



# Features, origin and distribution of microbial dolomite reservoirs: A case study of 4<sup>th</sup> Member of Sinian Dengying Formation in Sichuan Basin, SW China



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**Abstract:** Based on the drilling cores and slice observations, single well data and geochemical analysis, this paper analyzed features, origin and distribution of the 4<sup>th</sup> Member reservoirs of Sinian Dengying Formation ( $Z_2dn_4$ ) in the Sichuan Basin. It is demonstrated that the main reservoir is a set of microbial dolomites. The discovery of spherical dolomite has revealed that the dolomitization was related to the microbial action, belonging to the early protodolomite of low-temperature precipitation; the primary matrix pores and the penecontemporaneous eroded pores constituted the subject of the reservoir space, which was not due to the interlayer karst process related to the Tongwan Movement and burial-hydrothermal dissolutional process. The microbial mound-shoal complex and penecontemporaneous dissolution mainly control the development and distribution of the scaled reservoirs in  $Z_2dn_4$ . The microbial dolomite reservoir surrounding the intracratonic rift had a large thickness, good continuity and high quality, and was an important target of the survey.

**Key words:** Sichuan Basin; Sinian; Dengying Formation; microbial dolomite; mound-shoal complex; spherical dolomite; penecontemporaneous corrosion; intracratonic rift

## Introduction

The Sinian Dengying Formation dolomite is considered a major domain for natural gas exploration in the Sichuan Basin, and a hot spot of microbial carbonate reservoir study in old strata in recent years<sup>[1]</sup>. In 1964, the Weiyuan Gas Field with the proved geological reserves of  $400 \times 10^8 \text{ m}^3$  was discovered on the Leshan-Longnüsi paleo-uplift, in which the major pay is the Dengying Formation. A series of exploration activities were conducted in the crest and slope zone of the Leshan-Longnüsi paleo-uplift from the 1970s to 1990s, with 16 wells drilled on 11 structures (e.g., Longnüsi, Anpingdian and Ziyang). In 1971, Well Nüji was tested a  $1.85 \times 10^4 \text{ m}^3/\text{d}$  of industrial gas flow from the 5 206 m to 5 248 m interval in the Dengying Formation. From 1993 to 1997, Well Zi-1, Zi-3 and Zi-7 drilled on the Ziyang structure, produced  $(5.33\text{--}11.54) \times 10^4 \text{ m}^3/\text{d}$  of industrial gas from the Dengying Formation. Since 2010, major breakthroughs have been made in exploration of the Dengying Formation in the Gaoshiti-Moxi structure northeast of the Weiyuan structure, marking the commencement of exploration for large-scale gasfield with gas reserves of a trillion of cubic meters.

Although great efforts have been made by predecessors to determine the origin of the Dengying Formation dolomite reservoirs in the Sichuan Basin, there are four distinctly different ideas: (1) the karst reservoir concept proposed by Xiang Fang et al.<sup>[2–5]</sup>, which believes that the development of this type of reservoir is controlled primarily by the Tongwan Movement-related supergenetic karstification occurred at the top part of the Sinian strata, and the 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> members might outcrop beneath the unconformity surface, depending on the degree of denudation; (2) the grain bank reservoir concept proposed by Wang Xingzhi et al.<sup>[6–8]</sup>, which considers that the development of this type of reservoir was controlled primarily by the dolomitization of the shoal facies sediments and the crystalline dolomite with or without residual grain structure acted as the carrier of the reservoir; (3) the hydrothermal dolomite reservoir concept proposed by Feng Mingyou et al.<sup>[9–10]</sup>, which suggests that the development of the Dengying Formation dolomite reservoir was controlled primarily by the burial-hydrothermal effect; and (4) the microbial dolomite reservoir concept, which proposes that the Dengying Formation reservoirs can be classified as the mi-

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crobial dolomite reservoirs<sup>[11–13]</sup>, but an in-depth study with regard to the influence of microbes on the early-stage dolomite precipitation and reservoir space development remains absent.

This paper places emphasis on the features, origin and distribution of the 4<sup>th</sup> member reservoirs, since this formation is relatively less studied and confirmed to be the major pay zone from which wells drilled in the Gaoshiti-Moxi structure produced over a million cubic meters of gas.

### 1. Geological setting of reservoir development

The Sinian Dengying Formation in the Sichuan Basin can be divided into four members<sup>[14]</sup>. The 1<sup>st</sup> Member, 30 to 160 m thick, is composed of light grey to dark grey laminated micritic-powder crystalline dolomite, dolarenite and algal dolomite interbeds, and siliceous band and flint lump in local parts. The 2<sup>nd</sup> Member, 350 to 550 m thick, consists of light grey to grey white algal micritic dolomite, and a few thrombolite, laminar algal dolomite, dolarenite and algal dolomite, intercalated with gypsum salt rock and gypsum micritic dolomite, turning into powder-fine crystalline dolomite after recrystallization, in which there is an over 10 m thick grape-lace shaped dolomite bed containing residual dissolved pores and caves in the middle. The 3<sup>rd</sup> Member, 0 to 60 m thick, is made up of dark grey to grey micritic-powder crystalline dolomite, intercalated with dolarenite, algal dolomite and fine crystalline

dolomite; in the central Sichuan region a grey black mudstone is present at the bottom of this member, which thins gradually and vanishes towards southwest. The 4<sup>th</sup> Member, 0 to 350 m thick, consists of light grey to dark grey laminar algal dolomite or stromatolite algal dolomite and a few thrombolite, algal micritic dolomite, dolarenite and algal dolomite, with well-developed laminar algal and stromatolite algal textures, rare snowflake or grape-lace shaped structures and abundant matrix pores and dissolved pores and caves (Fig. 1).

