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The Study on Physical Properties of Unconventional Reservoir of the Mesozoic In Wangpanshan Area of Ordos Basin

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Summary

Ordos basin is one of the most potential petroleum reservoir region in China, Wangpanshan area is located at the middle-west in the Ordos Basin. It is one of key regions for recent petroleum exploration. Interval 4 and 5 of Yanchang Formation and Interval 6 of Yanchang Formation in the Triassic are the main objective exploration targets for elastic rocks in this area. The reservoir's characteristics including many genetic types, rock types, and reservoir interspaced types, as well as low porosity and permeability. The examination of the controls of the reservoir rocks indicates that the sedimentary micro-facies and diagenesis are the principal geological factor controlling the development and distribution of the reservoir rocks in the study area. This article mainly study physical properties of reservoir (porosity, permeability), the horizontal distribution of physical properties of reservoir and the vertical distribution of physical properties of reservoir.

Introduction

Reservoir properties contains geometry, lithology, physical property, and their influences on reservoir formation and exploitation. The reservoir research uses seismic, drilling, cores, test and development data to describe and analyze, thus evaluating and forecasting the reservoir. In order to evaluate oil and gas reservoirs, it is important to study the reservoir properties. The precision and effectiveness of studies on reservoir properties directly affect the evaluation.

Physical property is one of the important parts in reservoir research, and it is normally represented by porosity and permeability. Quantitative research on how physical property horizontally and vertically changes has significant meaning to the researches on sedimentary facies, heterogeneity and reserve calculation and evaluation. It is also the foundation of the analysis of residual oil distribution and the rule of oil-water movement. Research on changing of physical property has influence on reservoir exploitation and increasing production.

As the second largest sedimentary basin and important energy base, Ordos Basin's oil and gas resources have the characteristics of widespread, many oil-bearing intervals and large reservoir thickness [1]. Triassic Yanchang is the major oil-bearing stratigraphy series which has low permeability, low maturity of sand body's composition, poor physical property, small surface area and small pore throat, strong molecule interaction solid-liquid surface, thick oil boundary layer, high heterogeneity, low saturation of movable fluid and existence of starting pressure gradient. Precise evaluation and effectively exploitation of Ordos Basin's very low permeability reservoir has always been a hot area of research.

From years of exploration at Wangpanshan area in the middle-east Ordos Basin, we know that Wangpanshan has rich oil and gas research. Multiple oil-and gas-bearing layers from Mesozoic to Lower Palaeozoic were found in this area and surrounding areas. However, the special surface conditions and geological features make it hard to exploit.

These years, Interval 4+5 and Interval 6 of Yanchang Formation have got industrial oil output, which means Interval 4+5 has the potential of exploration. Structural traps are not fully developed in this area.

However, sedimentary facies having great changes in horizontal and vertical, complex spatial distribution of reservoir, high heterogeneity and low physical property make it to be very low permeability layer. Also, later diagenesis affects the oil and gas exploration and exploitation. Finding the main controlling geological factor of Interval 4+5 and 6 physical property and realizing the distribution of high quality reservoir are becoming major problems.

With the development of exploration and exploitation, weak research on basic geology is becoming a disadvantage, which seriously affect the further exploration and development. In this paper, the reservoir properties of Interval 4+5 and Interval 6 will be investigated. Meanwhile, since Interval 4+5 and Interval 6 have low porosity, very low permeability, high buried depth and complex diagenesis, a comprehensive study of reservoir is needed. Based on the fact that the area has thin particle size of sandstone, complex diagenesis and high heterogeneity, analysis is needed to be done towards the Interval 6₁ and Interval 4+5's physical property, pore structure, evolution of heterogeneity and reservoir distribution.

Theory and/or Method

All in all, research area Chang4+5 and Chang6₁ porosity is mainly about 7-9%, permeability is mainly about $(0.5-1.1) \times 10^{-3} \mu\text{m}^2$; they have little different between small intervals. Chang6₁ pore permeability parameters is better than others, porosity is about 10.33%, permeability is about $1.01 \times 10^{-3} \mu\text{m}^2$. Normally, as depth increase, compaction, the porosity and permeability of reservoir overall trends are decrease; but depend on different sedimentary facies belt and heterogeneity of diagenesis, lead to the pore-permeability in some part of intervals have different situations, such as Chang6₁ has an abnormal situation.

