

Prediction of Thin Pre-Salt Reservoir in PL Gas Field, Sichuan Basin

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Abstract. In this paper, the reservoir characteristics and favorable exploration zones of Jialingjiang Formation in Triassic Jialingjiang Formation in PL gas field, Sichuan Basin are studied in depth. By means of geophysical processing and prediction techniques such as seismic attribute analysis, inversion and structural interpretation, this paper focuses on the sedimentary facies, structure, fractures, reservoir thickness and physical properties of the porous reservoir in Jialingjiang Formation, in order to define the spatial distribution of the reservoir and the favorable exploration zones. The research results show that the development of Baiyun rock beach facies reservoir in Jiawumember is mainly concentrated in well area JT1-PS7-PY1, where the local deposition thickness increases and it is a favorable tidal beach facies zone. Based on multi-attribute analysis and phase-controlled p-wave velocity inversion, this paper predicts the lithology and gas distribution of carbonate and gypsum rocks in the Jiawu Member, revealing that the reservoir thickness of the Jiawu 1 submember is between 5 and 22 meters, and gradually thinning in the southeast direction. Based on paleogeomorphology analysis and fracture development characteristics, six favorable exploration areas with a total area of 48 square kilometers are selected, and three proposed well locations are proposed, which provide guidance for future exploration evaluation and deployment.

Keywords: Member 5 of Jia; Sedimentary facies; Reservoir prediction.

1. Introduction

Marine carbonate gas reservoir is an important part of natural gas production in Sichuan Basin, and its resources account for about 85% of the whole basin, which has become the main choice for realizing favorable development of conventional natural gas in Sichuan Basin. Although the natural gas resources in the basin are large, more than half of the resources are concentrated in deep-ultra-deep formations [1]. With the Sinian and Permian gas reservoirs in southern Sichuan, the Carboniferous, Permian and Triassic gas reservoirs in eastern Sichuan, and the Sinian Dengying Formation and Cambrian Longwangmiao Formation in central Sichuan, major breakthroughs have been made in gas exploration. It is also realized that deep-ultra-deep carbonate gas reservoirs have become an important field for increasing conventional gas storage and production in Sichuan Basin.

Under the influence of the Indosinian movement, the Jiasan-Jiasan-5 member of the core of the Paleo-uplift suffered strong denudation, and the early discovered gas reservoirs were mainly distributed in the southern Sichuan area, mainly in the Jiasan-Jiasan Member [2]. With the deepening of exploration, the main production layer in the peripheral area of Luzhou ancient uplift was extended from the Jiayi-Jiasan member to the Jiayi-Jiasan fifth member. Later, several small and medium-sized gas reservoirs were also discovered in eastern, central and northern Sichuan [3]. Previous studies on the oil and gas geology of Jialingjiang Formation on the periphery of Luzhou Ancient uplift were carried out, and the Maluchang and Moxi gas reservoirs on the periphery of the ancient uplift were taken as typical representatives, and it was believed that the Jialuchang and Jialu4th members developed high-quality porous carbonate reservoirs, whose development and evolution were controlled by sedimentation and diagenesis [4]. In March 2004, well M39 of Southwest Oil and Gas Field was drilled in the 4th member of Jialingjian Formation, showing that it produced 63,200 m³ / day of gas and 187.2 m³ / day of water, which is the highest gas yield in the current oil test. In recent years, Jia4 Member of JS1 Well in Southwest Sichuan and JH1 well in Weiyuan have obtained 23,200 m³ / d and 55,800 m³ / d respectively, revealing that Jia4 Member and 5 member of Middle and Southwest Sichuan still have certain exploration potential. But at the

same time, there are still some problems such as strong reservoir heterogeneity, unclear understanding of main control factors and causes, and unclear favorable exploration zones. On the basis of previous research results, this paper uses geophysical processing and prediction techniques such as seismic attribute, inversion and structural interpretation to study seismic sedimentary facies, structure, fractures, reservoir thickness, physical characteristics and favorable exploration zones of porous reservoirs in the Ji5th Member, so as to clarify the spatial distribution of reservoirs and favorable exploration areas, and guide their application in the next exploration and evaluation deployment.

