PETROLEUM EXPLORATION AND DEVELOPMENT
Volume 43, Issue 5, October 2016
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: PETROL. EXPLOR. DEVELOP., 2016, 43(5): 751–758.

RESEARCH PAPER

Restoration of paleokarst landform and its geological significance: A case from Middle Permian Maokou Formation in Northwestern Sichuan Basin

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Abstract: Based on the analysis of deposition and tectonism, "residual thickness method" is used to restore the paleokarst landform of Middle Permian Maokou Formation in northwestern Sichuan Basin. With the feature of plain with karst hilllock, the paleokarst landform in this area can be classified into three secondary geomorphic units: karst platform, karst slope and karst groove, in which the karst hillocks and monadnocks on karst platform and karst slope are the favorable zones for the development of karst reservoirs, and favorable exploration zones in the next step. Furthermore, in the karst grooves, the Maokou Formation are often denuded into Members Mao 3 or Mao 2, and the seismic profiles show the top of Maokou Formation in karst groove is missing due to erosion. Members Mao 4 and Mao 3 are generally preserved in the karst platform. The seismic profiles across the karst platform and karst groove show that the NE and NW striking erosion grooves were the result of differential uplift and erosion caused by basement faulting at the end of Middle Permian, which then successively developed and formed the NW striking Guangyuan-Wangcang and the NE striking Jiangyou-Guangyuan troughs in Changxing Period. It is suggested to pay more attention to the geological research and exploration of the shallow carbonate platform areas adjacent to the syneclise and trough in fairly deep water.

Key words: northwestern Sichuan Basin; Middle Permian; Maokou Formation; paleokarst; ancient landform; erosion groove

Introduction

It has been proved by drilling that weathering crust karstification is the main mechanism for the formation of high-quality reservoir in the Middle Permian Maokou Formation of northwestern Sichuan Basin[1], so restoring paleokarst landform is the key to predict development zones of this kind of karst reservoir[2]. Moldic and residual thickness methods are the most commonly used methods in restoring paleokarst landform[3–5]. However, due to the intensive extensional faulting activity during Wujiaping-Changxing period in late Permian and differential subsidence which created Guangyuan-Wangcang trough[6, 7], the deposition rate in the platform was greatly different from that in the trough[8, 9], so it is not practicable to restore the paleokarst landform by moldic method. Limited drilling data, outcrops profile of basin periphery and seismic data were used to restore the paleokarst landform of the Middle Permian Maokou Formation in northwestern Sichuan Basin by residual thickness method, and delve into its tectonic and petroleum geological significance.

1. Geological setting

The study area is located at the transition zone between Northern Sichuan low and even fault fold belt, Longmenshan fault fold belt and Micangshan uplift zone of the northwest of the Upper Yangtze Plate (Fig. 1). The collision and joining of the North China Plate and Upper Yangtze Plate lead to intensive foreland deformation including thrust-nappe structure dominating in the south of North China Plate and nappe-slip structure dominating in the north of Upper Yangtze plate[10]. Based on the measured outcrop sections, well logging data, and through analogy in lithologic and electrical property with western and southern Sichuan Basin[5], re-dividing the Middle Permian Maokou Formation in northwestern Sichuan Basin,

Received date: 21 Jan. 2016; **Revised date:** 10 Aug. 2016.
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the result shows that its thickness is about 120–240 m. According to lithologic property, the Maokou Formation is subdivided into four members from bottom to top: Mao 1(P_2m^1), Mao 2(P_2m^2), Mao 3(P_2m^3) and Mao 4(P_2m^4). The main lithology of P_2m^1 and lower-middle P_2m^2 is dark-grey micrite-bioclastic limestone (nodular limestone) with augen and eyelid structures, containing chert; the main lithology of upper-middle P_2m^2 and P_2m^3 is light grey-offwhite bioclastic limestone, leopard limestone/dolomite and crystal dolomite, and with dark-grey micrite-bioclastic limestone in local area; the main lithology of P_2m^4 is micrite limestone (Fig. 1).

During the late Middle Permian, under the effect of tectonic differential uplift caused by Tungwu Orogeny, the top Maokou Formation was exposed to surface for 1-3 Ma[11]. Long-term weathering denudation led to various degrees of denudation of the Maokou Formation, and nearly complete denudation of local area of P_2m^4 and upper P_2m^3 (Fig. 2), even affecting P_2m^2 in some area[3]. Till the Late Permian, the Maokou Formation and its top erosional surface was covered by the Wujiaping Formation and Dalong/Changxing Formation[7] successively.