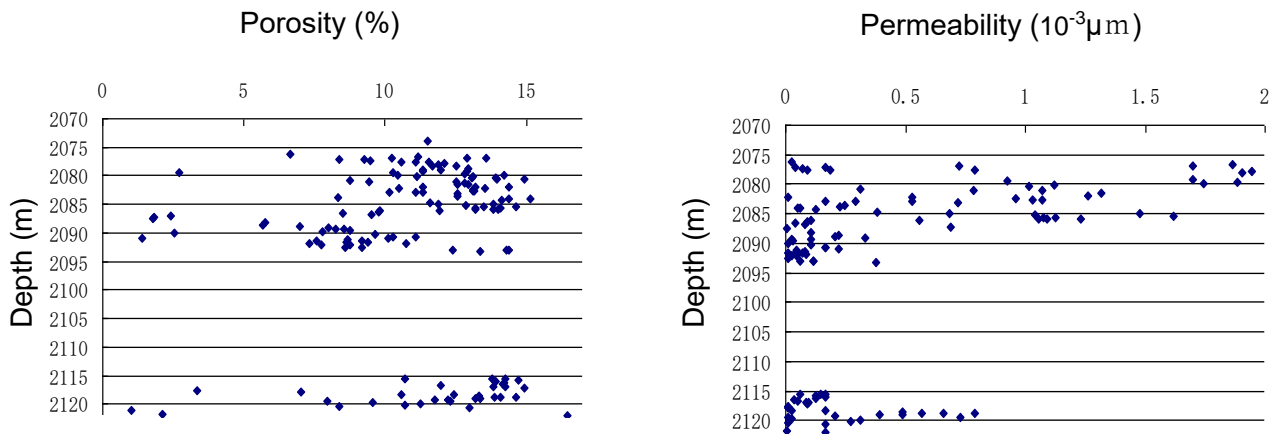
According to core data and well log data, this study made some cross plot of porosity and permeability with depth. From compared with different area, we got that different porosity-permeability makes the cross plot very different. Basically, it has three main types:

A type: Represented by Yuan73well、Yuan6₁well and Yuan95well (Figure3-38), With the increasing of buried depth, the permeability and porosity parameters as sand body overall showed a trend of decrease. Take Yuan95well for example, Yuan95well porosity and permeability with depth cross-plot demonstrated that Chang 4+5₂ and Chang6₁ these two intervals data points: there porosity and permeability at Chang 4+5₂ have more numerical value, but all trend is as the porosity and permeability increase, the depth decrease. Yuan73well and Yuan6₁well is similarity, from the depth cross-plot include Chang4+5₂ and Chang6₁ porosity and permeability data, demonstrated that the characteristics of porosity and permeability change with depth; with the depth change, the datum reveals that the porosity activity at the small range, the permeability activity reverse, it changes large.

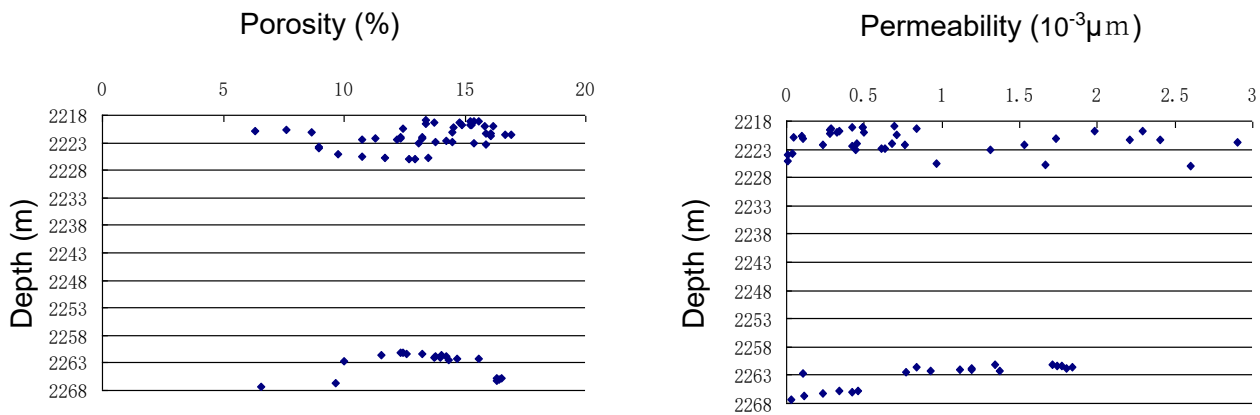
B type: Represented by Yuan118well、Geng59well and Yuan95well (Figure3-38), With the increasing of buried depth, the permeability and porosity parameters as sand body overall showed a trend of decrease and then increase. As shown in Figure3-39, Yuan118well includes Chang4+5₁、Chang4+5₂ and Chang6₁ three different intervals data, almost include all intervals in this study area. Mainly demonstrated these intervals' porosity and permeability change of characteristic with depth: Compared to the permeability decreased and then increased trend with the depth increase, the porosity changed so small Geng59well also have these characteristics.

