



The sedimentary facies characteristics and lithofacies palaeogeography during Middle-Late Cambrian, Sichuan Basin and adjacent area



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ABSTRACT

Combined with the regional strata filling characteristics of Middle-Upper Cambrian, the present paper conducts a systematic research on sedimentary facies in the basin and its peripheral area by utilizing 164 field outcrops and drilling and coring data. Further, the method of “multi-factor comprehensive synthesis based on single-factor analysis” was employed to investigate the sedimentary facies and palaeogeography of the study area and establish the sedimentary facies model. Stratigraphic reveals that the study area represents the pattern of thin-northwest and thick-southeast by stretching northeast-southwest. Within the present basin, the pattern of “one thin and two thick” predominates, while outside the basin “four thin and three thick” filling feature was found. Sedimentary facies shows that the study area was featured by rimmed carbonate platform. Specifically, carbonate platform, slope and northeastern corner Qinling paleoceanic Basin and southeastern corner Jiangnan Basin was identified from the west to the east. The carbonate platform contains restricted platform, evaporation-restricted platform, semi-restricted platform and the platform margin. Single factor analysis and lithofacies palaeogeographic characteristics manifests that during Middle-Late Cambrian, the western Old land evolved into peneplain stage, and that the eastern and southwestern sub-sags remained connected to the open-sea to some extent. At the time, the shallow seawater circulation was relatively restricted, while the ancient seabed tended to be flat and evaporation characteristics significantly diminished. Secondary sea-level fluctuation intensively influenced the development of scaled grain beach. It is suggested that tide marginal beach, intraplatform shoal subfacies zone, along with Shiqian-Sangzhi in southeast and Zhenba-Xinshan in northeast platform-margin beach subfacies zone to be preferable targets for the favorable reservoir facies zone and potential oil and gas reservoir area.

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1. Introduction

Sichuan Basin and its periphery possess basic conditions for forming high quality oil and gas reservoir in the Cambrian [1–5], among which, the carbonate reservoir mainly includes Lower Cambrian Longwangmiao Formation, Middle Cambrian Gaotai Formation and Middle–Upper Cambrian Xixiangchi Group [5–8]. In recent years, after the high production oil and gas are pleasantly discovered in the Longwangmiao Formation of the Central Sichuan paleo-uplift [3,9], a series of high quality gas reservoir are also successively discovered in the Central Sichuan paleo-uplift and its surrounding areas [10–12], and even in Yongshun of Hunan [13] and western areas of Xuefeng Mountain [14,15]. Thus, the Xixiangchi Group is gradually considered as the replacement stratum for oil and gas exploration in Sichuan Basin and its periphery [16,17]. For the existing types of high quality reservoir, the dolomite reformed through the overlay of epigenetic karst may be regarded as a high quality reservoir body [16–20]. At present, there is a great deal of argument about the dolomitisation types and causes of formation facilitate the formation of high quality reservoir [19–24], but for the mechanism of epigenetic karstification, the low-energy non-grainstone may rapidly trend to be more dense for the initial pore is difficult to store, so the karstic water cannot easily enter the inside of reservoir in the diagenesis phase, and only attach to the fracture zone for water-rock interaction, which just optimizes the permeability of initial reservoir to some extent [25], to form a fractured or hole - fractured reservoir with low porosity and high permeability; compared to this, for the grainstone, due to a number of initial pore are stored [26,27], the karstic water will make a sufficient water-rock interaction along the intergranular pore to form a hole or fractured hole type reservoir with a better permeability, which is widely reported for several carbonate reservoir in the basins [17,28–31]. From this, the grainstone has a material basis for forming high quality reservoir bodies [32–41], so to seek temporal-spacial distribution regularities of grainstone in the Xixiangchi Group and its paleogeographic environment for formation become the top priority for finding this karst reformed type dolomite reservoir. Till now, there are already many researches on the sedimentary characteristics and paleogeography in the Middle - Later Cambrian Epoch of Sichuan Basin and its periphery [5,8,42–48]; but there are few reports on rehabilitation for sedimentary characteristics [49] and paleogeography of large and medium scaled Xixiangchi Group in Sichuan Basin and its periphery, so undoubtedly, this limits the further fine oil and gas exploration and well placement in the basin. Therefore, for this research, by the use of 164 pieces of field and drilling data of basin and its periphery, relevant researches are made to the Xixiangchi Group sedimentary facies and paleogeography to expand the exploration filed of karstic reservoir of this beach facies.

