Coupled Stratigraphic, Diagenetic and Basin Modelling for an Ultra-Deep Petroleum System Analysis: A Case Study from the Tarim Basin, China

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9.29.2020 - 10.1.2020 – AAPG Annual Convention and Exhibition 2020, Online/Virtual

Abstract

Basin and petroleum system modelling (BPSM) has become an integrated part for modern hydrocarbon explorations. However, one challenge is how to build a fine-scale 3D geological model and quantitatively model the porosity evolution of individual lithofacies for a target layer, which may directly affect hydrocarbon generation, migration and accumulation results. We coupled forward stratigraphic, diagenetic and basin modelling to simulate hydrocarbon accumulations in three dimensions using the following procedures: (1) simulating the sedimentary evolution of a target layer in three dimensions using a process-based stratigraphic forward modelling method and constructing a 3D high-resolution lithofacies model capturing fine heterogeneities; (2) reconstructing porosity evolution curves for each lithofacies using both petrographic and numerical simulation approaches, and (3) integrating the high-resolution 3D lithofacies volume and their porosity curves for the target layer into a 3D basin model and simulating hydrocarbon accumulation histories. The Lower Paleozoic petroleum system of the central Tarim Basin in China is an ultra-deep petroleum system, which is presently in the forefront of hydrocarbon exploration with huge potentials. Depositional processes of the lower Ordovician Penglaiba Formation were simulated in 3D indicating that a general retrogradation patternwas developed in the carbonate platform margin due to an overall rise in sea level and slope slumping. Four types of carbonates were developed as the carbonate margin and inner beach, restrict platform,

slope and basin facies showing strong heterogeneities in lithofacies. Due to carbonate growth over-steepening, parts of the platform margin and slope sediments were slumped and deposited in the slope toes and basinal facies. Four porosity evolution curves corresponding to the four lithofacies were constructed with relatively higher porosities being in the carbonate margin and inner beach facies comparing with the restrict platform, slope and basinal facies. Comparing with the conventional layer-cake basin model, the couple model appears to have trapped more hydrocarbons in the platform and slope to basin (lithology reservoirs) facies in the Penglaiba Formation throughout of the geological histories, which better match with the current exploration results.