C type: Represented by Yuan228well、Yuan6₂well、Geng35well、Geng6₁well、Geng44well、Geng124well、Geng137well、Geng130well and Geng43well, With the increasing of buried depth, the permeability and porosity parameters showed a clearly trend of increase. For example figure3-40, Yuan228well includes Chang4+5₁、Chang4+5₂ and Chang 6₁. That is because, this area Chang6₁ sand bodies all thicker than Chang4+5₁、Chang4+5₂. From the reservoir space point of view, Chang6₁ is main

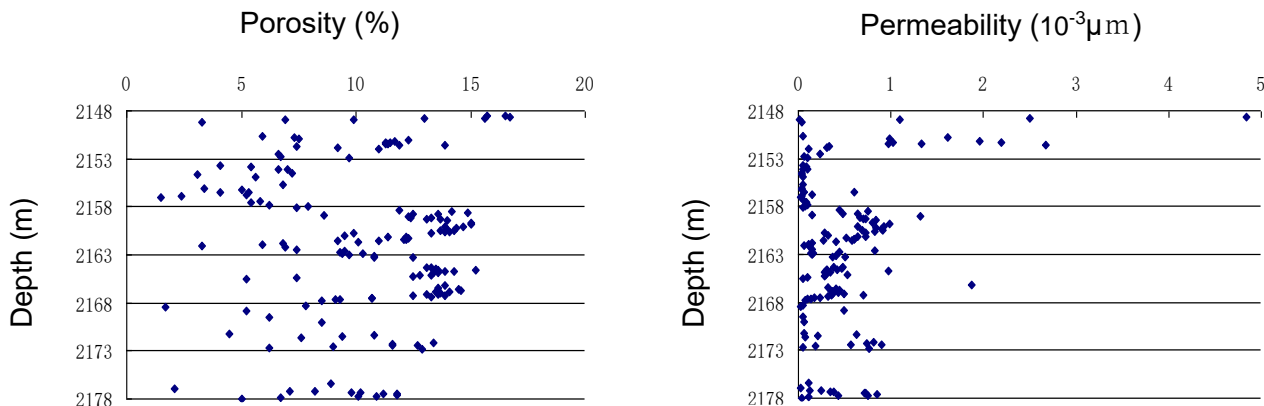
of residual intergranular pore, occupied the total rate of pores 38%, cement is iron argillaceous cement, generally, there are chlorite membranes protect pore, Pore throat connected is also well; however, Chang4+5₁、Chang4+5₂ is mainly about solution pores, most be filled in calcite, pretty compact, calcite cement plug throat, connectivity is poor (Figure3-41). Yuan62well、Geng35well、Geng61well、Geng44well、Geng124well、Geng137well、Geng130well and Geng43well also have same characteristics.



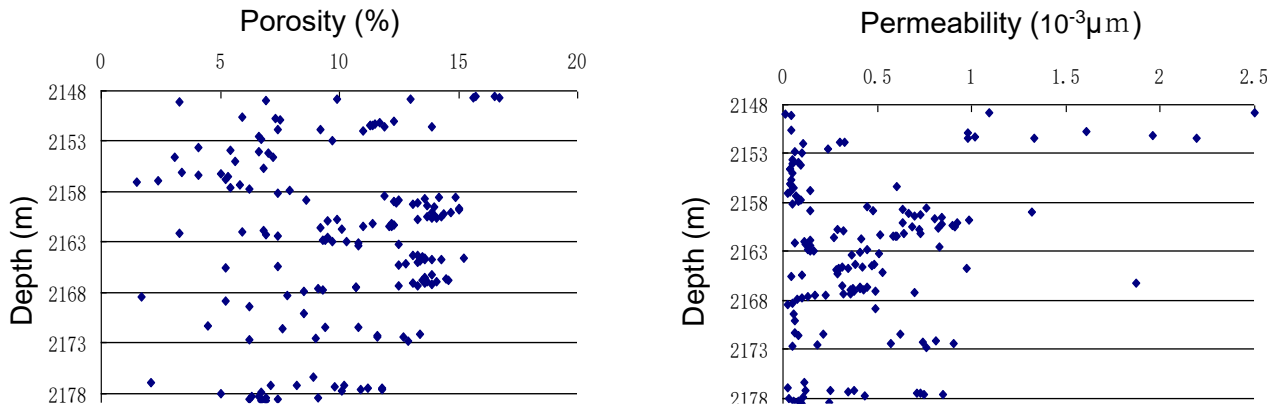
a. Yuan73well porosity and permeability with depth cross-plot



