

Characteristics of Sedimentary Facies in Carbonate Reservoirs

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Abstract

The complexity of carbonate reservoirs is a significant factor affecting their production, and the depositional environment is the primary controlling factor for the distribution of carbonate reservoirs. This paper conducts research and analysis on the depositional characteristics of carbonate reservoirs based on core samples from Carboniferous carbonate reservoirs in the eastern margin of the Precaspian Basin and various geological data. Identification and statistics are carried out from multiple aspects, including mineral composition, rock type, grain type, and fillings, to determine that the area is characterized by carbonate platform deposition. The upper strata are developed with limestone and dolomite, while the lower strata are dominated by limestone.

Keywords

Carbonate Reservoir, Sedimentary Facies, Carbonate Platform

1. Regional Geological Overview

The study area is located on the slope tectonic belt on the eastern edge of the Precaspian Basin, with its geotectonic position belonging to the southeastern part of the East European Platform. The eastern side of the basin is the Uralian Hercynian fold mountain system [1] [2]. Its oil and gas-bearing strata are Carboniferous carbonate reservoirs, which are divided into two sets of carbonate platform facies reservoirs: ZH-I and ZH-II. In between is a clastic rock interlayer with high MT shale content. ZH-I is divided into three formations: A, B, and C, while ZH-II is divided into three formations: D and E. Each formation is further subdivided into multiple sub-layers.

2. Physical Characteristics of Rocks

Firstly, conduct research on mineral composition, rock classification, Particle type

and Gap filling material.

2.1. Mineral Composition

Through the analysis of 60 rock samples taken from the core section, the average content of calcite in section A3 is 56.57%, the average content of dolomite is 32.44%, and the average content of acid insoluble substances is the highest, reaching 10.86%; The average content of dolomite in section B1 is 92.4%, and the average content of calcite is 6.29%. The D2-D6 sections of the ZH-II oil reservoir have similar rock mineral compositions, mainly composed of calcite with an average content of 91.41% - 97.23%, dolomite with an average content of 1.38% - 5.01%, and acid insoluble matter with an average content of 0.79% (lower than the average value of 6.21% in the ZH-I oil reservoir). The chemical composition is mainly calcium oxide, ranging from 52.74% to 54.89%, and the magnesium oxide content in the ZH-I oil reservoir is 13.64%. The lithification analysis results indicate that the ZH-II reservoir is a pure, brittle limestone with low mud content and no sulfate content.

2.2. Rock Classification

Based on the standards of the oil and gas industry and combined with the actual situation in the local area, rock classification was carried out on the basis of 291 carbonate thin section identification and 60 rock chemical analysis data. In order to facilitate the analysis of the relationship between reservoir properties, oil and gas recoverability, and rock types, a detailed classification was made based on dominant particle types [3]. Limestone is divided into 11 types, among which algal debris limestone (**Figure 1(a)**) and foraminifera limestone (**Figure 1(b)**) have high contents, accounting for 29.1% and 20.62%, respectively; Next are skeletal limestone (**Figure 1(c)**) and dragonfly limestone (**Figure 1(d)**), accounting for 8.59% and 6.19% respectively; Others only account for 13.85%. Dolomite is divided into 6 types, among which powder crystal dolomite (**Figure 1(e)** and **Figure 1(f)**) accounts for 10.31%, mud crystal dolomite (**Figure 1(g)**) and multi skeletal dolomite (**Figure 1(h)**) account for 4.81% and 4.12% respectively, and others account for 2.41%.

2.3. Particle Type

The particle types of dolomite and limestone are different. The average particle content of dolomite is 44.1%, all of which are biological particles, with particle dolomite accounting for 69.3% and grain dolomite accounting for 35.5%. The content, from high to low, is as follows: detritus (17.7%), dragonflies (15.3%), foraminifera (14.7%), and relatively few others. The average particle content of limestone is 81.6%, with particle limestone accounting for 84.3% and grain limestone accounting for 29.1%; The average content of particle types, from high to low, is as follows: algae (20.6%), foraminifera (16.0%), dragonflies (12.3%), and algal clumps (8.0%). Spiny grained limestone (4.6%) is higher than dolomite