2. Overview of Regional Geology

A large number of drilling and logging data in central Sichuan have confirmed that the Jiashan 4-Jiashan 5 member is a typical set of evaporative platform gypsum, salt rock and dolomite deposits [5], among which the Jiashan 43 and Jilashan 5 sub-members are dolomite developed segments with relatively stable vertical and horizontal development distribution. Studies have shown that the Jialingjiang Formation as a whole is dominated by an epicontinual-marine carbonate restricted environment, with multiple transgression-regressive cycles [6], and the deep lagoon on the east and west sides has a large physical capacity. The sedimentary facies of the Jialingjiang Formation is mainly a relatively limited carbonate platform background, which is divided into two large environmental units, the lagoon and the platform tideland flat. The lagoon has a large physical energy and forms a sheet sand beach between the tides. The primary intergranular pores and mold pores were developed in JH1, SB1 and other beach facies during the transgression stage of Jilalingjiang Formation in Jingyan and Zigong area of southwest Sichuan Province. In Moxi area, the high energy sand-chip beach facies and the primary intergranular pores were developed in the Jila-Wu developmental transgression stage. The high energy sandy shoal facies dolomite was developed in the Jiawu transgression stage in Penglai Gas field, central and northern Sichuan, which often contained paste (conducive to later dissolution into pores). There were strong hydrodynamic conditions in the early stage of the sedimentary evolution of the Jiawu Member, and favorable grain dolomite + beach dolomite composite reservoirs developed along the central low rise of the middle Sichuan. Evaporites were widely distributed along the lower plateau in the late very low sea level background. In the middle of Sichuan, the saddle is gripped by double depressions, and the favorable beach facies develops. During the Jiawu transgression period, the middle Sichuan area was located in the saddle area, which came from the east and west transgressions. It was an intermittent intertidal high energy zone, and the tidal marginal beach deposits such as arenaceous dolomite or oolitic dolomite were developed, which was a favorable reservoir facies zone. The open and open depressions in the east and west of Sichuan in the early stage of the Jiawu transgression were transformed into limited evaporation lagoons, and the vast areas in the middle of Sichuan were transformed into extremely shallow water evaporation platform, which was conducive to the formation of regional cap beds. Under such sedimentary background, favorable beach-facies reservoir of Jiafi-5 member in central Sichuan area should be implemented urgently.

Some research work has been carried out in the central Sichuan area in the early stage, but there are still some problems, such as lack of coring data, unclear logging response characteristics of gas-water layer, lack of systematic structural interpretation and research, leading to unascertained structural characteristics, unclear seismic response characteristics of reservoir shielded by plaster rock, and complex fracture characteristics. The favorable facies zone, reservoir distribution, physical characteristics and structural characteristics of Baiyun Yantan facies reservoir in Jia-4th and 5th member still need to be further refined and further studied. The research area is located in the north central part of Sichuan Province. The work area includes Pengan 3D block, Shehong 3D block and Xichong 3D block, covering an area of 3070km².

3. Seismic Sedimentary Facies Analysis in North-Central Sichuan

As shown in Figure 3-1, the lithofacies paleogeographic pattern of Jififth stage is as follows: in the middle of Sichuan, the saddle is gripped by double depressions, and the favorable beach facies is developed.

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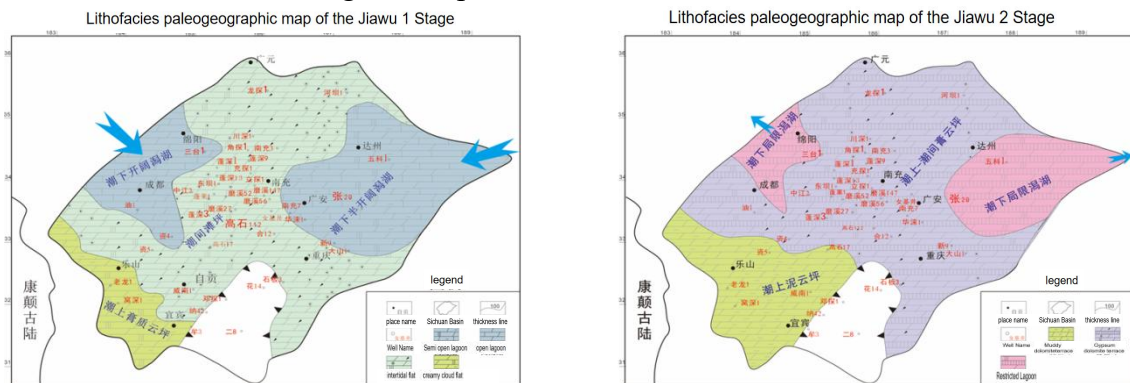


Fig. 3-1 Lithofacies paleogeographic map of the Jiawu Stage

The sedimentary evolution of the Jiawu Formation: in the early stage, there were strong hydrodynamic conditions, and favorable grain dolomite + beach dolomite composite reservoirs developed along the central low rise of the middle Sichuan basin. Widely distributed evaporites developed on the lower plateau in the late very low sea level background (FIG. 3-2). In general, the formation thickness of the Jiawu Member in the Sichuan Basin is thickened in the direction of east and northwest (lagoons). A low-rise tectonic unit is developed in the middle of the Sichuan Basin, with lagoons with large sedimentary thickness on the east and west sides (FIG. 3-3). The thickness comparison in the central Sichuan area reveals the same pattern, with low rise tectonic units developing in the middle and lagoons with larger sedimentary thickness on both sides (FIG. 3-4).

