



Discovery of Xuanhan-Kaijiang Paleouplift and its significance in the Sichuan Basin, SW China



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Abstract: A large inherited paleouplift from Pre-Sinian to Early Cambrian, named Xuanhan-Kaijiang paleouplift, has been discovered based on multiple geological information in the eastern Sichuan Basin: firstly, onlap deposition of Upper Sinian Dengying Formation and Lower Cambrian is observed from peripheral zone to central Xuanhan-Kaijiang area from the seismic profile; secondly, Dengying Formation thickness distribution map shows that this formation is thinnest in Xuanhan-Kaijiang area, and thickens towards the surrounding areas; thirdly, terrigenous clastic rock is observed in Upper Sinian Dengying Formation on outcrops in Chengkou County and Wuxi County etc., indicating the development of a paleouplift. The analysis of the characteristics, formation and evolution of the paleouplift reveals that the plane distribution of the paleouplift shows an arched structure, stretching in a north-south trend. The area of the paleouplift is around 16 000 km². Vertically, the paleouplift can be divided into three parts: platform in the middle, steep slope in the west and ramp in the east. Originally, the paleouplift was an erosion-type uplift above the water level during the early stage of the Late Sinian; and gradually transformed into deposition-type uplift under water level during the late stage of the Late Sinian to the Early Cambrian. The formation of the paleouplift was controlled by several factors, including basement uplift, intracratonic rift, basement faults and regional uplifting. The paleouplift and its slope areas, favorable for the development of high energy facies and karst weathering reservoirs, are important exploration target areas in the eastern Sichuan Basin in the near future.

Key words: Sichuan Basin; eastern Sichuan; paleouplift; Xuanhan-Kaijiang paleouplift; Sinian to Early Cambrian; intracratonic rift; onlap deposition

Introduction

The “paleouplift” refers to the uplift structure in a certain stage of geological history during the basin evolution process^[1]. Cratonic basins often develop on stable and thick continental lithosphere^[2–4], where multi-phase paleouplifts may form due to multi-phase episodic uplift and subsidence during the evolution of the basins^[4–8]. Paleouplift in cratonic basin and its slope area are main oil and gas enrichment area, so they are important field and direction of oil and gas exploration, and the research on paleouplift is of great significance^[1, 9–14]. Major oil and gas discoveries have been made in all paleouplift areas of cratonic basin across the world, such as Russia’s Eastern Siberia, Permian basin in North America, the North Sea in Europe, Illizi in North Africa, and Australia’s Cooper Basin^[11–12, 15]. Major discoveries have also been made in Leshan–Longnüsi paleouplift^[16], Kaijing paleouplift^[17] and

Luzhou paleouplift^[18] in Sichuan Basin, Tazhong paleouplift in Tarim Basin^[13] and the central paleouplift in Ordos Basin^[9, 14] in China.

In the early period of Early Cambrian, the Upper Yangtze paleo-geographic pattern was made up of several islands, paleo-lands and underwater uplifts as well as the confined gulfs^[19]. Based on detailed research on field outcrops before, obvious sedimentary discontinuity has been found in Zhenba and Ziyang area of Dabashan during the early period of Early Cambrian^[20–23], called “Zhenba uplift” by Cheng et al.^[22]. It was proposed by many researchers that there was a NS-trending paleouplift at Sishang of Xixiang and in Zhenba–Wanyuan area, for example, the proposals of “Dabashan uplift”^[22, 24], “Bashan uplift”^[24], “Beiba paleo-land”^[24], “Sishang island”^[25], “Sishang–Wanyuan uplift”^[26], “Zhenba–Wanyuan barrier”^[25], “Zhenba–Wanyuan ridge”^[25]. But due

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to limited data available, paleo-structures inside the basin was not studied previously; and little study on the horizontal and vertical characteristics, formation and evolution of the paleouplifts and their control on sedimentary reservoir development have been conducted. Based on fine seismic interpretation, a large inherited Pre-Sinian–Early Cambrian paleouplift has been found in Eastern Sichuan through this study, as the uplift core is located in Xuanhan–Kaijiang region, it is named “Xuanhan–Kaijiang paleouplift”. This understanding was first proposed in the exploration seminar organized by the Northeastern Sichuan Gas Field of PetroChina Southwest Oil and Gas Field Company in Dazhou, Sichuan on October 21, 2015.

