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# Characterization and Preservation of Karst Networks in the Carbonate Reservoir Modeling

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## Abstract

Karstification was developed in the Ordovician carbonate reservoirs resulted from the action of meteoric waters during subaerial exposure. Poor core recovery and borehole imaging logs in permeable sections of the Ordovician carbonate reservoirs lead to poor understanding on karst networks. Due to the complex in geometry and lateral variability in thickness, features of karst networks cannot be clearly explained on 3D seismic. A new integrated approach is proposed, which consists of integrating 3D specially processed seismic geometric attributes, lithofacies and well log and drilling data into imaging karst networks and characterizing their effective properties. Geometric attributes, describing reservoir coherence, dip and lineaments, are seismic frequency dependent and allow reservoir architectures and karst features such as channels, dissolution fractures and sink holes to be identified in different frequency scales. The model-based classification technique is used to describe karst full geometry with estimated geometric attributes. The interpreted karst features are verified with total drilling losses encountered in drilled wells. To incorporate karst network geometries into a deterministic reservoir model, other reservoir heterogeneities based on their effects on reservoir connectivity and permeability are identified. The detailed reservoir architecture mapping for each layer related to karst connectivity and flow heterogeneity is the basis for the modeling carbonate reservoirs. Lithofacies units are characterized by reconciling lithology related attribute data at seismic and well log scales. Reservoir dynamic data are also used to quantify the karst network properties in terms of size, trend and pattern of permeability. With the case study, we demonstrate the application of our new integrated approach to the characterization and modeling of karst networks in the Ordovician carbonate reservoirs. Our results show that quantitative integrated interpretation of karst networks and reservoir architectures can provide a new understanding of carbonate reservoir modeling and underlying geological controls.

## Introduction

Knowledge of the processes of collapsed-paleocave system formation and evaluation is helpful in identifying karst draining systems and characterize their reservoir properties. Loucks (1999) described the evolutionary process of paleocave systems. Near-surface processes include dissolution excavation, collapse of cave walls and ceilings, clastic deposition and chemical precipitation. Palmer (1991) estimated that 99% of mapped continental cave passages (weighted by length) are initiated along fractures and bedding-plane partings.

Loucks (1999) noted that paleocave systems are a product of coalesced, collapsed-cave systems hundreds to several thousands of meters across, thousands of meters long, and tens of meters to more than 100 m thick. Loucks et al. (2004) defined six paleocave-related facies for the paleocave system. The six facies constitute the geological model, which include (1) the continuous strata facies; (2) disturbed strata facies; (3) highly disturbed strata facies; (4) coarse-clast chaotic breccia facies; (5) fine-clast chaotic breccia facies and (6) finer grained sediment facies.

The integration of the well and seismic data allowed the construction of the three-dimensional architecture of the paleocave system at the interwell scale. Although six paleocave-related facies were defined in the geological model (Loucks et al., 1999), only one seismic facies in each depth zone can be identified from seismic data (Loucks et al., 2004). The three depth zones, undisturbed host rock, disturbed host rock and breccia, can be characterized with seismic data. Their associated three seismic facies include continuous reflection seismic facies, relatively continuous reflection seismic facies and chaotic reflection seismic facies (McMechan et al., 2002).

To understand karst contribution in the reservoir, it is necessary to integrate geological and geophysical data with production data. Dissolution processes and their products in carbonate reservoirs have important efforts on karst development and reservoir characteristics. Seismic data can help to delineate the distributions of large scale karst features such as karst channels, sink holes and corrosion fractures. The