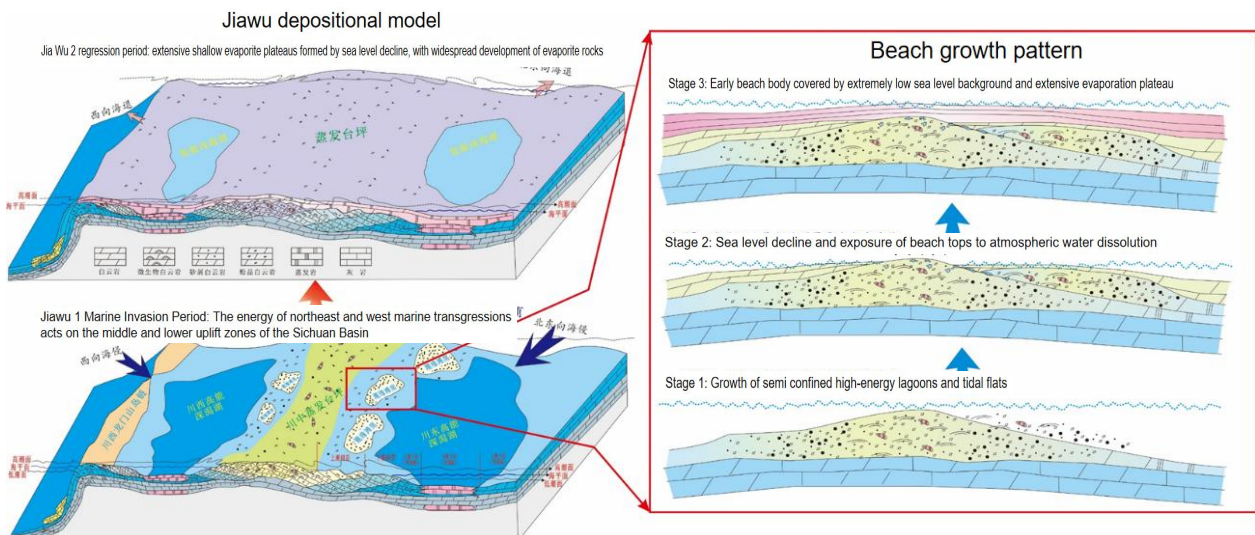


Fig. 3-2 Sedimentary pattern map of Jiawu Stage of Middle Triassic in Sichuan Basin (quoted from relevant materials of Party A)

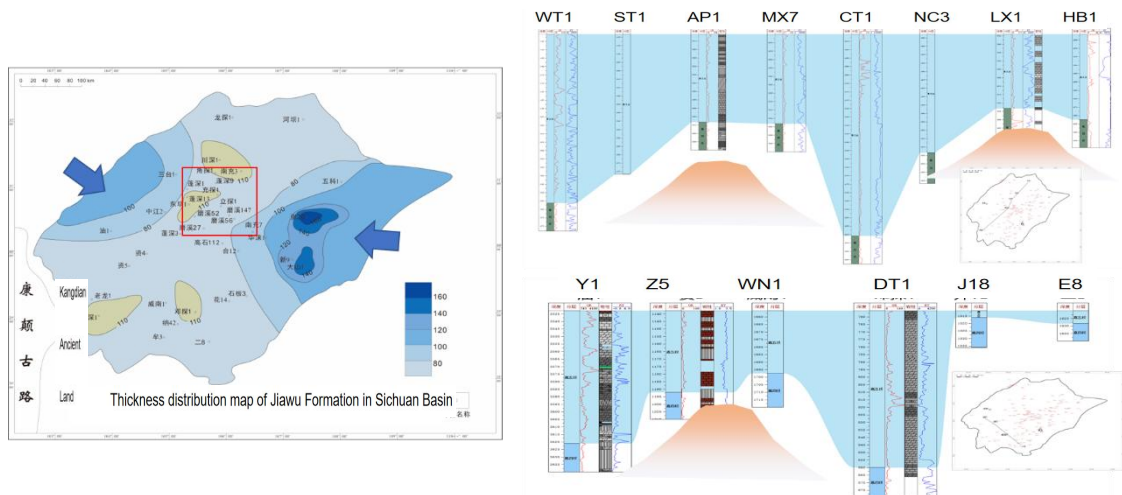


Fig. 3-3 Schematic diagram of the general structure of Member Jiawu in Sichuan Basin