2. Geological background

Sichuan Basin is a kind of rhombohedral structure - sedimentary basin (Fig. 1) on the northwest of Yangtze paraplatform and becomes the present tectonic feature after the action of transpressional faulted fold of himalayan epoch [50]. The basin is under the expansion period in the Sinian Period - Early Paleozoic Era, mainly expressing as tensile extended luffing [51]. Northern and southeast margins of Yangtze region are transited to be continental margin basin [52]. In the early stage of Early Cambrian, Mianzhu - Changning area develops a nearly south - north large intercratonic inner fault depression zone [4], and in the later stage of Early Cambrian, this fault depression zone is

gradually combined as depression inside the platform (Fig. 1), with a relative reliable intra structure mainly having reliable decline [11]. For the central and western area of rese arch area at this period, the “Central Sichuan paleo-uplift” part evolves into a synsedimentary upheaval area [53] having a palaeohigh rudiment (Fig. 1), and for the south to the research area and central part of Guizhong, “Qianzhong Palaeohigh” is gently distributed from east-west to downstream by promotion of Yunan Motion and lifted as a land in the Meitan period of Early Ordovician [54]. The middle and upper Yangtze region at the Later Cambrian entirely inherits the palaeogeographical pattern at the later period of Early Cambrian [42,43]. The Kangdian old land, Motianling old land and Hannan old land exist in the western and northwestern basin [8,43,47] (Fig. 1), mostly shallow carbonate platform [5,55], developing much dolomite lack of organic fossil and little evaporate, transited to little limestone sediment towards one side of extensive sea; slope facies and deep-water basin facies exist in the northeastern and southeastern basin [46,56]. The Middle - Upper Cambrian Series indicated in this research can be corresponding to the middle and upper part of Third Series and the whole Furong Series in the latest international standard Cambrian System, including 5 fossil zones [57,58]. This period exists several contemporaneous units, and among them, the Xixiangchi Group is initially named by the Xixiangchi in the Emei Mountain of Sichuan [59], common in the Emei and Ebian in the southwest of Sichuan, mainly light grey - grey and brownish grey dolomite, with dolomitic shale and few sandstone and clay shale [60]; its corresponding contemporaneous rock units include Loushanguan Group in Meitan - Jiangkou - Zunyi - Zheng'an of northern Guizhou and Tongren of western Hunan, the upper rock unit combination of Sanyoudong Group and Tanjiamiao Group in Chengkou - Wuxi, Badong - Wufeng of western Hubei, the rock unit combination of Maotian Group, Houba Group and Pingjing Group in Yanhe of northern Guizhou and Nanchuan of southern Chongqing. Generally speaking, the Xixiangchi Group is mainly of carbonate sediment, partially mixed of terrigenous detrital; the upper rock unit combination of Loushanguan Group, Sanyoudong Group and Tanjiamiao Group appear as granular carbonate and micrite-micritic carbonatite vertically overlaid, partially with gypsum breccia, halite pseudocrystal etc.; the rock unit combination of Maotian Group, Houba Group and Pingjing Group as micrite-micritic carbonatite with granular carbonate, much limestone and dolomite in differently thick interbedding.

3. Strata fill characteristics of Middle - Later Cambrian

For the Cambrian System strata, due to its old age, the drilling data of basin is relatively lacked of, so a number of field outcrop data can be used as the basis for and constraining and controlling the sedimentary facies and paleogeography of basin. According to the systematic examinations and 164 pieces of field outcrop data and drilling strata thickness (Table 1) in this research, it is found that Sichuan Basin and its periphery in the Middle - Later Cambrian are distributed and extended weakly in the northwest and strongly in the southeast and strongly and weakly alternative distribution in the northeast - southwest direction (Fig. 2). To be specific, in the west and north of Sichuan Basin, that is areas to the west of Shimian - Meishan - Ziyang and northwest areas in Guangyuan - Nanjiang, are of zero strata thickness, corresponding to the location of Kangdian Old Land, Motianling Old Land and Hannan Old Land. The eastern sea covered area has a large change of strata thickness, between 300 and 1800 m, and the current basin inside is generally distributed in a plane of “one thin and two thick” style, “one thin” is in the areas of Mabian -

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