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ScienceDirect

Natural Gas Industry B 4 (2017) 294–304

www.elsevier.com/locate/ngib

Research Article

Forming mechanism of the Ordovician karst carbonate reservoirs on the northern slope of central Tarim Basin☆

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Received 16 January 2017; accepted 25 March 2017
Available online 14 October 2017

Abstract

The Ordovician karst carbonate reservoirs on the northern slope of central Tarim Basin are important oil and gas exploration targets in the basin, but their dissolution mechanisms are in controversy. In this paper, based on the integrated study of sedimentation, sequence and reservoir, together with microscopic analysis and macroscopic seismic data analysis, the carbonate karst reservoirs in the study area were divided into three types: dissolved pore-cavity limestone reservoir, pore-cavity dolomite reservoir and fracture-cavity siliceous reservoir, and their forming mechanisms were discussed respectively. Some findings were obtained. First, dissolved pore-cavity limestone reservoirs are distributed in the upper Yingshan Fm and Yijianfang Fm of the Ordovician vertically, while pore-cavity dolomite reservoirs are mainly developed in the Penglai Fm and lower Yingshan Fm of the Ordovician with great thickness. Second, dissolved pore-cavity limestone reservoirs were formed by karstification on the third-order sequence boundary (lowstand tract), while pore-cavity dolomite reservoirs were formed by deep burial dolomitization controlled by karstification on the third-order sequence boundary, both of which are distributed in the highstand tract below the third-order sequence boundary. Third, siliceous reservoirs are developed under the control of faulting, as a result of reworking of deep hydrothermal fluids along faults to the limestone, and the siliceous reservoirs and their hydrothermal solution fracture-cavity systems are distributed near faults. It is further predicted that, in addition to the three types of reservoir above, platform-margin reef-flat reservoirs are developed in the Ordovician on the northern slope of central Tarim Basin.

Keywords: Central Tarim Basin; Ordovician; Carbonate reservoir; Third-order sequence boundary karstification; Karstification during lowstand tract; Burial dolomitization

1. Geologic setting

The North Slope in the central Tarim Basin lies in the middle part of the central uplifted zone in the Tarim Basin. It particularly refers to the Middle–Lower Ordovician carbonate platform–platform margin at the footwall of No. 1 fault zone in central Tarim Basin (Fig. 1). Tectonically it lies at the conjunction of the southeastern Shuntuoguole Low Uplift, western Guchengxu Uplift and southwestern Manjar Depression. The North Slope is separated from the Katake Uplift by (the hanging wall of) No. 1 fault zone on the southwest. The North Slope is a monoclinal structure nowadays with structural high in the southeast and structural low in the northwest.

A great breakthrough has been made in natural gas exploration in the Ordovician carbonate reservoirs at the North Slope in the central Tarim Basin. After oil and gas discoveries in the Middle Ordovician Yijianfang Fm in Well SN1, high-yield gas flow was obtained from the Ordovician System in Wells SN4, SN5 and SN7 (open flow capacity from the Middle–Lower Ordovician Yingshan Fm in Well SN5 reached

☆ Supported by the Sinopec Northwest Oilfield Company Project "Genesis and occurrence of Ordovician reservoirs at the North Slope in the central Tarim Basin" (No. 34400000-14-ZC0607-0031).
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Peer review under responsibility of Sichuan Petroleum Administration.

