Characteristics of Changxing-Feixianguan Formations on Panlongdong Outcrop in Northeastern Sichuan Basin, China*

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Search and Discovery Article #50598 (2012)
Posted April 23, 2012

*Adapted from extended abstract prepared for oral presentation at AAPG Annual Convention and Exhibition, Long Beach, California, April 22-25, 2012, AAPG © 2012

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Abstract

Panlongdong outcrop lies in Xuanhan County, Sichuan Province in China. In this outcrop, both Upper Permian Changxing Formation and Lower Triassic Feixianguan Formation are well exposed. According to combined lithology study in the field and thin-section analysis in the laboratory, three-depositional facies (basin margin slope, open platform, and restricted platform) are identified. The stratigraphic boundary between Permian and Triassic Formations in this outcrop was redefined, and reservoir-type rockss of Permian reef and Triassic shoal dolomite are recognized.

The thickness of Changxing Formation is about 130m, with 2 cycles of reef complex, each cycle divided into reef-base, reef-core and reef-cap. Reef-base is mostly composed of bioclastic limestones. Mainly bafflestones and framestones formed the reef-core facies, with sponges, hydroids and algae being the main reef-building organisms, and brachiopods, bivalves, crinoids, gastropods, foraminifera, etc., with micritic or sparry cements filling the spaces between skeletons. On top of the reef-core are dolomitized boundstones and bioclastic dolostones. Grain banks and oolitic shoals comprise Feixianguan Formation Member 1, with a thickness of about 35m. Upward, micritic dolostones interbedded with marlstones of tidal-flat or lagoonal facies are present.

Both reef-core skeleton and bioclastic rocks in Changxing Formation and grain bank and oolitic shoal facies in Feixianguan Formation are intensively dolomitized. Favorable reservoir-type rocks are present, with considerable dissolution pores and cavities filled or half-filled with calcite or bitumen, where dolomitization is best developed (e.g., 5th, 6th, and 11th layers) of the outcrop. Intercrystalline and intergranular dissolved pores are the most important pore types, followed by vugs, moldic pores, and dissolved fractures. Dolomitized sponge framestones in Changxing Formation and oolites in Feixianguan Formation Member 1 show the best porosity, and reservoir potential, a feature which is different from results of previous studies of this region, and thereby includes Feixianguan Formation Member 1 to the exploration targets.

Dolostones in both Changxing and Feixianguan formations show similiar petrographic properties of burial dolomite, and geochemical characteristics of high $^{87}Sr/^{86}Sr$ isotopes, lower Sr content, higher Fe^{2+} content, relatively higher ä^{13}C, and very negative ä ^{18}O. The homogenization temperature and salinity of fluid inclusions are very high, indicating that the dolomitization fluid of both formations originated from the same marine saline formation water, in Feixianguan Formation.

Stratigraphy

In Sichuan Basin, the Permian System is divided into Lower, Middle, and Upper. After Middle Permian was deposited, large-scale regression developed on Yangtze platform, while massive basalt eruption invaded the Kangtien ancient land areas and east Sichuan Basin. Then Upper Permian beds, deposited during the marine transgression, overlie the widespread basaltic sand units.

Upper Permian Changxing Formation mainly consists of a set of marine carbonates. Influenced by Kaijiang-Liangping trough and Chengkou-Exi trough, thickness of Changxing Formation varies in different areas of Sichuan basin, mainly 50m to 500m, with an average of 180m. Lower Triassic Feixianguan Formation overlies Changxing Formation and underlies Lower Triassic Jialingjiang Formation (Table 1). Deposition of Feixianguan Formation in northeastern Sichuan Basin was also controlled by the paleogeography of Kaijiang-Liangping trough. Traditionally, Feixianguan Formation is divided into 4 members. In northeastern Sichuan Basin, internal boundaries within Member 1 to Member 3 are blurred, with pelite and evaporite of Member 4 being the uppermost unit

