guo SF, Zou Y, Ma LN, Zhang LX. 2022. Hydrate morphology and mechanical behavior of hydrate-bearing sediments: A critical review. Geomechanics and Geophysics for Geo-Energy and Geo-Resources, 8, 161. doi: 10.1007/s40948-022-00461-8.

Hu QB, Li YL, Wu NY, Sun JX, Chen Q, Sun XF. 2023. Study on creep behaviors and nonlinear creep constitutive model for sandy marine hydrate-bearing sediments. Ocean Engineering, 286, 115717. doi: 10.1016/j.oceaneng.2023.115717.

Huang TJ, Li XS, Zhang Y, Wang Y, Chen ZY. 2020a. Experimental study of the drilling process in hydrate-bearing sediments under different circulation rates of drilling fluid. Journal of Petroleum Science and Engineering, 189, 107001. doi: 10.1016/j.petrol.2020.107001.

Huang TJ, Zhang Y, Li G, Li XS, Chen ZY. 2020b. Numerical modeling for drilling fluid invasion into hydrate-bearing sediments and effects of permeability. Journal of Natural Gas Science and Engineering, 77, 103239. doi: 10.1016/j.jngse.2020.103239.

Kayen RE, Lee HJ. 1991. Pleistocene slope instability of gas hydrate-laden sediment on the Beaufort sea margin. Marine Geotechnology, 10, 125–141. doi: 10.1080/10641199109379886.

Koh CA, Sum AK, Sloan ED. 2012. State of the art: Natural gas hydrates as a natural resource. Journal of Natural Gas Science and Engineering, 8, 132–138. doi: 10.1016/j.jngse.2012.01.005.

Kim JH, Lee YJ. 2009. Elemental, Rock-Eval, and isotopic compositions of bulk sediments, IODP Expedition 311. Proceedings of the Integrated Ocean Drilling Program, 311, 1–15 doi: 10.2204/iodp.proc.311.207.2008.

Li QC, Cheng YF, Ansari U, Han Y, Liu X, Yan CL. 2022. Experimental investigation on hydrate dissociation in near-wellbore region caused by invasion of drilling fluid: ultrasonic measurement and analysis. Environmental Science and Pollution Research, 29, 36920–36937. doi: 10.1007/s11356-021-18309-1.

Li YL, Chen MT, Zhang YJ, Xu HZ, Deng JY, Shen KX, Jiang YJ, Wu NY. 2024. Time-dependent deformation of marine gas hydrate-bearing strata conditioned to a wellbore: Experiments and implications. Ocean Engineering, 308, 118220. doi: 10.1016/j.oceaneng.2024.118220.

Li YL, Hu QB, Wu NY, Wang HB, Sun XF, Hu GW, Sun ZW, Jiang YJ. 2023. Acoustic characterization for creep behaviors of marine sandy hydrate-bearing sediment. Scientific Reports, 13, 22199. doi: 10.1038/s41598-023-49523-1.

Liao YQ, Sun Q, Wang ZY, Sun XH, Lou WQ, Sun BJ. 2022. Modeling of wellbore multiphase flow with free gas influx during horizontal drilling in marine hydrate reservoirs. Journal of Natural Gas Science and Engineering, 97, 104375. doi: 10.1016/j.jngse.2021.104375.

Lijith KP, Malagar BRC, Singh DN. 2019. A comprehensive review on the geomechanical properties of gas hydrate bearing sediments. Marine and Petroleum Geology, 104, 270–285. doi: 10.1016/j.marpetgeo.2019.03.024.

Liu C, Han YH, Phan DT, Abousleiman YN. 2022. Stress solutions for short- and long-term wellbore stability analysis. Journal of Natural Gas Science and Engineering, 105, 104693. doi: 10.1016/j.jngse.2022.104693.

Maslin M, Mikkelsen N, Vilela C, Haq B. 1998. Sea-level– and gas-hydrate–controlled catastrophic sediment failures of the Amazon Fan. Geology, 26(12), 1107–1110. doi: 10.1130/0091-7613(1998)026<1107:SLAGHC>2.3.CO;2.

McConnell DR, Zhang ZJ, Boswell R. 2012. Review of progress in evaluating gas hydrate drilling hazards. Marine and Petroleum Geology, 34, 209–223. doi: 10.1016/j.marpetgeo.2012.02.010.

Merey Ş. 2016. Drilling of gas hydrate reservoirs. Journal of Natural Gas Science and Engineering, 35, 1167–1179. doi: 10.1016/j.jngse.2016.09.058.

Merey Ş. 2019. Evaluation of drilling parameters in gas hydrate exploration wells. Journal of Petroleum Science and Engineering, 172, 855–877. doi: 10.1016/j.petrol.2018.08.079.

Merey S. 2020. Geomechanical wellbore stability analysis for the wells drilled in the shallow sediments of the Mediterranean Sea. Journal of Petroleum Science and Engineering, 186, 106714. doi: 10.1016/j.petrol.2019.106714.

