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Karst development of buried dolomite hill reservoir in Wumishan formation of Renqiu oilfield

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Abstract

Based on the statistics of the features, dropping and leaking of well drilling, and the geophysical & logging data, the developing regulation of karst of buried hill in Renqiu oilfield was systematically studied. The results show that the period of the karst development is mainly in Tertiary, with spatial inhomogeneity. The inhomogeneity is mainly controlled by the geological construction in the horizontal direction. There are 3~4 level karst developing zones in the profile section, which are mainly controlled by the intermittent subsidence of the earth’s crust started from Tertiary. The forming time of the lower karst zones is earlier than that of the upper ones. The horizontal karst zones are cut off by the latter faults. At present, the chief potential areas of residual oil of Renqiu oilfield are in the weak karst developing zones.

Keywords: Renqiu; buried hill; dolomite of Wumishan formation; karst; oilfield developing

1. Introduction

The carbonate reservoir in buried hill of Renqiu oilfield is located from Chengguan town to Xinzhongyi in Renqiu city, Hebei province. That’s located in the down-warped basin in the middle of Hebei province. The carbonate reservoir was discovered in July, 1975. Its petrolierous layer is dolomite in Wumishan formation in Jixian system of mid-Proterozic Erathem, which is covered with Neozoic stratum with thickness of 2587.5 m~3510 m.

The west side of the buried hill in Renqiu is cut off by Renxi great fault with 1000~2600 m fault throw and become a ruptured cliff, the peak of the hill extends along the fault, and the east grading slope lies in the down-warped basin. The buried hill is one-side, with west steep and east grading. Four faults extending NEE cut transversely the hill into 5 smaller hills with different heights. They are N11, N7, N6, N9 and N57 hill (Fig. 1). The Wumishan formation is mainly made up of marine carbonate of dolomite. Its thickness is over 2300 m. There are 10 oil groups named Wu1~Wu10 and 70 smaller layers from the top to the bottom and new to old. Crude oil exists in

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the upper place and water in the bottom and the depth of the original oil-water interface is 3510 m deep, it is a oil reservoir of dual-medium with holes, cavities and fissures\[1,2\].

The faults in the buried hill are mostly tensile drop faults. There are about 3 episodes according to the formation of the buried hill. The earlier inner faults are formed in Paleozoic and the sharp edges of the faults have become obtuse with denudation. It is hard to find them on earthquake Tg reflection figures. In this period, there are two sets of faults: in NE and NW directions, such as FN1 and FN2 in Fig.1. Frequently active faults were formed in Mesozoic era and kept active in Cenozoic. They are in east-west direction, such as F8. The latter faults formed in Cenozoic are two sets of tensile faults which are in NNE and NEE directions, and they are formed with the subsidence of the Cenozoic basins. Such as the great faults in the west of Renqiu, F5, F7, F9 etc. The faults formed in the latter two episodes decided the present landforms and patterns of the buried hill in Renqiu.

![Fig. 1. Horizontal zoning of Wumishan formation’s karst in Renqiu oilfield](image)

The processes of development of the buried reservoir include four stages since it was first mined in September, 1975 in Renqiu oilfield. They are: increasing production, high and safe yield, rapid reduction of output, and slow
reduction of output. At present, the percentage of water is about 84% and the production situation is very serious. It is in the stage of tapping the talent power. In order to improve the mining ability and find potential oil-bearing formation, it’s essential to study the karst developing regulations.

2. Karst developing regulation

Based on the analyses and statistics of the drilling tool dropping, leaking and logging about more than 200 wells in the oilfield and comprehensive observation and description of core of karst of the core-drilling wells in the buried hill, the macroscopical karst developing regulations of buried hill in Wumishan formation of Renqiu oilfield have been systematically discussed in this paper.

Because of the violent ascending geotectonic movements in Mesozoic in this area, severe denudations have taken place and resulted in thorough denudations of all thick Paleozoic stratum in Renqiu. The existent karst was mainly developed after Mesozoic for the karst formed before Mesozoic has been denuded in this area.

According to the karst theory, karst develops in soluble terranes when they are exposed. Pulling and tensility were main processes in Himalayan movement in Cenozoic Tertiary. Mass block subsidence was main movement in this region. When thick river-and-lake sediment of Shahejie formation (Es) deposited in early Tertiary, original exposed karst in dolomite in early Tertiary period was formed in Wumishan formation and covered with latter stratums.