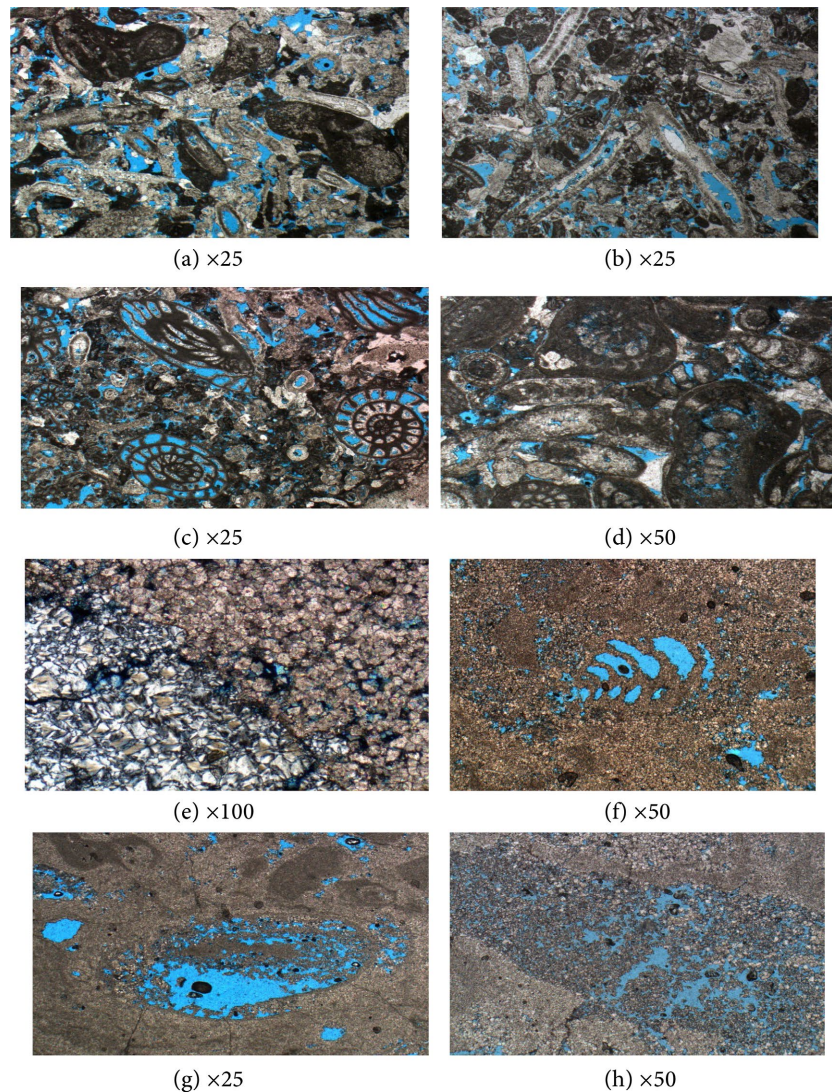


Figure 1. The detailed classification of rock type.

(1.7%), and non biogenic particles only exist in small amounts in limestone.

The physical properties of rocks vary depending on the type of rock particles [4]. Limestone and dolomite, mainly composed of algae debris, skeletons, nematodes, foraminifera, etc., have well-developed intergranular pores and large pore sizes, which are conducive to the formation of reservoir rocks. Limestone, mainly composed of particles such as inclusions, ooids, and chondrules, has large differences in particle size, small pore size, and high degree of early cementation, but weak dissolution and transformation in the later stage, so its oil and gas storage capacity is relatively poor. Spiny debris is widely distributed in the ZH-II oil reservoir limestone, although the content is not high, there is generally strong coaxial growth, which reduces intergranular pores and damages the reservoir space.

2.4. Gap Filling Material

The filling material in granular dolomite is mud crystal dolomite, with a content

of 30.7%. The main filler in granular limestone is bright crystal calcite, with a content of 10.8%, and the content of mud (powder) crystal filler is 4.9%.

The type of filler is closely related to the pore permeability conditions of the reservoir. The filling degree of bright crystal cement is generally less than 50%, and a thin shell is formed on the pore wall to reduce the compaction degree, so that the intergranular pores will not disappear due to compaction. Therefore, the intergranular (dissolved) pores of bright crystal particle limestone are more developed. There are also a large number of intergranular micropores in the mud powder crystal filling material, with very small pore sizes, mainly relying on intergranular micropores to communicate with each other. Although there are many of them, their oil and gas storage capacity is relatively low.

3. Sedimentary Characteristics

Based on the physical characteristics of rocks, research on sedimentary features has been conducted.

3.1. Depositional Environment

The eastern edge of the Carboniferous platform, including the Rangnaror and central blocks, is located in a low latitude tropical or subtropical environment, which is a normal marine sedimentary environment under humid climate conditions and rich in marine organisms [5] [6]. According to the statistical results of thin section data, the average fossil content of ZH-I is 56.47%, while that of ZH-II is 78.94%, indicating that this area is a shallow sea environment conducive to biological growth. Adding non biological particles, the granular carbonate rocks in the block become the most important rock type, with rock layers accounting for more than 90% of the total thickness of carbonate rocks, reflecting the shallow sea environment with turbulent water, strong energy, abundant sunshine, and abundant nutrients at that time.