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Previous studies on this outcrop have placed the stratigraphic boundary between Permian and Triassic Formations at the base of a set of thin, interbedded marlstones and argillaceous dolomite of Layer 14 (Figure 1a). According to our detailed observation of the outcrop, a paleokarst interface is present between Layer 10 and Layer 11 (Figure 1b). We concluded that it is the boundary between the Permian and Triassic, based mainly on two lines of evidence. Firstly, the paleokarst interface is present in other outcrops in nearby areas and was proved to be the stratigraphic boundary between Permian and Triassic formations. Secondly, the amount of bioclasts declines markedly from across the boundary to the younger beds. Also there are no obvious differences in lithology across the “old” boundary.

Depositional Structures

Based on the new division of formations, the thickness of Changxing Formation in Panlongdong outcrop is about 130m, and it can be divided into three subsequences. Layers 1to 3 are the first subsequence deposited on basin margin slope, with a thickness of about 25m. The lithology is medium-thick, dark to light grey, bioclastic-bearing micritic limestone (Figure 2a), with coarsening-upward texture. Layers 4 to 6 were deposited on an open platform; they contain 2 stages of platform-margin reef complexes. Each reef cycle is divided into reef-base, reef-core, and reef-cap. Reef-base is composed mostly of bioclastic limestones. Mainly bafflestones and framestones form the reef-core facies, with sponges, hydroids, and algae being the main reef-building organisms, and brachiopods, bivalves, crinoids, gastropods, foraminifera, etc. and micritic or sparry cements filling the spaces between skeletons (Figure 2b, c). On top of the reef-core are dolomitized boundstones. Layers 7 to 10 are composed of bioclastic or intraclastic dolostones of open-platform, bioclastic banks and grain banks. Layers 11 to 14 are grain banks and oolitic shoals were depositional sites for Feixianguan Formation Member 1, with a thickness of about 35m. Upward, micrite dolostones interbedded with marlstones of tidal-flat or lagoonal facies are present. The whole outcrop is dolomitized to varying degrees.

Potential Reservoir Genesis and Distribution

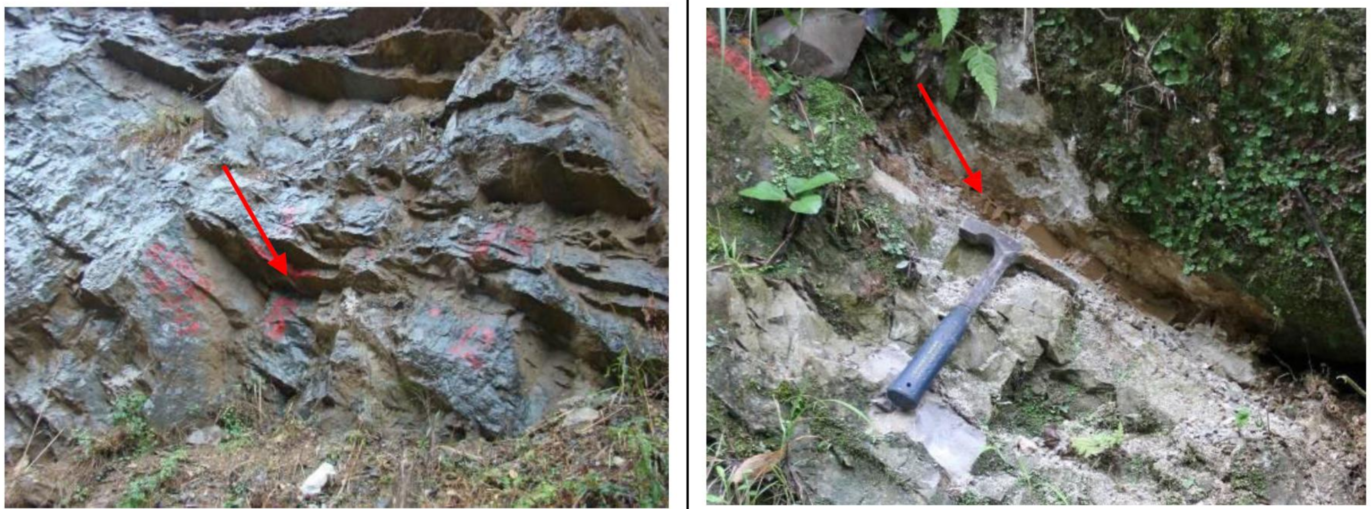
Both reef-core skeleton and bioclastic rocks in Changxing Formation and grain bank and oolitic shoal facies in Feixianguan Formation are intensively dolomitized. Based on microscopic analysis, diagenetic sequence of both Upper Permian Changxing and Lower Triassic Feixianguan carbonates is summarized as:
(1)micritization→(2)cementation→(3)compaction→(4)presolution→(5)dissolution→(6)dolomitization→(7)dissolution→(8)hydrocarbon charging→(9)dissolution→(10)quartz participation→late calcite cement. Among these diagenesis processes, dolomitization and dissolution are most beneficial for reservoir development, while compaction, cementation, and late mineral fillings destroy the reservoir to some extent.

