Effects of Diagenesis on the Acoustic Velocity of the Triassic Oolitic Shoals in the Yudongzi Outcrop of Erlangmiao Area, Northwest Sichuan Basin

Hui Rong (荣辉), Yangquan Jiao (焦养泉), Liqun Wu* (吴立群)
Key Laboratory of Tectonics and Petroleum Resources of Ministry of Education, China University of Geosciences, Wuhan 430074, China; Faculty of Earth Resources, China University of Geosciences, Wuhan 430074, China

Yuan Gu (顾元)
Faculty of Geophysics and Geomatics, China University of Geosciences, Wuhan 430074, China

Liya Zhang (张利亚)
Key Laboratory of Tectonics and Petroleum Resources of Ministry of Education, China University of Geosciences, Wuhan 430074, China; Faculty of Earth Resources, China University of Geosciences, Wuhan 430074, China

Rong Li (李荣)
Department of Earth and Atmospheric Sciences, University of Alberta, Alberta T6G1H7, Canada

Fanping Zeng (曾凡平)
BGP Dagang Branch, BGP Inc., China National Petroleum Corporation, Tianjin 300280, China

ABSTRACT: The oolitic shoals of the Triassic carbonate platform margin in the Yudongzi (鱼洞子) outcrop of Erlangmiao (二郞庙) area in the northwestern Sichuan (四川) basin present a scarce opportunity to quantitatively describe their diagenesis and its effects on the acoustic velocity. Using a detailed field geologic survey, profiles illustration of typical depositional system, and systematic testing, five types of diagenesis have been identified in the oolitic shoals: micritization, cementation, compaction and pressolution, dissolution, and dolomitisation. The cementation is composed of four subtypes (micrite cements, fibrous calcite cements, granular calcite cements, and blocky calcite cements). The dissolution is formed from three subtypes (freshwater selective dissolution, burial non-selective dissolution, and burial selective dissolution). The dolomitisation is composed of three subtypes (fine-crystalline dolomites, microcrystalline dolomites, and medium-crystalline dolomites). In order to quantitatively describe the diagenetic fabric of oolitic shoals, the micritic grain content, calcite cement content, mean pore diameter, pore types, dolomite content, and dolomite types have been evaluated. Based on these data, the relationship between the acoustic velocity and diagenesis of oolitic shoals has been established. The results show that the diagenetic fabric is linearly related with the acoustic velocity, and the general trend observed is as expected a decrease of velocity as the micritic grain content, mean pore diameter, and dolomite content increase, or the sparite cement content decreases. This study will demonstrate that the transformation of diagenetic facies will probably make the petrophysical properties of
the oolitic shoals regularly changed. The reflection configuration of diagenetic facies in the oolitic shoals can be shown in the synthetic seismic model simulated according to the P-wave impedance and S-wave impedance.

KEY WORDS: oolitic shoal, diagenesis, acoustic velocity, Feixianguan Formation, Sichuan basin.

INTRODUCTION

Compared with other regions overseas, marine strata are thermally overmature and have experienced multiple-stage tectonic deformation and complicated diagenetic evolution in most regions of China (Hao et al., 2008; Ma et al., 2008, 2007; Cai et al., 2004), which make petroleum exploration in marine sequences more difficult. In recent years, several commercial productive hydrocarbon reservoirs with the burial depth of over 5 000 m have been found in the oolitic shoal depositional system of the Triassic carbonate platform margin in the northeastern Sichuan basin, such as Puguang gas field, Dukouhe gas field, Luojiazhai gas field, and Yuanba gas field (Guo, 2010; Ma et al., 2007; Wang et al., 2007; Zhang et al., 2006; Chen, 2001), showing great potential for the deep carbonate reservoirs in the region. However, there are great challenges to exactly predicate these reservoirs based on seismic data augmented with limited well data, since the vertical resolution of typical industry seismic data and the lateral spacing of well data are insufficient to accurately model the heterogeneity (Grammer et al., 2004; Westphal et al., 2004; Doherty et al., 2002). Accordingly, outcrop analogs present an effective way to understand the heterogeneity of the oolitic shoal reservoirs of the carbonate platform margin.

The strong diagenesis of Triassic oolitic shoal reservoirs may significantly change the acoustic properties, which makes interpretation of acoustic logging data and seismic reflection data complicated. Many researchers have tried to understand the relationships between the acoustic velocity and a series of parameters, including temperature, pressure, water saturation, porosity, and clay content (Ma, 2008; Rezaee et al., 2007; Sams and Andrea, 2001; Klimentos, 1991). Most of these studies have been carried out in sandstone reservoirs. However, studies of the relationships between the acoustic velocity and the parameters of rock fabric in carbonate reservoirs have been sparse (Dou et al., 2011; Croizé et al., 2010; Rajabi et al., 2010; Ameen et al., 2009). Therefore, quantitatively describing the diagenesis fabric of oolitic shoal reservoirs and establishing predictive relationships between the diagenesis fabric and acoustic properties are key to enhancing exploitation success in these systems.

The purpose of this article is to identify types of diagenesis and to quantitatively evaluate the diagenetic fabric of oolitic shoal reservoirs. The micritic grain content, calcite cement content, mean pore diameter, pore types, dolomite content, and dolomite types are used to describe their diagenetic fabric. Based on these data, we will establish the predictive relationships between the acoustic velocity and diagenetic fabric of the oolitic shoal reservoirs and then simulate the two-dimensional synthetic seismic sections according to the P-wave and S-wave impedance of oolitic shoal reservoirs. This will provide guidance for understanding reservoir heterogeneity and improving predictions for this depositional system.

GEOLOGIC BACKGROUND

The Sichuan basin, one of the most important gas-producing provinces in western China, is situated in the western part of the Yangtze craton. It is a Late Mesozoic–Cenozoic foreland basin overlying a Sinian–Middle Mesozoic passive margin (Wang, 1989). The Yudongzi outcrop of Erlangmiao area is located on the Longmenshan fold belt of the Sichuan basin, near about 10 km in the northwest of Erlangmiao (Fig. 1a). The outcropping strata in the Yudongzi outcrop of Erlangmiao area include the Late Permian Changxing Formation (P2c) and the Early Triassic Feixianguan Formation (T1f). The Feixianguan Formation is divided into four members, named T1f1, T1f2, T1f3, and T1f4 from base to top (Ma et al., 2007). The lithology of T1f1 and T1f2 is primarily mudstone, oolitic grainstone, and oolitic dolostones, the lower part of T1f3 is mudstone, and the upper part is oolitic grainstone or grainstone, and T1f4 features a set of purplish-red gypsolite and micrite (Fig. 1b). It is gen-