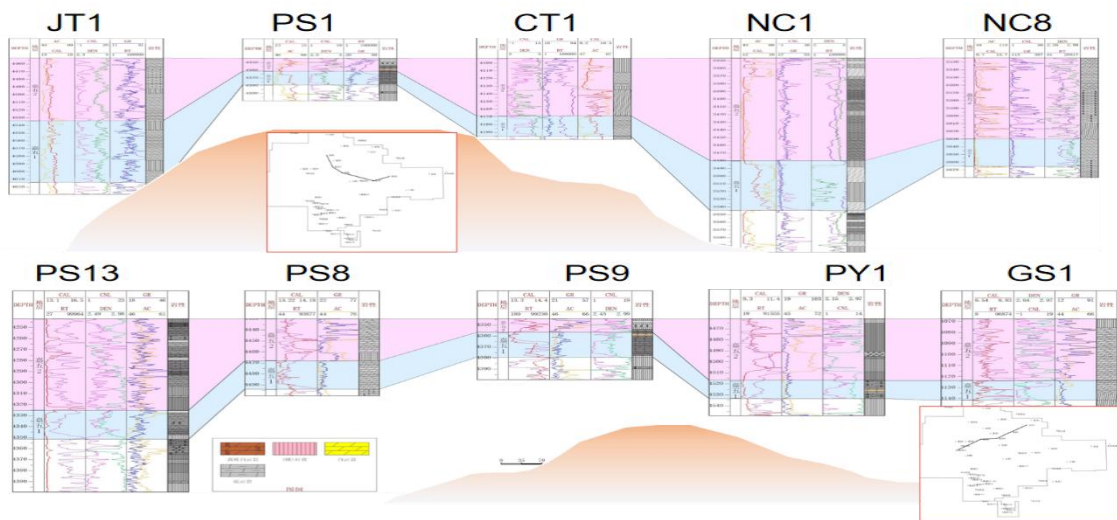


Fig. 3-4 Thickness comparison map of the central Sichuan area

Local strata thickening exists in Zhongjia 5th Member of the low rise tectonic unit in the central Sichuan area, which is the sedimentary facies of the intertidal sheet sandy beach under the background of limited platform (FIG. 3-5). The seismic response of the lagoon and supratide Yunping is shown in FIG. 3-6.

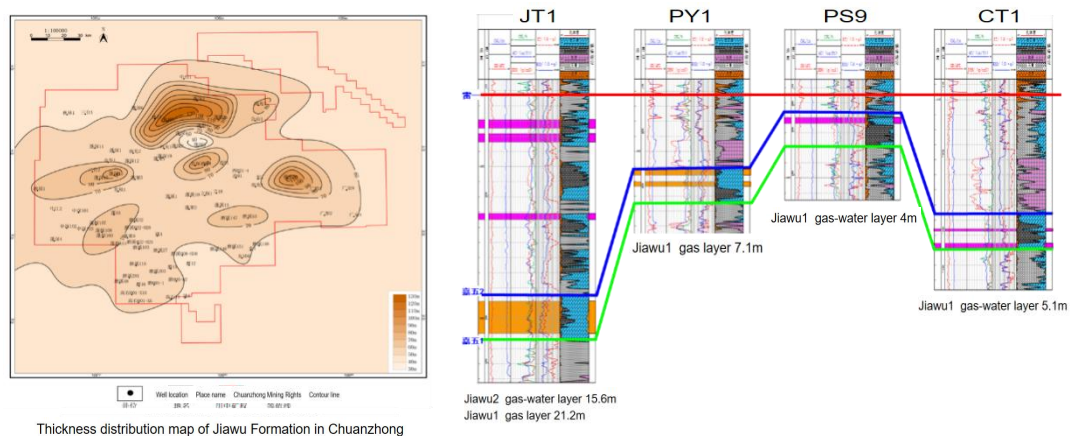


Fig. 3-5 Schematic diagram of the low rise tectonic unit in the middle Sichuan area

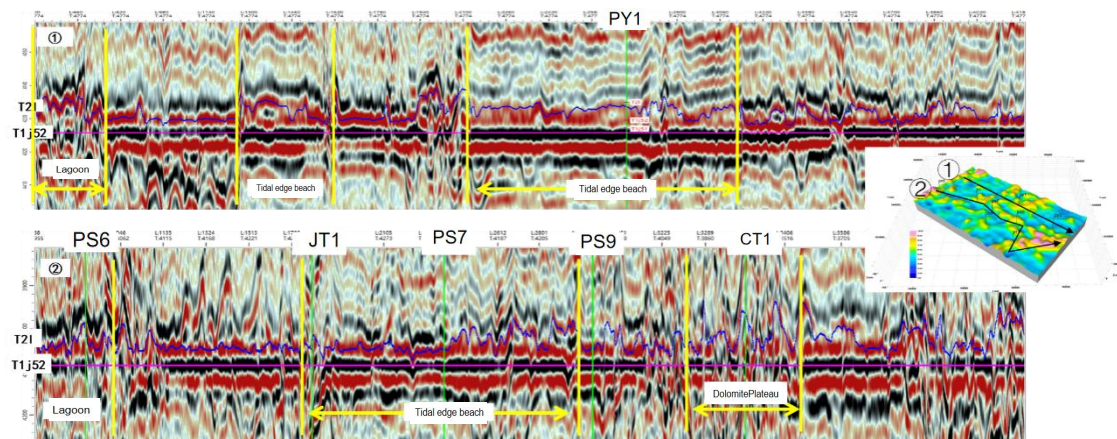


Fig. 3-6 Seismic response map of lagoon and supratide cloud flat

Combining paleogeomorphology analysis with geological understanding, it is clear that the favorable facies of the tidal shoal facies mainly developed in well area JT1-PS7-PY1 (FIG. 3-7).