1. Geological settings

The study area is located in the Eastern Sichuan Basin (Eastern Sichuan for short); in terms of ground structure, it is the most typical barrier folded belt development area in China^[27], dominated by NE and NNE trend. The Palaeozoic, Carboniferous and Permian strata are exposed at the core of Huayingshan anticline, while Triassic and Jurassic strata are exposed at the core of other anticlines. The study area is neighboring to NE-trending Qiyueshan fault and trough-like folded belt of the western Hunan–Hubei in the southeast, the NNE-trending Huayingshan fault and central Sichuan block in the northwest, Chongqing, Nanchuan and Wulong in the south, Dabashan and Micangshan orogenic belts in the north, as well as Qinling tectonic belt and southern Hannan block. Dabashan orogenic belt is a series of prominent arcuate fold belts in SW trending, and divided into Northern Dabashan thrust nappe belt and Southern Dabashan foreland fold-and-thrust belt by Ankang fault belt, Chengkou–Fang County fault belt and Tiexi–WuXi fault belt. Northern Dabashan thrust nappe belt is mainly composed of a set of Proterozoic and Early Paleozoic volcanic clastic rocks and deep water sedimentary rocks, lack of Devonian and Carboniferous strata. Southern Dabashan foreland fold-and-thrust belt is divided into basement decoupling structure belt and cap rock decollement belt by Zhenba–Xujiaba fault belt, and Dabashan foreland depression belt is to the south of Tiexi–Wuxi concealed fault^[28–29] (Fig. 1). In Dabashan area, Micangshan and Chengkou–Wuxi stratigraphic microprovinces have obvious different Cambrian characteristics. In Micangshan stratigraphic microprovince, the Lower Cambrian consists of Kuanchuanpu Formation, Guojiaba Formation, Xiannüdong Formation, Yanwangbian Formation and Kongmingdong Formation from bottom to top. In the Chengkou–Wuxi stratigraphic microprovince, the Lower Cambrian consists of Shuijingtuo Formation, Shipai Formation, Tianheban Formation and Shilongdong Formation from bottom to top^[26].

2. Evidence supporting the Xuanhan–Kaijiang paleouplift

2.1. Evidence on seismic profiles

The Sinian System has not been encountered during well

drilling in Eastern Sichuan. Based on fine synthetic record calibration of the wells encountering the Sinian in Central Sichuan, a regional seismic profile from Central Sichuan to Eastern Sichuan (Gaoshi 1–Moxi 39–Guangtan 2–Kaijiang area) has been made (Fig. 2). Meanwhile, by introducing the calibrated horizons into Eastern Sichuan, a NW–SE leveling seismic profile of Mid-Cambrian bottom in this region has been made. The profiles show the Sinian Dengying Formation and Lower Cambrian overlap from Eastern Sichuan periphery to Xuanhan–Kaijiang region, revealing the development of Xuanhan–Kaijiang paleouplift.

The seismic profiles show that in the early period of Late Sinian, an obvious uplift existed in Xuanhan–Kaijiang region, which was transited to wide and gentle slope towards both sides. At the paleouplift core, Members 1 and 2 of Dengying Formation are absent. Members 1 and 2 of Dengying Formation at the paleouplift wings overlap towards the paleouplift core, and the overlap in the NW side is more obvious than that in the SE side. In the late period of Late Sinian, paleouplift development scale was reduced to some extent; Members 3 and 4 of Dengying Formation present overlap sedimentation towards the paleouplift core. Member 3 and the lower part of Member 4 of Dengying Formation are lost at the paleouplift core. In the early period of Early Cambrian, obvious overlap sediments existed in Kuanchuanpu Formation and Guojiaba Formation in the NW side of paleouplift, but the overlap in the SE side was not obvious. In the middle period of Early Cambrian, the paleouplift development scale reduced gradually, but slight overlap sedimentation can still be seen. The strata at paleouplift wings became slightly thicker than core strata till the late period of Early Cambrian (Figs. 3 and 4).

2.2. Evidence of stratum thickness

2D and 3D seismic data of 57 000 km² in Eastern Sichuan and its periphery have been interpreted in detail, and a plane figure of the thickness of Dengying Formation has been plotted. As mentioned earlier, due to the absence of the early sedimentary strata in Dengying Formation at the core of Xuanhan–Kaijiang paleouplift, the thickness of Dengying Formation should be thinner. At paleouplift wings, due to the overlap sediments of early formation in Dengying Formation, the thickness of Dengying Formation increases. The thickness diagram of Dengying Formation clearly shows the change pattern of stratum thickness increasing from the core to wings of Xuanhan–Kaijiang paleouplift. The figure shows that Dengying Formation is thinnest in Xuanhan–Kaijiang region with a thickness of less than 200 meters, and thickens towards the periphery, reaching up to 750 m and above 1300 m in the SE and NW respectively (Fig. 5), which further proves the existence of Xuanhan–Kaijiang paleouplift.

2.3. Indirect evidence of field outcrops

The development of clastic rocks in marine carbonate sedimentary strata not only indicates the peripheral supply of

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