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钻井液侵入海洋含水合物地层的一维数值模拟研究

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Invasion of water-based drilling mud into oceanic gas-hydrate-bearing sediment: One-dimensional numerical simulations

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摘要

本文以墨西哥湾水合物区域为背景,利用数值模拟方法研究了过平衡钻井条件下,当钻井液温度高于地层中水合物稳定温度时,水基钻井液侵入海洋含水合物地层的动态过程及其一般性规律.与侵入常规油气地层相比,耦合水合物分解和再形成是钻井液侵入海洋含水合物地层的主要特征.模拟结果表明,钻井液密度、温度和盐度都对侵入过程有影响.在一定条件下,钻井液密度越大,温度和含盐量越高,则钻井液侵入程度越深,热量传递越远,水合物分解程度越大.分解的水气在合适条件下又会重新形成水合物,影响了钻井液进一步侵入.而重新形成的水合物的饱和度甚至可能高于原位水合物饱和度,在井周形成一个"高饱水合物"环带.这一现象归因于钻井液侵入的驱替推挤、水合物分解的吸热以及地层传热的滞后等因素共同作用.在地层物性一定的条件下,高饱水合物环带的出现与否主要受钻井液温度和盐度控制.水合物分解以及高饱水合物环带的出现对井壁稳定和电阻率测井解释有很大影响.因此,为维护井壁稳定、确保测井准确和减少水合物储层伤害,就必须对钻井液密度、温度和滤失量进行严格控制,防止地层中的水合物大量分解.最好采用控制压力钻井(MPD)和深侧向测井方式,同时尽量选用低矿化度的含水合物动力学抑制剂的钻井液体系,采取低温快速循环方式.

关键词 天然气水合物, 钻井液, 侵入, 水合物分解, 二次水合物, 井壁稳定, 测井

Abstract:

Integrating 3D seismic survey and well logging can achieve more accurate quantification of natural gas hydrates as a potential energy and environmental impact. However, some factors can influence the accurate interpretation and evaluation of well logging results. Except washouts, the invasions of drilling fluid probably also seriously distorts the results of well logging. In this work, we performed numerical simulations to study the dynamic behavior and general rules of mud invasion into oceanic gas hydrate bearing sediments (GHBS) by taking hydrate reservoirs in the Gulf of Mexico as a case. Compared with the conventional oil/gas-bearing sediments, hydrate dissociation and reformation are the main characteristics of mud invasion in GHBS when the invasion condition is in an unstable region of gas hydrates phase diagram. The simulation results show that the density (i.e., corresponding pressure), temperature, and salt content of drilling fluids have great effects on the process of drilling fluid invasion. When the temperature and salt content of drilling fluids are constants, the higher the density of the drilling fluid is, the greater degree of invasion and hydrate dissociation are. The increased pore pressure caused by the mud invasion, endothermic cooling with hydrate dissociation compounded by the Joule-Thompson effect and lagged effect of heat transfer in sediments, together make water and gas forming secondary hydrates. The secondary hydrate together with existing hydrate probably makes the hydrate saturation higher than original hydrate saturation. This high saturation hydrate ring could be attributed to the displacement effect of mud

invasion and the permeability reduction because of secondary hydrates forming. Under the same temperature and pressure of drilling fluids, the higher the salt concentration of the drilling fluid, the faster rate and greater degree of hydrate dissociation due to the stronger thermodynamic inhibition effect and heat transfer efficiency. The occurrence of high-saturation hydrate girdle band seems to mainly depend on the temperature and salinity of drilling fluids. The dissociated free gas, the dilution of water salinity associated with hydrate dissociation and the occurrence of high saturation hydrate ring probably cause the calculated hydrate saturation based on well logging is higher than that of actual hydrate-bearing sediments. Our simulations suggest that in order to keep wellbore stability and well logging accuracy during drilling through the hydrate-bearing sediment, it is better to adopt the managed pressure drilling and low-temperature mud circulation, and add kinetic inhibitors or anti-agglomerants instead of salts into drilling fluids for preventing hydrate re-formation in the well.
Keywords Gas hydrate, Drilling fluid, Invasion, Hydrate dissociation, Secondary hydrate, Wellbore stability, Well logging

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