The karst in Wumishan formation was characteristic of partitioned space in the horizontal and partitioned zones in the section. Karst developing zones were formed during the subsidence of the earth’s crust, so the lower karst zones were formed earlier and the upper later. The distributing of time sequence of the karst zones in the section is very special. The macroscopical phenomena are dropping of drill stem, leaking of well drilling and broadening of well diameter.

2.1. Karst developing regulation in horizontal direction

Because of many times tectonic movements and karstification, a lot of dissolved pores, holes and fractures are formed in the buried hill reservoir, which makes it become effective reservoir.

The developing degree of karst of buried hill in Wumishan formation of Renqiu oilfield varies from hill to hill. It depends on geological factors, such as tectonic faults. Strong karst developing zones are characteristic of more than 25 m³/m leaking intensity or dropping. The others are secondary and weak zones.

The karst development is mainly controlled by the geological structure in transverse direction and the karst near faults develops fully. The development of karst in N6 hill is the fullest among all hills. The strong karst developing regions are 56.1% of all areas of the hill and the percentage of dropping and leaking well is 64.3%. The development of karst is obviously controlled by the former inner faults and frequently active faults. For example, the karst near FN1, its fallen throw is 613.6 m (W49), develops fully and is strong karst region. The dropping length of W22 is 2.0 m, W6 is 0.5 m and W349 is 1.52 m in all and the leaking intensity is 166.7 m³/m. Another example: There is a strong karst band near F8 which is frequently active. The dropping length of W255 is 1.0 m and the leaking intensity of W342 next to it is 98.88 m³/m (Fig. 1).

The development of karst of N7 is weaker than N6. The strong karst regions are 35.7% of all areas of the hill and the percentage of dropping and leaking wells are 63.6%~80%.

The development of karst of N9 is weaker than N7. The strong karst zones are 7.0% and the dropping and leaking wells are 66.7%.

The development of karst of N11 in the middle and west of Wumishan formation which is not covered with Fujunshan formation is stronger. There are 5 wells (W304, W204, W205, W12 and W26) dropping and leaking seriously and W309, G1 and W202 leaking seriously. The strong karst developing zones around the above wells are 50% of all exposed areas.

The development of karst is quite weak in the areas covered with Fujunshan formation. There is no dropping and leaking phenomena for most wells. Being covered, this area’s hydrodynamic conditions are poor during the development of karst in Wumishan formation and thus the development of karst is limited.

The strong karst zones are less than 5% of the area of N11 hill. So compared with other hills, the development of N11 is weaker as a whole.
Karstic caves, fissures, and pores in dolomite of Wumishan Formation are the most important reservoir voids\(^5\).

### 2.2 Karst developing regulation in the profile section

Violent geotectonic movements, faults, ancient relief and temporal diversity of karstification controled the formation of the karst developing zones in the profile section. The zones in which pore, hole and fracture are developed are favorable reservoir\(^4,6\).

The formation of the karst developing zones in the profile section of Renqiu oilfield is affected and controlled by crustal movements and paleotopography. A karst developing zone in the profile section indicates the relative steady phase of the crust and shows the base level of denudation.

The distributing of karst in Wumishan formation of Renqiu oilfield is zonal in the profile section. There are 3 karst developing zones in hills of N57, N9, N6 and N7. There are 4 karst developing zones in the northern hill of N11. All the zones are parallel with each other in each hill (Figs. 2 and 3).

If we recover the paleotopography before Himalayan movement, the topography will go down gradually from north to south. Then the N11 hill will become the highest and over 450m higher than the N7 hill. The karst in buried hills of Renqiu oilfield was formed during the subsidence of the earth’s crust. When other hills were covered or sank under the base level of denudation of the time, the top of the N11 hill was still above the base level of denudation. So zone  was formed there and one more karst zone than other hills.

At the beginning of the formation of the karst zones, each karst zone was continuous and almost horizontal. Because of the violent movements of the new faults during Himalayan orogeny after the zones were formed and then covered with Tertiary system, the above karst zones were seriously cut off by the new faults respectively in NE, NW and EW directions and resulted in the discontinuity and incline of the zones transversely (Figs. 2 and 3). At the same time, the hills were cut off and lead to the present situations.

The fault throw between N11 hill and N7 hill is not long. The fault throw between N7 and N6 is 120 m caused by the cutting off of F7 and N7 hill drops down. The fault throw between N6 and N9 is 300~580 m caused by the cutting off of F8 and N6 hill drops down The distance between N9 hill and N57 hill is short. The fault throw between N7 and N6 is about 350m caused by the cutting off of F9 and N9 hill drops down.