Dolostones in both Changxing and Feixianguan formations show similiar petrographic properties of burial dolomite, and geochemical characteristics of high $^{87}Sr/^{86}Sr$ isotopes, lower Sr content, higher Fe^{2+} content, relatively higher $\delta^{13}C$, and very negative $\delta^{18}O$. The homogenization temperature and salinity of fluid inclusions are very high, indicating that the dolomitization fluid of both formations comes from the same marine-originated saline formation water in Feixianguan Formation. Similar diagenetic sequence features also demonstrate that the dolomites formed or were reformed.

Favorable potential reservoirs are present, with considerable dissolution pores and cavities filled or half-filled with calcite or bitumen, where dolomitization most develops, such as in the 5th, 6th, and 11th layers of the outcrop. Intercrystalline and intergranular dissolution pores are the most important types in developing reservoir space (Figure 3a, b), followed by vugs, moldic pores and dissolved fractures (Figure 3c, d). Dolomitized sponge framestones in Changxing Formation and oolites in Feixianguan Formation Member 1 form the best potential reservoirs; this determination is unlike that from previous studies of this region. It also means that Feixianguan Formation Member 1 should be considered as a exploration target.

	Northwestern Sichuan	Middle Sichuan	Northeastern Sichuan	Average thickness (m)
Lower Triassic	Jialingjiang Formation			1010
	Daye Formation	Feixianguan Formation		450
Upper Permian	Dalong Formation	Changxing Formation		180
	Wujiaping Formation	Longtan Formation	Wujiaping Formation	120
	Bassalt			

Table 1. Stratigraphic correlation from Upper Permian to Lower Triassic in Sichuan Basin.



a. previous formation boundary

b. new formation boundary

Figure 1. Stratigraphic boundary between Permian and Triassic (red arrows). A (left): Previous formation boundary. B (right): New formation boundary.