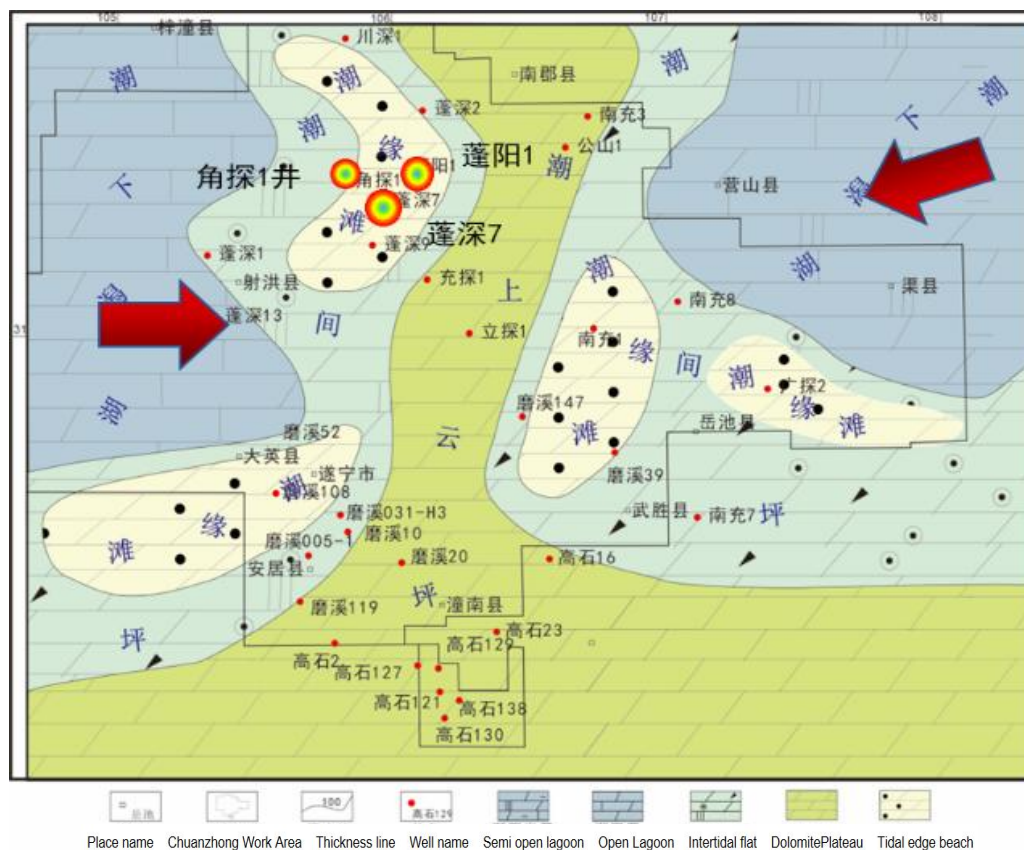


Fig. 3-7 Sedimentary facies map of Jiawu Member

4. Reservoir Prediction and Application Effect Analysis

4.1 Phase Controlled P-Wave Velocity Inversion Lithology Prediction

Constrained sparse pulse inversion is a widely used method in wave impedance inversion technology at present [7]. Compared with other wave impedance inversion methods, the constrained sparse pulse inversion technology starts from the well point with the log data as the constraint condition [8]. It first completes the inversion of the well side path, then takes the seismic interpretation horizon and fault structure as the geological framework control, and extrapolates all

seismic tracks to complete the wave impedance inversion, so that the inversion results approximate the logging resolution. At the same time, it maintains good transverse continuity.

Sparse pulse inversion assumes that the reflection coefficient sequence corresponding to the wave impedance of underground strata is sparse, mainly composed of the superposition of the dominant (strong) reflection coefficient sequence and the weak reflection coefficient sequence with Gaussian background [9]. The main advantage of this method is that wide band reflection coefficients can be obtained, which can better solve the problem of underdetermination of seismic records. Sparse pulse inversion consists of three processes: obtaining a sparse reflection coefficient sequence by maximum likelihood deconvolution; The wideband wave impedance is derived by the maximum likelihood inversion; The absolute wave impedance of a full band is obtained by channel merging [10].