Motghare PD, Musale A. 2017. Unconventional hydrocarbons: Gas hydrates-drilling challenges and suitable technology. SPE Oil and Gas India Conference and Exhibition, Mumbai, India, SPE-185424-MS. doi: 10.2118/185424-ms.

Najjarpour M, Jalalifar H, Norouzi A. 2021. Fifty years of experience in

rate of penetration management: Managed pressure drilling technology, mechanical specific energy concept, bit management approach and expert systems–A review. Journal of Petroleum Science and Engineering, 208(4), 109184. doi: 10.1016/j.petrol.2021.109184.

Ning FL, Wu NY, Yu YB, Zhang KN, Jiang GS, Zhang L, Sun JX, Zheng MM. 2013a. Invasion of drilling mud into gas-hydrate-bearing sediments. Part II: Effects of geophysical properties of sediments. Geophysical Journal International, 193, 1385–1398. doi: 10.1093/gji/ggt016.

Ning FL, Zhang KN, Wu NY, Zhang L, Li G, Jiang GH, Yu YB, Liu L, Qin YH. 2013b. Invasion of drilling mud into gas-hydrate-bearing sediments. Part I: Effect of drilling mud properties. Geophysical Journal International, 193, 1370–1384. doi: 10.1093/gji/ggt015.

Paull CK, Ussler W, Holbrook WS. 2007. Assessing methane release from the colossal Storegga submarine landslide. Geophysical Research Letters, 34, L04601. doi: 10.1029/2006GL028331.

Paull CK. 1997. Drilling for gas hydrates: Ocean Drilling Program Leg 164. Offshore Technology Conference, Houston, Texas, OTC-8294-MS. doi: 10.4043/8294-MS.

Peng XB, Lian ZH, Yu H, Liu T, Huang ZY. 2022. Is the drill pipe safe during drilling process?–A new method for evaluating drill pipe failure risk based on the Noisy-OR gate and bayesian network. Journal of Loss Prevention in the Process Industries, 80, 104906. doi: 10.1016/j.jlp.2022.104906.

Pratama MA, Khan HJ, Daigle H. 2023. A review of formation damage processes encountered during gas hydrate production. Geoenergy Science and Engineering, 228, 211958. doi: 10.1016/j.geoen.2023.211958.

Ruppel C, Boswell R, Jones E. 2008. Scientific results from Gulf of Mexico Gas Hydrates Joint Industry Project Leg 1 drilling: Introduction and overview. Marine and Petroleum Geology, 25, 819–829 doi: 10.1016/j.marpetgeo.2008.02.007.

Ruppel CD, Waite WF. 2020. Timescales and processes of methane hydrate formation and breakdown, with application to geologic systems. Journal of Geophysical Research: Solid Earth, 125, e2018JB016459. doi: 10.1029/2018JB016459.

Sahu C, Kumar R, Sangwai JS. 2020. Comprehensive review on exploration and drilling techniques for natural gas hydrate reservoirs. Energy and Fuels, 34, 11813–11839. doi: 10.1021/acs.energyfuels.0c02202.

Shao ZH, Wang JT, Lv KH, Wang ZL, Bai YJ, Wang R, Sun JS. 2023. NMR based experiment of fluid invasion to natural gas hydrate reservoir and hydrate dissociation inhibition mechanism. Fuel, 354, 129372. doi: 10.1016/j.fuel.2023.129372.

Song BJ, Cheng YF, Yan CL, Han ZY, Ding JP, Li Y, Wei J. 2019. Influences of hydrate decomposition on submarine landslide. Landslides, 16, 2127–2150. doi: 10.1007/s10346-019-01217-4.

Song YC, Luo TT, Madhusudhan BN, Sun X, Liu Y, Kong XJ, Li YH. 2019. Strength behaviors of CH4 hydrate-bearing silty sediments during thermal decomposition. Journal of Natural Gas Science and Engineering, 72, 103031. doi: 10.1016/j.jngse.2019.103031.

Sun JX, Ning FL, Lei HW, Gai XR, Sánchez M, Lu JG, Li YL, Liu LL, Liu CL, Wu NY, He Y, Wu M. 2018. Wellbore stability analysis during drilling through marine gas hydrate-bearing sediments in Shenhu area: A case study. Journal of Petroleum Science and Engineering, 170, 345–367. doi: 10.1016/j.petrol.2018.06.032.

Sun WT, Pei J, Wei N, Zhao JZ, Xue J, Zhou SW, Zhang LH, Kvamme B, Li QP, Li HT, Jiang L, Zhang Ch, Li C. 2021. Sensitivity analysis of reservoir risk in marine gas hydrate drilling. Petroleum, Safe and Efficient Use of Natural Gas Hydrate, 7, 427–438. doi: 10.1016/j.petlm.2021.10.013.

Sun X, Wang L, Luo H, Song YC, Li YH. 2019. Numerical modeling for the mechanical behavior of marine gas hydrate-bearing sediments during hydrate production by depressurization. Journal of Petroleum Science and Engineering, 177, 971–982. doi: 10.1016/j.petrol.2019.03.012.