3.2. Sedimentary Model

Based on the sedimentary characteristics of the Carboniferous system and the previous research results of our institute [7] [8], a Carboniferous sedimentary model was established in the study area (**Figure 2**), which was divided into 3 facies, 7 subfacies, and 16 microfacies.

3.3. Distribution of Sedimentary Facies

Based on lithofacies and electrofacies analysis, it is confirmed that ZH-I reservoir in North Tluwa Oilfield in the eastern margin of the Pre-Caspian Basin is deposited in the environments of open platform-restricted platform-evaporative platform, where the sedimentary microfacies of dolomitic flat, limestone flat, grain shoal and lagoon are mainly developed (**Figure 3**). And in ZH-II reservoir, it is open platform facies where algal reef, intraplatform shoal and interbank microfacies are mainly developed (**Figure 4**).

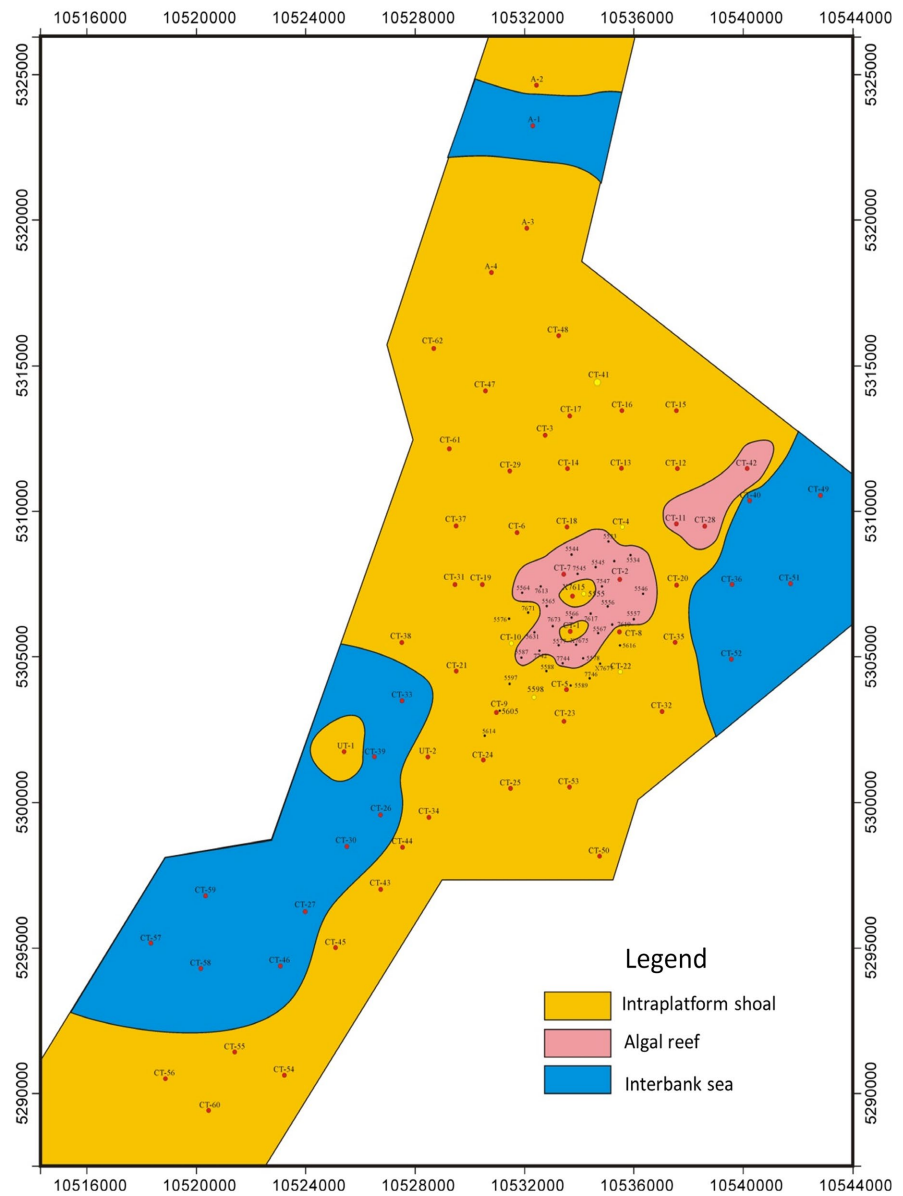


Figure 4. Sedimentary microfacies in ZH-II.

4. Conclusion

The Carboniferous carbonate reservoirs on the eastern edge of the Binhai Basin are carbonate platform sediments, while the ZH-I layer is composed of open platform, confined platform, and evaporative platform sediments from bottom to top. The lower ZH-II layer is a relatively simple open platform sediment.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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