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A Review of Gas Hydrate Rock Physics Models

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Abstract : Gas hydrate is drawing attention due to the fact that it has an enormous amount all over the world, which is almost twice the conventional hydrocarbon reserves, making it a potential alternative source of energy. It is widely distributed in permafrost and continental ocean shelves, and many countries have launched national programs for investigating the gas hydrate. Gas hydrate is mainly explored through seismic methods, which include bottom simulating reflectors (BSR), amplitude blanking, and polarity reverse. These seismic methods are effective at finding the gas hydrate formations but usually contain large uncertainties when applying to invert the micro-scale petrophysical properties of the formations due to lack of constraints. Rock physics modeling links the micro-scale structures of the rocks to the macro-scale elastic properties and can work as effective constraints for the seismic methods. A number of rock physics models have been proposed for gas hydrate modeling, which addresses different mechanisms and applications. However, these models are generally not well classified, and it is confusing to determine the appropriate model for a specific study. Moreover, since the modeling usually involves multiple models and steps, it is difficult to determine the source of uncertainties. To solve these problems, we summarize the developed models/methods and make four classifications of the models according to the hydrate micro-scale morphology in sediments, the purpose of reservoir characterization, the stage of gas hydrate generation, and the lithology type of hosting sediments. Some sub-categories may overlap each other, but they have different priorities. Besides, we also analyze the priorities of different models, bring up the shortcomings, and explain the appropriate application scenarios. Moreover, by comparing the models, we summarize a general workflow of the modeling procedure, which includes rock matrix forming, dry rock frame generating, pore fluids mixing, and final fluid substitution in the rock frame. These procedures have been widely used in various gas hydrate modeling and have been confirmed to be effective. We also analyze the potential sources of uncertainties in each modeling step, which enables us to clearly recognize the potential uncertainties in the modeling. In the end, we explicate the general problems of the current models, including the influences of pressure and temperature, pore geometry, hydrate morphology, and rock structure change during gas hydrate dissociation and re-generation. We also point out that attenuation is also severely affected by gas hydrate in sediments and may work as an indicator to map gas hydrate concentration. Our work classifies rock physics models of gas hydrate into different categories, generalizes the modeling workflow, analyzes the modeling uncertainties and potential problems, which can facilitate the rock physics characterization of gas hydrate bearding sediments and provide hints for future studies.

Keywords : gas hydrate, rock physics model, modeling classification, hydrate morphology
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