Formation and Controlling Factors of Effective Weat-hered Crust Carbonate Reservoirs-taking the Yingmaili-Yaha Area of Tarim Basin as an Example

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Formation and ControIling Factors of Effective Weat-hered Crust Carbonate Reservoirs-taking the Yingmaili-Yaha Area of Tarim Basin as an Example

Huanhuan Wang

Daqing oilfield water service company, Daqing 163458,China
*****Corresponding author e-mail: yjywangzhq@petrochina.com.cn

Abstract: In recent years, the marine oil and gas exploration in China has made great progress and lots of high quality carbonate reservoirs in deep strata have been found. As one of the most important carbonate reservoirs,the weathered crust reservoir has taken much more attention. Especially in the Tabei area of Tarim Basin, plenty of hydrocarbon resources are stored in the weathered crust reservoir, which arouses lots of concerns at present. In the Yingmaili-Yaha area of Tabei, the main accumulation spaces of the Cam-brian-Ordovician weathered crust are dissolved pores, fractures and caverns, and these reservoirs have good physical properties, great thickness and large distribution range. Research shows that the formation of the reservoir in this area is restricted by factors such as early stage sedimentary facies, weathering and leaching, fractures created by the tectonic movement and associated denudation. The Weathering crust karstification and the tectonic disruption has greatly improved the nature of the accommodation spaces, as a result, in the Yingmaili-Yaha area, even buried in the depth of about 6000m, high porosity and permeability weathering crust reservoirs are still well preserved. There are many controlling factors, such as paleogeomorphology, tectonic subsidence and uplifting, weathering and leaching time, paleoclimate, etc, thus forming lots of dissolved pores, fractures and caverns, and they are mainly distributed in the depth of 150m under the weathering front, and it is up to 200m in local areas.

1. Introduction

Tabei swell up is considered to be one of the most oil-rich areas in the tarim basin, is by the Yingmaili low bulge and the Luntai bulge(including the hongqi-qimanl-yaha tectonic belt) (Fig.1).That region investigates to explore degree higher, totally have 31 explore-wells to drill to meet the carbonate rock morals and custom hull.In this area in the sinian period-early ordovician sedimentary thick carbonate,multiphase tectonic movement caused by strata distribution in this area is extremely complex,in the high part of the formation of long-term severe erosion is shown,layer around the pinchout lines converge in YingMaiLi-YaHa region,including lack of Permian,but in YingMaiLi region distribution of volcanic rocks in Permian;The silurian system is only preservde in some areas,so the Cambrian ordovician remains in most areas of the lutai uplift and the low yingmaili uplift,forming a weathering and bright reservoir with exploration value.

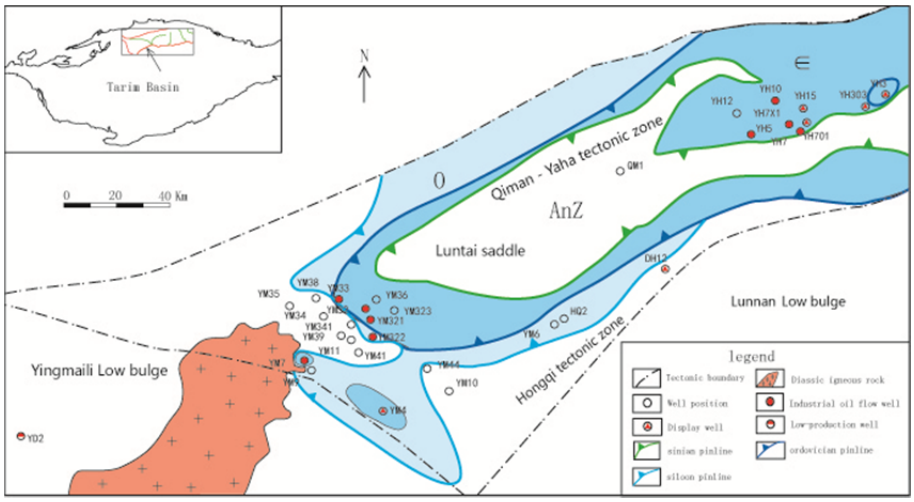

Figure 1. Carbonate stratum plane distribution in yingmaili-yaha area, tabei, tarim basin