4.2 Wave Impedance Reservoir Prediction

Figure 4-1 shows the p-wave velocity inversion profile of Ji2awu Member. The P-wave velocity inversion indicates that gypsum rock is developed in PY1 well area of Ji2awu Member, while carbonate rock and gypsum rock are interstratified in JT1 and PS7 well areas. The thickness of the carbonate rock with high P-wave velocity in the Jila-Wu Member has a thinning trend from JT1 phase to PY1 well.

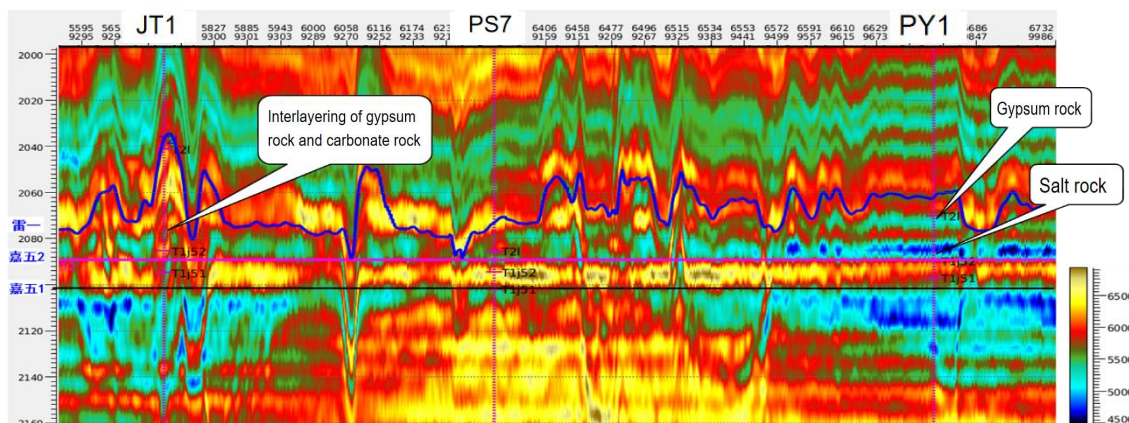


Fig. 4-1 inverse profile of P-wave velocity in Jiawu 2 Member

The P-wave velocity of Ji2awu Member is lower than that of Jiaw1u Member as a whole, mainly due to the characteristics of gypsum and salt rock. Well JT1 has an abnormally high speed. The Jiaw1u Member has a high velocity as a whole, and the velocity tends to decrease from southwest to northeast, which is consistent with the actual drilling in the well. (Figure 4-2, Figure 4-3). Based on the statistical results of rock physics, the distribution of carbonate rock, gypsum rock, salt rock and other rock facies is further identified. The Ji2awu Member is a gypsum rock, and the Jilawu member is a carbonate rock, and the thickness of the carbonate rock decreases from southwest to northeast (Figure 4-4). Carbonate rocks are developed in the Jia51 Member as a whole, and the thick carbonate rocks are concentrated in well JT1-PS7-PS16 in the southwest of the study area, and the thickness of the carbonate rocks decreases and the paste content increases from southwest to northeast. As a whole2, the Jia5 Member is mainly composed of gypsum rock, which is distributed in the southwest of the study area, and salt rock is distributed in the east of the study area (Figure 4-5, Figure 4-6). Based on the results of lithofacies prediction, the carbonate reservoir thickness prediction was carried out, and it was confirmed that the reservoir development area was mainly located in the southwest and northeast of the study area, and the thickness was greater than 10m (see FIG. 4-7 and 4-8).

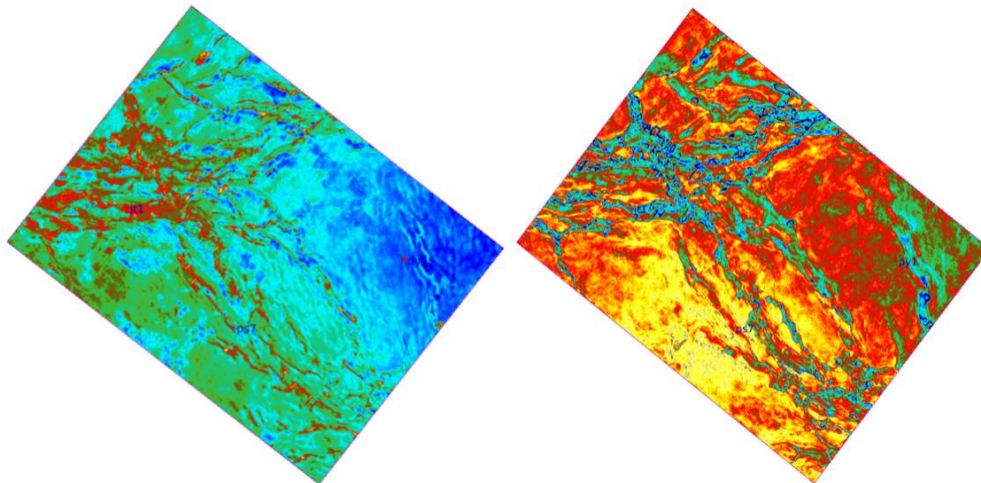


Fig. 4-2 longitudinal wave velocity plan of Jia251 (left) and Jia5 (right)

