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Quantitative Classification of Shallow Gas Blowout during Offshore Drilling Process

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There is abundant offshore oil and gas resource in the South China Sea and its prospective development has been speeded up in recent years. In the last ten years, many large oil and gas fields have been discovered, and more than 60 percent of them are in deep water areas of over 500m water depth. Exploration of offshore oil and gas resources, especially in deep water areas, will take an important role in the future development of the South China Sea.

A survey by ICES (International Council for the Exploration of the Sea) indicates that more than 20% blowouts in offshore drilling were caused by shallow gas, which resulted in a lot of disastrous accidents causing human losses and serious damage to be drilling facilities. In 1975, an offshore drilling platform working in the Gulf of Mexico encountered a high-pressure shallow gas zone when drilling to 300 m depth below the seabed. The well killing operation failed because of the extensive heat of the fire, and the platform rig was burned off and fallen into the lake eventually.

Assessment of SG hazard and its prevention and control techniques in offshore drilling have received a lot of concerns, especially for well drilling in new development areas. Geologic identification and assessment of NGH, SWF and SG gas formations can be carried out before drilling via geological survey and seismic data analysis, but the common method adopted to prevent SG hazard is to avoid drilling in the suspected region due to the hazardous nature of the shallow gas. Consequently, there has been lack of quantitative description of the SG blowout, and its hazard classification has not been clarified yet.

The source of the natural gas in offshore shallow gas zone can be from deep gas reservoirs, which migrated into and accumulated in shallow sediments under the seafloor along different types of channels, such as porous sand body, fractures and faults. In low permeability sediments, gas can migrate in vertical direction, and it can also flow along the formation dip in high permeability formations. The migrated gas can be gathered in a formation with cap layers of very low permeability, forming the so-called “stratified shallow gas”. If the pressure in a stratified shallow gas zone (or formation layer) is high over a long time, the gas will extrude into of the upper weak formation, and then a high-pressure gas diapir can be formed. Many gas diapirs were evolved from stratified shallow gas, while some gas diapirs can be formed due to volcano-like sand or mud flow, accumulating with gas later.

In the studies of offshore shallow hazards on drilling, well blowout has been classified into 5 grades as miner flow, low flow, moderate flow, strong flow and severe flow but without quantitative description. For gas-liquid two phase flow, the effect of liquid compressibility can be negligible under normal oil and gas field operations (2-50 MPa, 5-150°C), while gas can have huge volume change when the pressure and temperature change during its flow and migration from bottom of the hole to wellhead. Therefore, the volume of gas at both wellhead and well bottom conditions needs to be calculated. According to the field operation experience of the China National Offshore Oil Corp (CNOOC) in offshore drilling, shallow gas and hydrate were encountered in the South China Sea, in which gas invasion can be observed as an obvious drilling fluid overflow at the wellhead.

In this study, a quantitative classification of shallow gas hazards is given based on gas blowout rate, including slight flow (with gas

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inflow rate of less than 10 sm3/s), bubble flow (10-100 sm3/s), slug gas flow (100-270 sm3/s) and annular gas flow (more than 270 sm3/s), which can provide guidelines for the assessment and control of the shallow gas hazards. Once a shallow gas zone is encountered (e.g. with early gas kick signs), several measures can be taken to prevent the SG hazards in offshore drilling, such as dynamic well killing technology.

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