2. Reservoir Characteristics of Carbonate Weathering Crust in Yingmaili-Yaha Area

After studying the pore permeability of carbonate reservoirs in Yingmaili-Yaha area, Tabei, it is considered that the secondary pore formed by weathering karstification is well developed and the reservoirs formed have high porosity and permeability (Fig.2). The pore of Ordovician reservoir is obviously less developed than that of Cambrian reservoir. The pore distribution ranges from 0 to 5%, and the permeability is $(0.00798\text{-}17.9)*10^{-3}\mu m^2$. Compared with limestone, dolomite generally has greater mechanical strength and chemical stability, so once the pore of dolomite is formed, it can usually be preserved. Therefore, its burial depth has little effect on the porosity. It can often form (or maintain) good reservoir property in deep burial environment. The Cambrian strata of Well Yaha 10 (6159-6450m) are buried deeper than 6000m, and its maximum porosity can reach 15%.

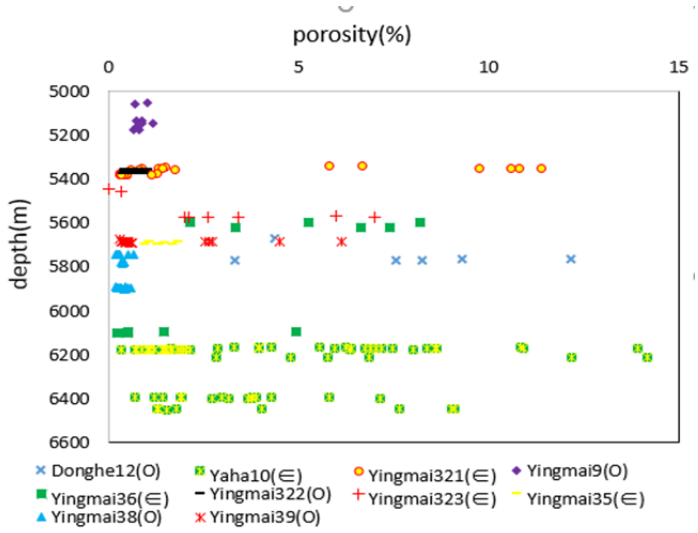

Figure 2. The relationship between measured porosity and permeability of carbonate weathered crust reservoir in Yingmaili-Yaha area

Previous studies on carbonate weathering crust reservoir have divided the complete karst structure of the reservoir vertically into four zones: surface karst zone, vertical seepage zone, horizontal underflow zone and deep slow flow zone [3-6]. The Cambrian-Ordovician uplift in Yingmaili-Yaha area has been exposed to long-term weathering and denudation due to the influence of multi-stage tectonic movements from Caledonian to Indosinian. The surface karst zones in some areas have been missing.

In Fig. 3, the surface karst zones are composed of some weathering cracks and dissolution structural cracks. A small number of cracks are filled and cemented by some muddy sand and calcite. Weathered rocks are extremely irregular in shape. Such as: Yingmai 11 well (interval 5725.18-5731.18m), light grey lime breccia, disorderly accumulation of gravel, dense yellow shale cementation. Vertical seepage zone is located between the weathered crust surface and the highest diving surface. Vertical dissolution holes, dissolution cracks, weathered cracks and structural cracks are the most developed, and these cracks have signs of dissolution. Some cracks and caves are filled with mud sand or calcite cements, such as Well Yaha 303 (see core photograph,. Unfilled caves are formed by dissolution along vertical cracks. The horizontal subsurface zone in Fig. 3 is located below the lowest diving surface in dry season. Its thickness is related to the height of the recharge zone. A large number of horizontal dissolution voids and fractures are mainly developed. Core photographs of Yingmai 32 well show horizontal dissolution voids along the fractures. The deep slow-flow zone is located below the horizontal subsurface flow zone, where the action of water is limited and dissolution voids and cracks are rare.