http://dx.doi.org/10.1016/j.ngib.2017.03.001

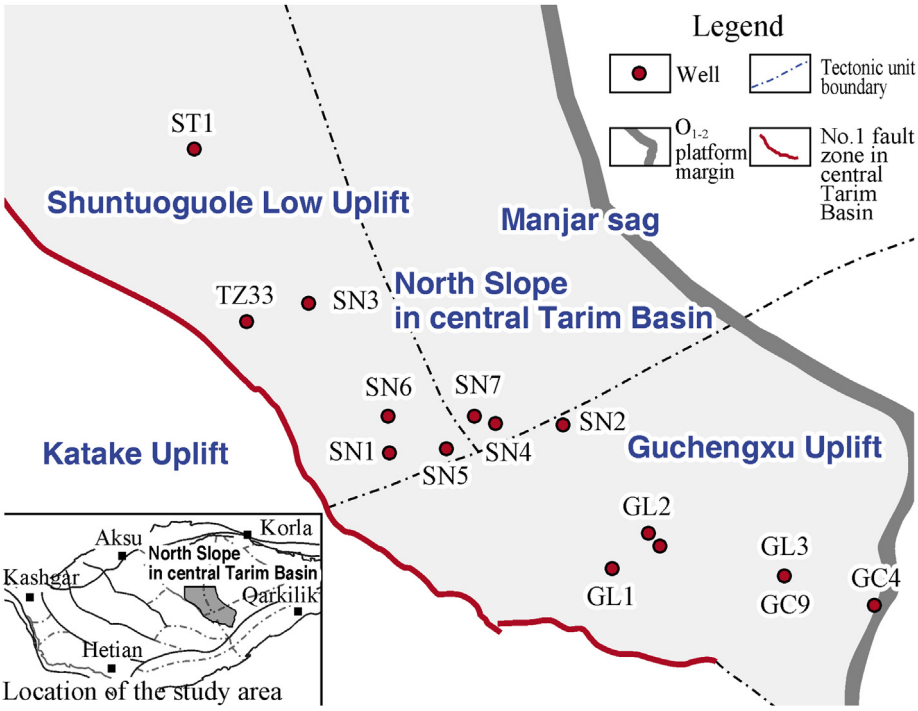

Fig. 1. Location of the North Slope in central Tarim Basin.

165.8 × 10^4 m^3/d) [1] and gas production rate in Well GC9 reached 107.8 × 10^4 m^3/d [1]. Well ST1 drilled in the northwest of Shunnan well field witnessed oil and gas discoveries in the Yingshan Fm. The Ordovician System at the North Slope has become an important target in hydrocarbon exploration in the Tarim Basin. Ordovician carbonate reservoirs in central Tarim Basin were commonly considered to be of corrosion origin, but the mechanism of corrosion is still in dispute. It may be hydrothermal corrosion caused by Permian magmatism-volcanism [2–13], or inter-stratal karstification, i.e. weathering crust karstification in the middle Caledonian [14–24], or karstification at sequence boundaries [25–30]. The Ordovician carbonate reservoirs in central Tarim Basin may include buried-hill karstic reservoirs, buried corroded reservoirs and internal dolomite reservoirs [31–38].

Our studies show that the Ordovician carbonate reservoirs at the North Slope in central Tarim Basin are related to karstification at the third-order sequence boundaries (in the lowstand) and relevant buried dolomitization which is also dominated by the third-order sequence boundaries. They were not generated by weathering crust karstification with ancient life break (karstification at the first-order or second-order sequence boundaries). The Ordovician karstic carbonate reservoirs at the North Slope occur extensively below the third-order sequence boundaries. Limestone reservoirs with dissolved pores and cavities were mainly generated by karstification at the third-order sequence boundaries. Intrastratal dissolved pores, cavities and fractures were generated by karstification in the lowstand; Mg^{2+}-rich fluids may flow into these channels and trigger dolomitization in the deep burial period to form dolomite reservoirs.

2. Sedimentation and reservoir properties

2.1. Sedimentation

A sedimentary framework formed in the Late Sinian Epoch in Tarim was preserved till the end of the Ordovician Period, with carbonate platforms developed at the structural high in the west (present-day central–northern Tarim) and undercompensation basins formed at the structural low in the east (present-day Manjar). The carbonate platform facies field in the west are distributed in Bachu–central Tarim–northern Tarim–Kalpin and is composed of carbonate platforms, platform margins and gentle slopes. The basin facies field in the east is distributed in eastern Tarim-Kuruktag and is composed of slopes, shelves and abysmal undercompensation basins (before O_2) or turbidite basins (after O_3). The Ordovician carbonate reservoirs in Tarim vertically exist in the Lower Ordovician Penglaiba and Yingshan Fms, Middle Ordovician Yijianfang Fm, and Upper Ordovician Lianglitage Fm. In central and northern Tarim Basin, carbonate platforms are overlain with the Upper Ordovician Sangtamu Fm, which consists of hybrid shelves and turbidite basin argillaceous sediments of 1000–3000 m in thickness deposited in a short period (1.8 Myr. ago) (Fig. 2).

The Penglaiba Fm at the North Slope in central Tarim Basin is 205–337 m thick and consists of crystalline dolomite changing upward into limy dolomite and dolomitic limestone; limestone occurs at the bottom. The lower Yingshan Fm is 380 m thick and consists of interbedded micritic to powder-scale crystalline dolomite, crystalline dolomite, limy dolomite, dolomitized micrite, dolomitic limestone, dolomitized