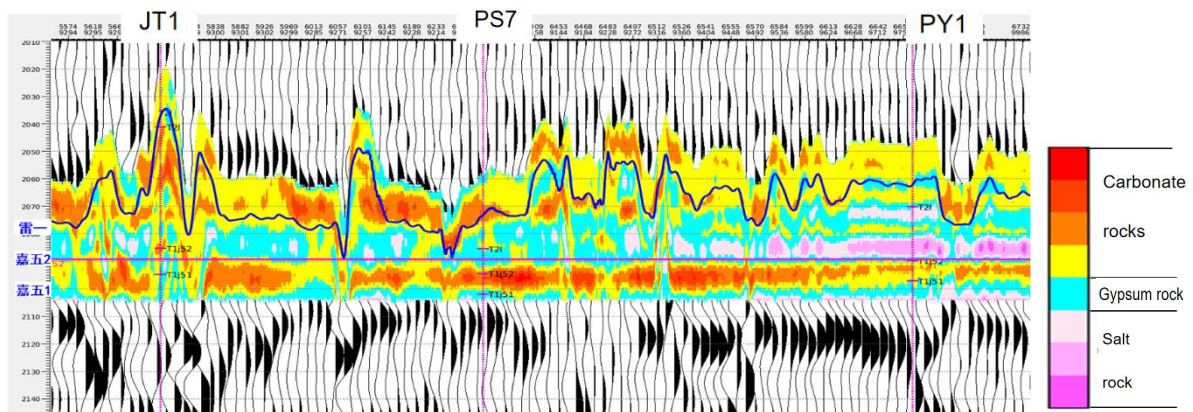


Fig. 4-3 Distribution map of carbonate rock, paste rock, salt rock and other lithofacies in Jiawu Member

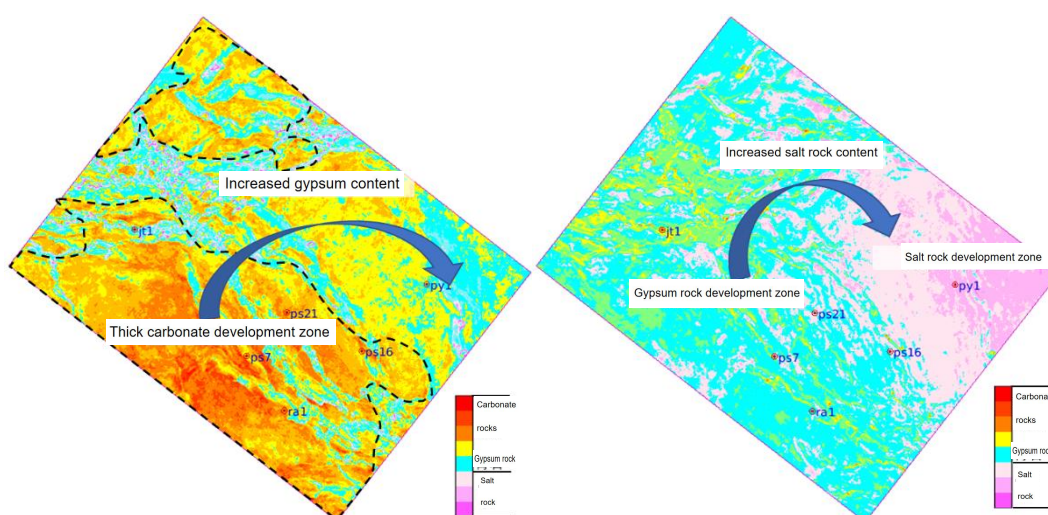


Fig. 4-5 Prediction maps of Ji1awu Member (left) and Ji2awu Member (right) lithofacies