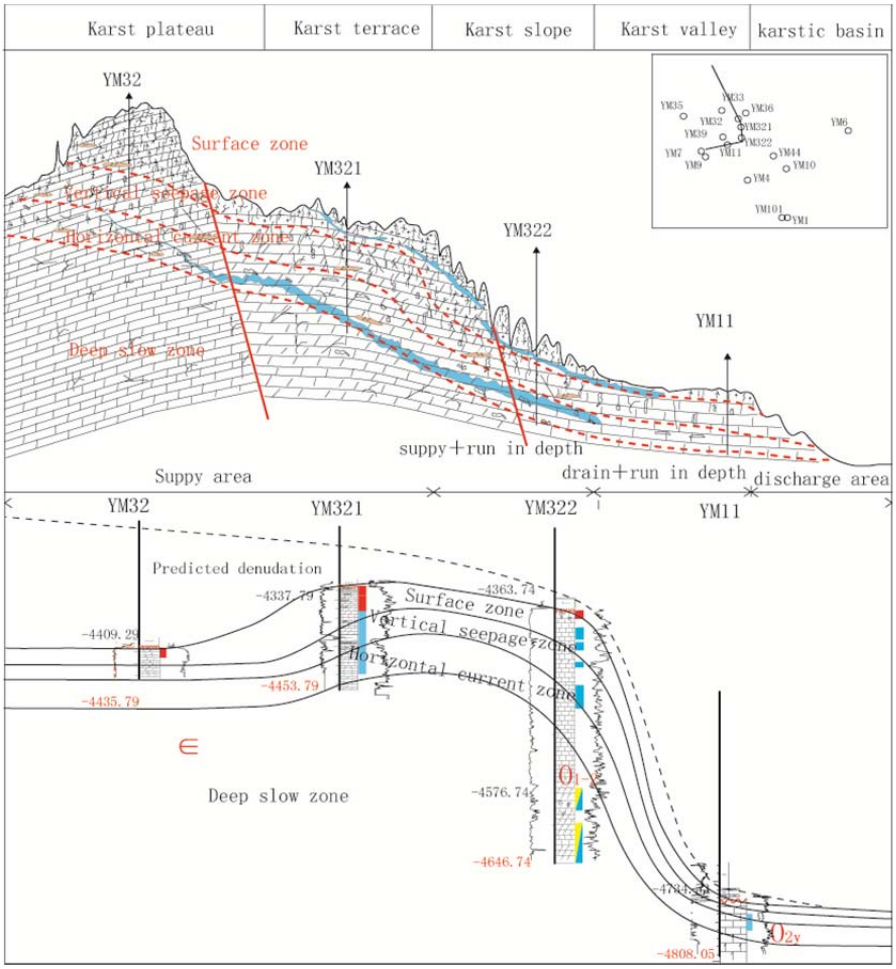

Figure 3. Ideal vertical karst development model of carbonate weathering crust in Yingmaili-Yaha area and actual vertical karst development model

3. Controlling Factors of Carbonate Weathering Crust Reservoir Development

The study shows that sedimentary facies belts are the basis for controlling the development of high quality carbonate reservoirs. The benthic shoal sedimentary subfacies in marine sediments, reef-shoal complexes under high energy conditions and subtidal high energy sedimentary facies belts are favorable areas for the development of high quality reservoirs. In the Yingmaili-Yaha area, the open

platform facies and the limited-semi-limited platform facies are the main intertidal and intra-platform facies.

