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Characterization of a Reef Reservoir Permeability Using Well and Seismic Data

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Abstract
This study is based on a field development planning study of a reef reservoir with only one well and 3D seismic data. The reef has porosity of inter-grain, organically-derived pores and depositional or structural fractures. A high degree of heterogeneity of the reef reservoir makes the characterization more difficult. This work implemented an approach starting with core description, and deposition-driven interpretation, inversion and forward modeling of seismic data. Subsequently, pore structures, fractures and facies are identified using core description and logs. Fracture density is obtained from the core description for each facies. Porosity and permeability are statistically related using the core data according to the facies in the core. The matrix permeability field is generated in three dimensions based on porosity from the seismic. The fracture permeability is found to correlate with the matrix porosity from an adjacent reef field. However, due to the complexity of the fracturing in the reef, the core description needs to be corrected using the well test data and an analytical model of cracks, such that the core-described fracture can be equivalent to well test-detectable fractures. The fracture permeability is added to the matrix permeability according to the facies. Based on the different possible depositional models, the uncertainty is analyzed through the corresponding seismic inversions, and derived facies.

Background
The field for this study, LH 4-1, is located in the Zhujiangkou Basin of the South China Sea. The biggest reef oil field in China, LH1-1 was discovered in 1987. During follow-up exploration activity, a well named LH4-1-1 was drilled in LH4-1. Until then, LH4-1 remained undeveloped due to the reserves limits and the oil price. Recently, an attempt to re-evaluate this field was made. The sparcity of data or information is a challenge. However, the production history and related studies in a nearby field may help to improve the evaluation[1]. For this evaluation, log, core and their related measurements, and well test data for well LH4-1-1 – which is the only well in this field – are available. 3D reprocessed seismic data are available. With more wells drilled in the nearby field, more studies were conducted including depositional modeling, formation correlation and other aspects. This study intends to use the limited core data, logs and 3D seismic data to characterize the reservoir. The goal of this study is to build a reservoir model for field development evaluation. Understanding the uncertainty in the reserves and the petrophysical properties such as permeability is critical in the process. Therefore, the work starts with reservoir characterization, especially the modeling of porosity and permeability. Thereafter, the uncertainty is analyzed based on the possible depositional models.

Workflow
With limited data, a reasonable workflow for characterizing the reservoir is critical. For this field, the biggest uncertainty is in the reservoir property distribution beyond the drilled areas. Therefore, a depositional model-driven workflow is implemented in the study. The workflow is shown in Figure 1. The study starts with a revisit of the cores. With the core description, the formation is correlated with the adjacent field's formation and facies. The pore types are described carefully. This will give the possibility of inferring a depositional process. Following the development of the possible depositional models, seismic re-interpretation/inversion and forward modeling will be conducted. Afterwards, the core sample measurements are used to analyze the relationships between the different petrophyiscal properties. Furthermore, porosity and permeability will be modeled using the core description and the seismic inversion results. Finally, the uncertainty of the modeling is analyzed. A deterministic approach is used for the analysis.

To revisit the cores, the regional depositional and adjacent field depositional models are studied first. The revisit of the cores is to understand the spatial facies distribution possibilities and pore types. The model defines the deposition