2. Restoration of paleokarst landform

There are limited wells drilling to the Maokou Formation in the study area, and it is difficult to identify and divide inside strata of the Maokou Formation through outcrop and seismic profile, while its bottom interface is isochronous and with lithologic conversion characteristic, which is easy to be identified by outcrops and logging[3, 12], and corresponds to a strong phase peak with better continuity in seismic profile. So the bottom interface of the Maokou Formation was chosen as the restoration datum, and residual thickness method was adopted to restore the paleokarst landform of the Maokou Formation.

2.1. Distribution of strata thickness and ancient landform implications

Taking the variation trend of 2D seismic reflection time thickness as a constraint, residual thickness of the Maokou Formation was acquired by means of drilling, field measured and regional geological surveying data with scale of 1:200000 (Table 1), and then formation residual thickness map of the Maokou Formation was drawn (Fig. 3). In combination with the conservation and distribution of the Maokou Formation revealed by drilling and outcrops, paleogeologic map of the top Maokou Formation before the sedimentation of the Wujiaping Formation in northwestern Sichuan Basin was drawn (Fig. 4). Fig. 4 indicates that NE-striking and NW-striking stratum thinning zones (with depth of 120–160 m) are respectively developed in Jiangyou- Guangyuan and Guangyuan-Wangcang area. The Chejiaba profile near the stratum thinning zone and drilling data in Well Long16 reveal that P_2m^4 and upper P_2m^3 are missing there, indicating that the stratum thinning is related to denudation. The stratum thinning zone divides the study area into three stratum thickening zones: Zitong-Cangxi, eastern Wangcang and northern Jiange. The Maokou Formation is the thickest in Jiange, Wangcang, Cangxi, Shuangyushi and Laoguanmiao areas, ranging from 190 m to 230 m, and 160–190 m thick in other areas.

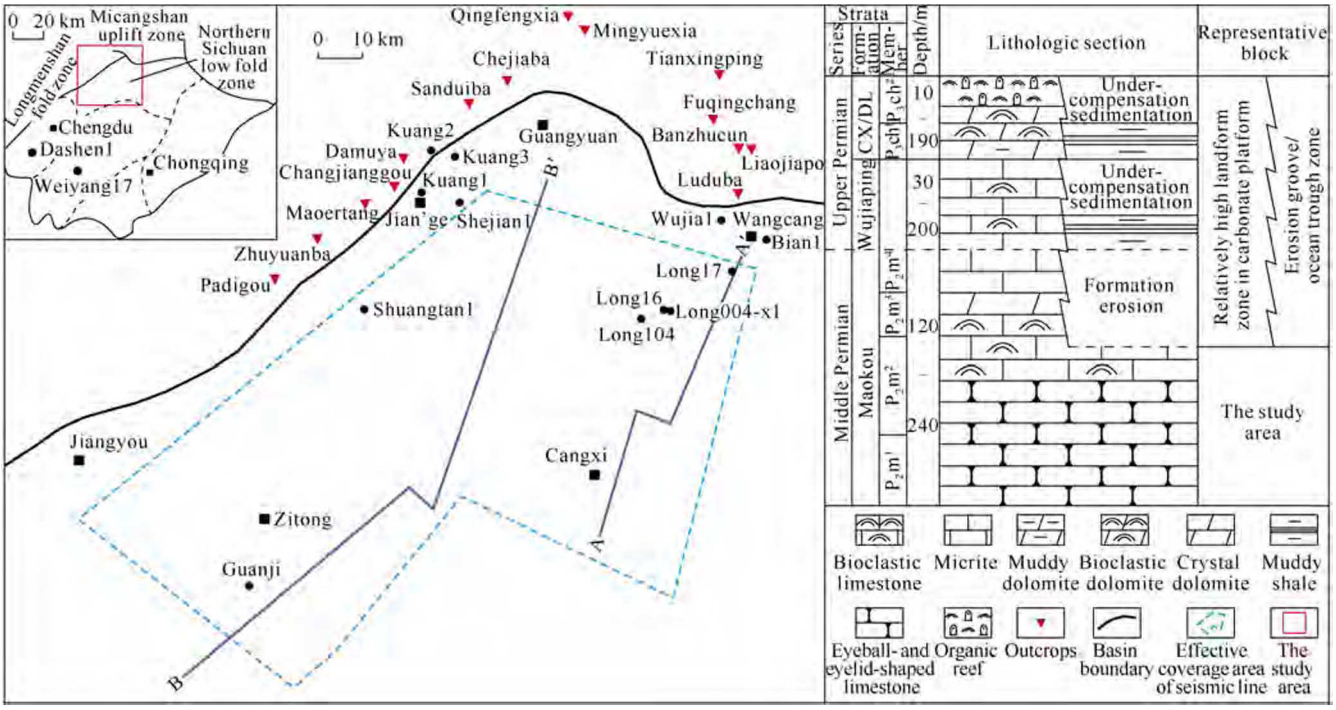

Fig. 1. Geological setting of the study area.