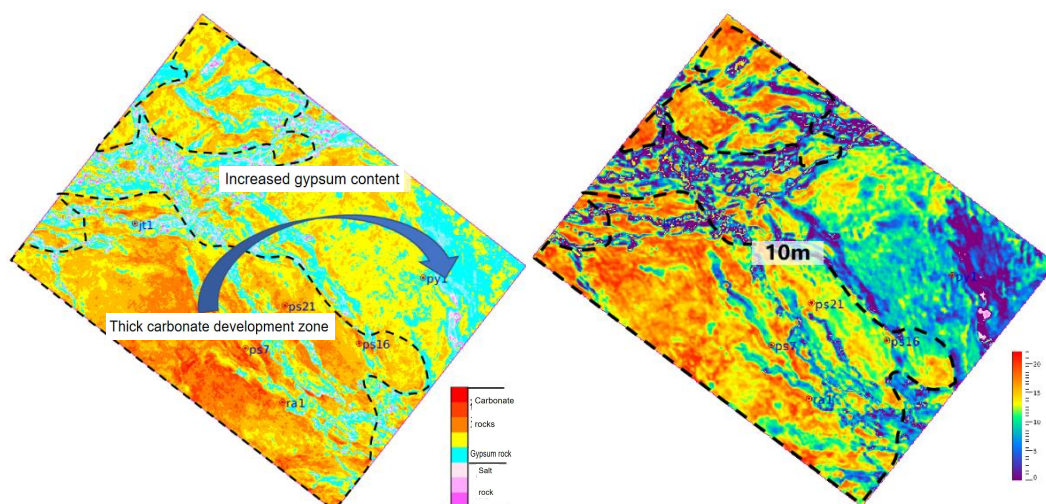


Fig. 4-7 Lithofacies prediction (left) and reservoir thickness prediction (right) of Jilawu Member

4.3 Suggestions for Exploration Deployment

According to the inversion results of reservoir thickness, three proposed Wells are designed to guide well location deployment. The diagram of well location deployment is as follows.

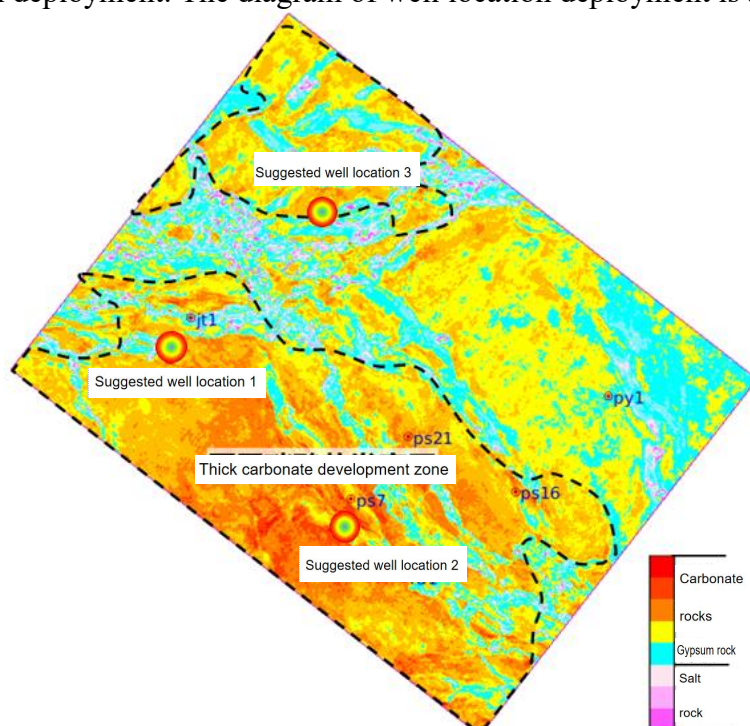


Fig. 4-9 Lithofacies prediction map1 of Member 5 of Jia Formation

5. Conclusion and Understanding

1) Based on the sedimentary facies characteristics of 11 Wells in the study area, the paleogeomorphology analysis of the study area was completed, and it was confirmed that the JT1-PS7-PY1 well area was locally thickened and was the main developing area of favorable facies zone of the tidal beach. Based on multi-attribute analysis and seismic waveform classification, the vertical and horizontal spatial distribution characteristics of sedimentary microfacies in well area JT1-PS7-PY1 were finely characterized. It is confirmed that the northwest and southeast Jiawu member of the study area has large sedimentary thickness and well-developed salt-rock, which are supratidal lagoons and supratidal Yunping facies zones. The JT1-PS7-PY1 well area has a local

thickening of sedimentary thickness, and the Baiyun Beach facies reservoir of Jiawu Member has developed, which is a tidal beach facies belt.

2) Through phase-controlled P-wave velocity inversion, lithology prediction of gypsum and carbonate rocks and gas reservoir distribution prediction of Jiawu Member in JT1-PS7-PY1 well area are realized. It is clear that the reservoir thickness of Jiawu Member is between 5-22m, and it shows a thinning trend from northwest to southeast.

3) Based on the results of paleogeomorphology and waveform clustering sedimentary facies analysis, combined with the characteristics of structure and fracture development, and considering the results of reservoir thickness and gas bearing prediction, a total of 6 favorable exploration areas with reservoir thickness greater than 10m, good gas bearing, small scale fracture development and no Tongtian fault development are selected within the favorable facies belt, covering an area of 48km², and 3 well location suggestions are put forward.

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