The Sinian Dengying Formation in the Sichuan Basin consists mainly of platform facies sediments<sup>[15]</sup>. The 1<sup>st</sup> Member is the product of an early-stage transgression occurred at the Late Sinian, which is in conformable or disconformable contact with the Lower Sinian Doushantuo Formation and overlain by the 2<sup>nd</sup> Member. At the end of depositional stage of the 2<sup>nd</sup> Member, the climate became arid, and the salinity of seawater rose, which was favorable for microbial reproduction. This member in the central Sichuan region, during the Episode I of the Tongwan Movement<sup>[13]</sup>, was uplifted to weathering and erosion, and thus is disconformably overlain by the 3<sup>rd</sup> Member. The 3<sup>rd</sup> Member consists of a transgressive facies mudstone deposited at early-stage and a platform-margin and intraplatform grain bank formed at later-stage, and is overlain by the 4<sup>th</sup> Member. The 4<sup>th</sup> Member was deposited when the platform margin and intraplatform microbial mound-shoal complex were developing. This member was leached and

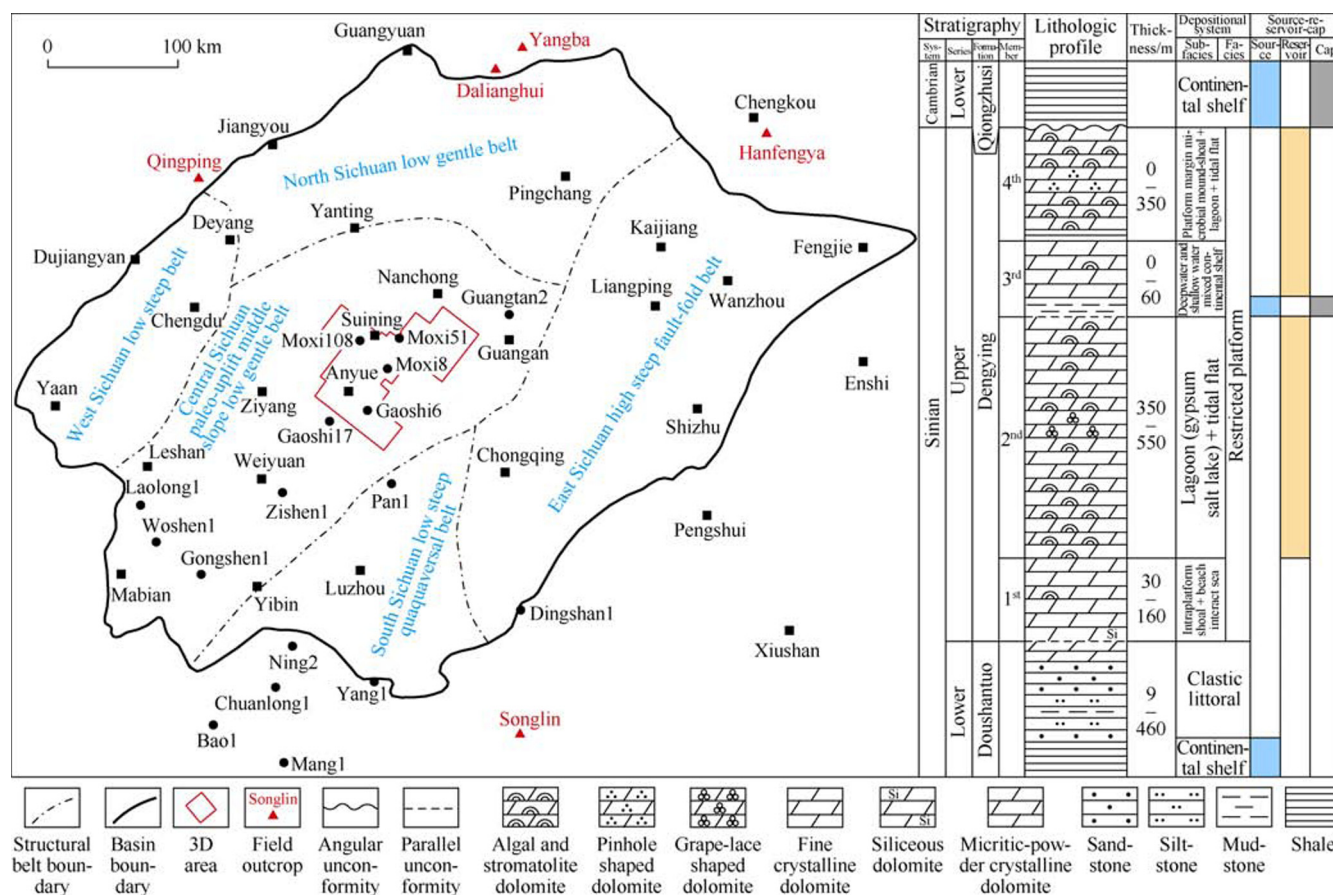


Fig. 1. Features of the Sinian strata in the Sichuan Basin and the location of the study area.

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