According to our statistics, the reservoirs developed in the beach bar and tidal flat subfacies of the restricted platform-open platform in the study area are of great thickness and good physical properties. For example, Yingmai 7 well experienced long-term weathering and leaching in tidal flat and Tainei beach subfacies, and developed 135.5 m thick karst reservoir; Yingmai 321 well weathering crust reservoir also has 115 m thick, good reservoir physical properties, its average porosity is 8.06%, average permeability is $11.1*10^{-3}um^2$; Yingmai 322 well also developed about 189.5 m thick carbonate karst reservoir. Comprehensive analysis shows that the high-energy sedimentary facies belt of semi-limited platform-open platform in Yingmaili-Yaha area is a favorable sedimentary facies belt for the development of high-quality reservoirs.

Palaeogeomorphology determines the depth, vertical distribution and intensity of karstification, while fractures control the intensity of karstification. Structural movement causes fractures and fractures in strata. These fractures are the main channels for dissolving carbonate rock under fresh water in atmosphere. On the other hand, they can be used as bridges to connect holes, caves and fractures in carbonate rock, and the fractures themselves are often eroded and expanded, even forming caves and caves. Therefore, tectonic movement largely controls the development and distribution of karst geomorphologic fissures in weathering crust, changes the hydrodynamic conditions of karst, and indirectly controls the development of karst.

The Yingmaili-Yaha area has been in the high part of structure (i.e. Karst Plateau and slope development zone) during Caledonian-Hercynian period. After the transformation of Cambrian carbonate rocks by dolomitization, the content of dolomite increased, the brittleness of rocks increased, and the fracture activity resulted in the widespread fragmentation of Cambrian dolomite to form breccia dolomite, forming a large number of inter-breccia caves. In the later stage, a large number of dilatation cracks and cavities were formed near the fault. These phenomena are shown in exploration wells in the study area. Structural movement and fractures generated greatly improve reservoir physical properties.

Paleoclimate also has a very important influence on the development of karst in weathering crust reservoirs, in which the atmospheric precipitation and temperature play a vital role. In the warm and humid zone with abundant precipitation, the dissolution of carbonate rocks by surface water seepage along fissures and underground subsurface flow is strengthened, and dissolution phenomena such as karst caves, karst breccia and shale filling of caves can be formed under the surface of weathering crust.

Rock temperature varies with temperature and season in the morning and evening. Weathering cracks are easy to occur in rocks with great difference between cold and hot temperatures. The Tarim Basin is located in the low latitude area near the equator from the Early Paleozoic to the Devonian. It is located in the paleoclimate condition with abundant rainfall and hot climate, which creates a very favorable climate environment for the formation of weathering crust reservoirs.

4. Conclusion

The reservoir space of carbonate weathering crust reservoir in Yingmaili-Yaha area is mainly composed of karstification-induced dissolution holes, dissolution holes and caves. In addition, there are weathering cracks, structural cracks, the size and scale of fracture holes vary greatly, their distribution and irregularity are strong, and the reservoir heterogeneity is strong. (2) Weathering crust karstification and tectonic fracturing greatly improve the performance of reservoir space, so that the Yingmaili-Yaha area is buried at a depth of about 6000 m, and the weathering crust-type karst reservoirs with high porosity and permeability are still preserved. (3) The vertical thickness of the weathered crust-type karst reservoirs in the study area is large, mainly distributed 150 m below the surface of the weathered crust, and up to 200 m in some areas. (4) The karstification is controlled by many factors, such as palaeogeomorphology, tectonic subsidence and uplift, weathering and leaching time and palaeoclimate, so that a large number of dissolution holes, caves and fractures are formed in the lower part of the carbonate weathering crust surface, and high-quality weathering karst reservoirs are developed. These factors are very important for pore construction and effective reservoir formation

in Yingmaili-Yaha area. (5) Weathering crust type karst reservoirs are mainly distributed in: a) high-energy sedimentary facies belt of platform beach bar; b) fracture and fracture development; c) karst highland and karst slope with long weathering and leaching time, which are coupled areas.

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