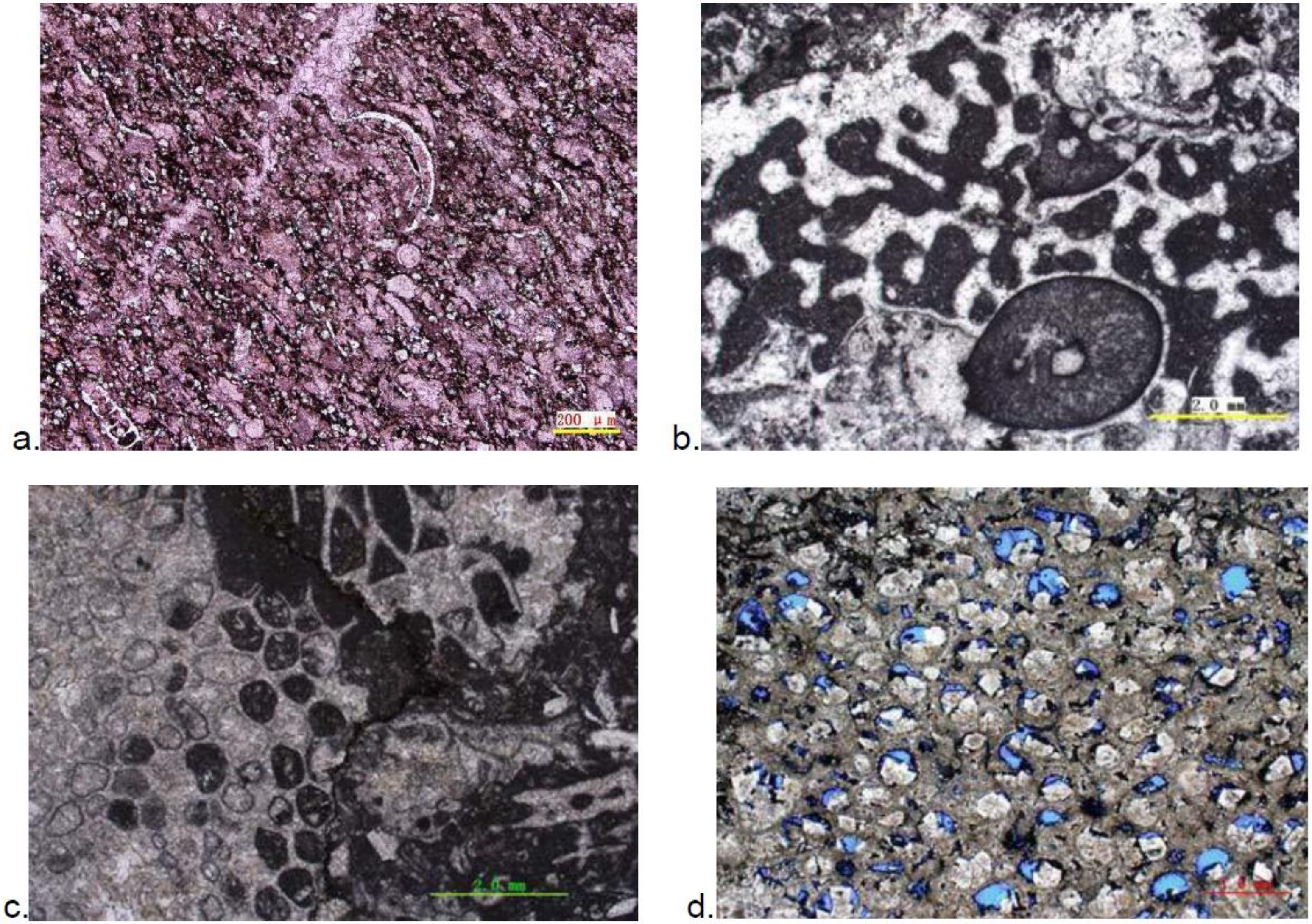


Figure 2. Depositional structures. A (upper left). Layer 2: Sparite, bioclastic limestone, PPL, AFeS. B (upper right). Layer 4: Sponge framestone, 84% dolomite, PPL. C (lower left). Layer 6: Sponge framestone, 97% dolomite, PPL. D (lower right). Layer 12: Oolitic dolostone, 97% dolomite, PPL, BSE.