Different gradients of hills lead to a bit different gradients of karst zones. The karst zones in all hills incline southwards. The obliquity of the karst zone of N9 hill is the largest and the secondary is N11. N7 and N6 are smaller.

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*Fig. 2. Karst section of No.7 well block hill*
In all karst zones, the ones near the earth's surface and the undermost karst zone Ⅰ develop fully. The middle zones are relatively weak. The most noticeable is that the dropping distance of drilling tool and leaking intensity of the undermost karst zone (zone Ⅰ) are the most massive. For example, the dropping distance of well J1 in zone Ⅰ in N7 hill is 2.0m and the quantity of leaking is 522.6 m\(^3\). The quantity of leaking of W216 is 365.67 m\(^3\). The development of karst zones in zone Ⅰ of N11 hill is also the most strongest. That indicates the vast dropping & leaking of the 3 wells in this zone. There are two dropping places next to each other in W204 and the distance is 0.92 m in all, the quantity of leaking is 2900.86 m\(^3\); there are two leaking places in W205 and the quantity is 601.0 m\(^3\). The total quantity of leaking of G1 in this zone is 551.88 m\(^3\), there is a leaking quantity of 168.54 m\(^3\) in 3392.52 meters’ deep spot. However, there is only one leaking place in W205 and G1 in zone Ⅱ (Fig. 3). There are two dropping places next to each other in W9 in zone Ⅰ in No.9 hill, the total dropping distance is 1.76 m and the quantity of leaking is 482.36 m\(^3\). That indicates when the karst of zone Ⅰ develops, the crust is long-time inactive.

3. Influences of karst on the occurrence and development of oil reservoir

The karst development of dolomite in Wumishan formation of Renqiu oilfield typically controls the occurrence and development of oil and gas reservoirs in buried hill.

The great solution caves and fissures in strong karst zones have good connectivity and penetrability and high oil mining rate, so wells are mainly located in the strong karst zones in the early development period of the reservoir when the production is high and safe. The mining practice proves that wells which have long dropping length and mass leaking quantity have high production. For example, the early production of W9 is 5435 t/d, the early production of W7, W11, W18 and W31 which have long dropping length and mass leaking quantity is over 4000 t/d [1, 5].

In the medium-term development, the productions reduce sharply and later slowly. People have to pour water to gain stratum power. But this measure will cause random water flows and inundation in strong karst zones. According to karst developing regulations, on the one hand, we can plug up in strong karst zones in order to prevent from random water flows, on the other hand, we can arrange filling wells exactly.

Now Renqiu oilfield has come to the stage of tapping the talent power. There are two directions: one is to search undetected oil-bearing formation isolated and screened by undeveloped terranes in strong karst zones. Much effort has been made in Renqiu oilfield, so it is hopeless to find new oil-bearing formation. The other is to detect weak karst developing zones with low penetrability. Water and oil flows slowly in these areas. After mined and flooded, these areas are still hopeful. For example, in early 1999, W480 and X362 were arranged in the low penetrating areas.
in the south of N9 hill. The oil layers of the two wells were under the interfaces of oil-water. The early production of W480 is 18.2 t/d and the percentage of water was 67.6%. The production was 10.5 t/d and the percentage of water was 82% till December, 2001. X362 produced pure oil in early days and it could produce pure oil without water for a long time. Its percentage of water was 9.2% till October, 1999. It indicates that there is oil in weak karst developing zones even if the producing places are under the interfaces of oil-water. So the chief direction of tapping is in the foregoing weak karst developing zones. We will do further study in this field to improve production of Renqiu oilfield.

4. Summary

The period of karst development in Renqiu oilfield is mainly in Tertiary, with inhomogeneity in spatial. The inhomogeneity in the horizontal is mainly controlled by the geological construction.

The karst developing zones are zonal in the profile section. There are 4 level karst developing zones on N11 hill and 3 zones on others. These zones are controlled by the intermittent subsidence of the earth’s crust started from Tertiary. One zone indicates a relatively inactive stage of crust. The forming time of the lower karst zones are earlier than that of the upper ones. The karst zones are cut off by the latter faults.

The karst development is controlled by earlier inner faults and frequently active faults. The new faults after the hill was buried have little influence on karst development of the buried hill.

The karst developing regulations control the occurrence and mining of reservoirs in Renqiu oilfield. At present, the chief direction of tapping the talent power of Renqiu oilfield is the potential oil in low penetrating area in the weak karst developing areas.

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