Tan L, Liu F, Huang Y, Crosta G, Frattini P, Cen XQ. 2021. Production-induced instability of a gentle submarine slope: Potential impact of gas hydrate exploitation with the huff-puff method. Engineering Geology, 289, 106174. doi: 10.1016/j.enggeo.2021.106174.

Wan YZ, Yuan YL, Zhou C, Liu LL. 2023. Multiphysics coupling in exploitation and utilization of geo-energy: State-of-the-art and future perspectives. Advances in Geo-Energy Research, 10, 7–13. doi: 10.46690/ager.2023.10.02.

Wei JG, Fang YX, Lu HL, Lu HF, Lu JA, Liang JQ, Yang SX, 2018. Distribution and characteristics of natural gas hydrates in the Shenhu Sea Area, South China Sea. Marine and Petroleum Geology, 98, 622–628. doi: 10.1016/j.marpetgeo.2018.07.028.

Wei J, Cheng YF, Yan CL, Li QC, Han SC, Ansari U. 2019. Decomposition prevention through thermal sensitivity of hydrate formations around wellbore. Applied Thermal Engineering, 159, 113921. doi: 10.1016/j.applthermaleng.2019.113921.

Wu NY, Li YL, Chen Q, Liu CL, Jin YR, Tan MJ, Dong L, Hu GW. 2021. Sand production management during marine natural gas hydrate exploitation: Review and an innovative solution. Energy and Fuels, 35, 4617–4632. doi: 10.1021/acs.energyfuels.0c03822.

Yan CL, Ren X, Cheng YF, Song BJ, Li Y, Tian WQ. 2020. Geomechanical issues in the exploitation of natural gas hydrate. Gondwana Research, 81, 403–422. doi: 10.1016/j.gr.2019.11.014.

Yang MJ, Zhao J, Zheng JN, Song YC. 2019. Hydrate reformation characteristics in natural gas hydrate dissociation process: A review. Applied Energy 256, 113878. doi: 10.1016/j.apenergy.2019.113878.

Yin FL, Ni XY, Han JD, Di JW, Zhou YW, Zhao XX, Gao YH. 2023. Impact assessment of hydrate cuttings migration and decomposition on annular temperature and pressure in deep water gas hydrate formation riserless drilling. Energies, 16, 5903. doi: 10.3390/en16165903.

Zeng ZY, Kong L, Zhao YP, Sang SK, Niu G, Liu JQ, Wang N. 2023. Mechanical properties of gas hydrate-bearing sediments influenced by multiple factors: A comprehensive review of triaxial tests. Energy and Fuels, 37(21), 16190–16220. doi: 10.1021/acs.energyfuels.3c02623.

Zhang HW, Cheng YF, Shi JH, Li LD, Li ML, Han XT, Yan CL. 2017. Experimental study of water-based drilling fluid disturbance on natural gas hydrate-bearing sediments. Journal of Natural Gas Science and Engineering, 47, 1–10. doi: 10.1016/j.jngse.2017.08.029.

Zhang M, Niu M, Shen SW, Dai SL, Xu Y. 2021. Review of natural gas hydrate dissociation effects on seabed stability. Natural Hazards, 107, 1035–1045. doi: 10.1007/s11069-021-04629-5.

Zhao JF, Lang C, Chu JW, Yang L, Zhang LX. 2023. Flow assurance of hydrate risk in natural gas/oil transportation: State-of-the-art and future challenges. Journal of Physical Chemistry C, 127(28), 13439–13450. doi: 10.1021/acs.jpcc.3c02134.

Zhao X, Qiu ZS, Wang ML, Xu JG, Huang WA. 2019. Experimental investigation of the effect of drilling fluid on wellbore stability in shallow unconsolidated formations in deep water. Journal of Petroleum Science and Engineering, 175, 595–603. doi: 10.1016/j.petrol.2018.12.067.

Zhao YP, Liu JQ, Sang SK, Hua LK, Kong L, Zeng ZY, Yuan QM. 2023. Experimental investigation on the permeability characteristics of methane hydrate-bearing clayey-silty sediments considering various factors. Energy, 269, 126811. doi: 10.1016/j.energy.2023.126811.

Zheng MM, Liu TL, Jiang GS, Wei M, Huo YX, Liu L. 2020. Large-scale and high-similarity experimental study of the effect of drilling fluid penetration on physical properties of gas hydrate-bearing sediments in the Gulf of Mexico. Journal of Petroleum Science and Engineering, 187, 106832. doi: 10.1016/j.petrol.2019.106832.

Zhong RZ, Salehi C, Johnson R. 2022. Machine learning for drilling applications: A review. Journal of Natural Gas Science and Engineering, 108, 104807. doi: 10.1016/j.jngse.2022.104807.

Zhou SW, Zhao JZ, Li QP, Chen W, Zhou JL, Wei N, Guo P, Sun WT. 2018. Optimal design of the engineering parameters for the first global trial production of marine natural gas hydrates through solid fluidization. Natural Gas Industry B, 5(2), 118–131. doi: 10.1016/j.ngib.2018.01.004.