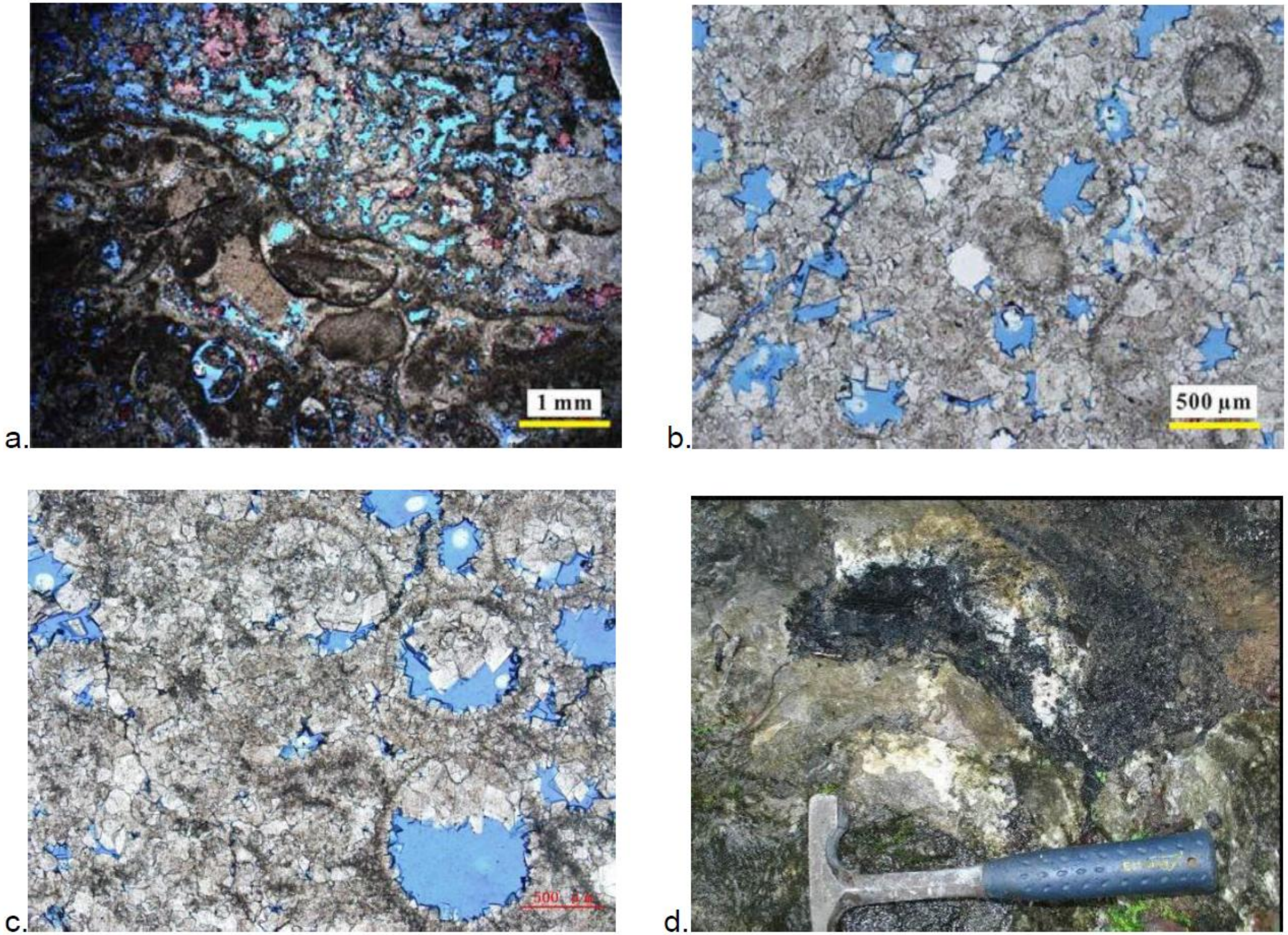


Figure 3. Pore space types. A (upper left). Layer 6: PPL, AFeS, BSE, sponge reef dolostone, dissolution pores. B (upper right). Layer 12: PPL, BSE, dissolution pores are connected by fractures. C (lower left). Layer 12: PPL, BSE, moldic pores formed by dissolution of ooids. D (lower right). Layer 6: Vug filled by bitumen.