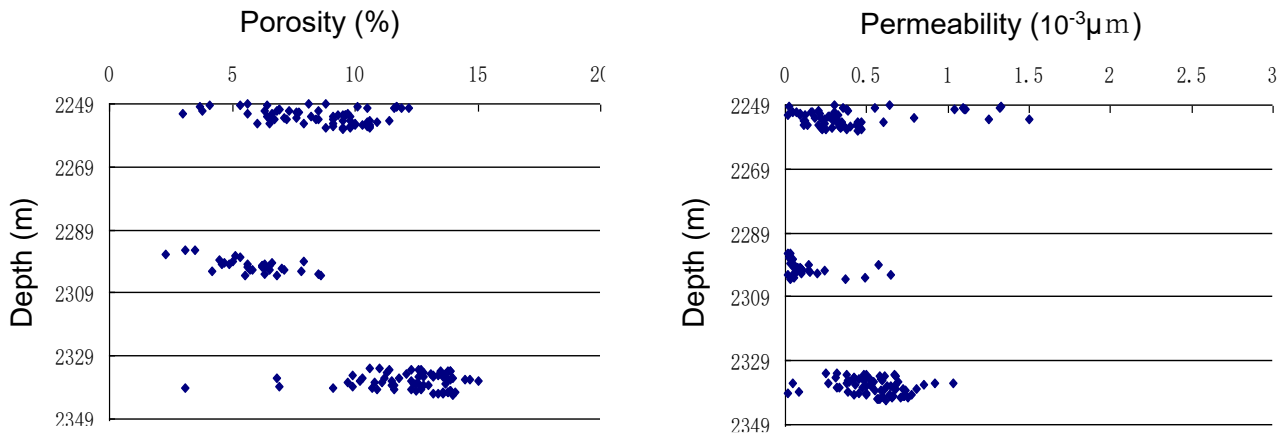
b. Yuan61well porosity and permeability with depth crossplot



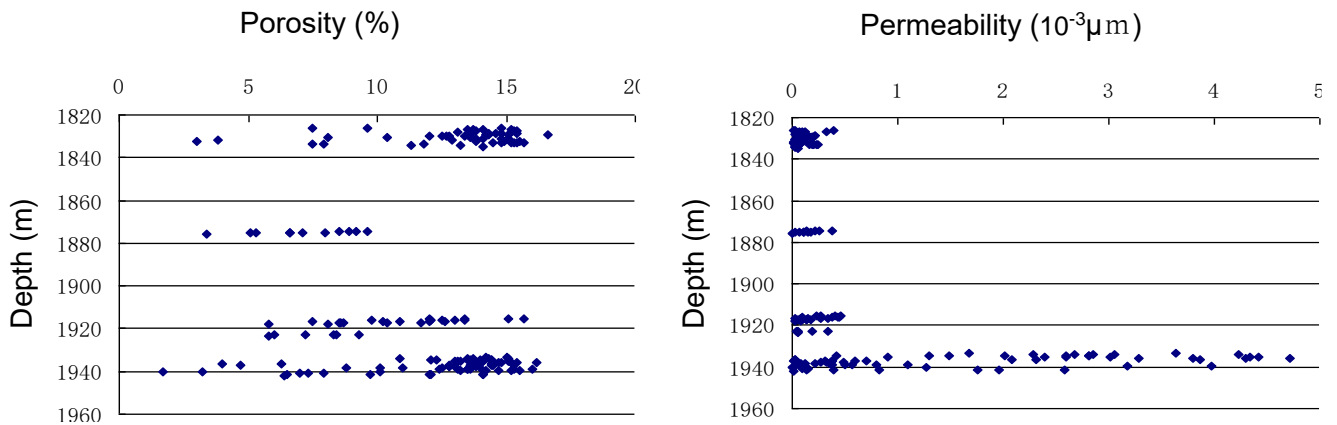
c. Yuan95 well porosity and permeability with depth cross-plot



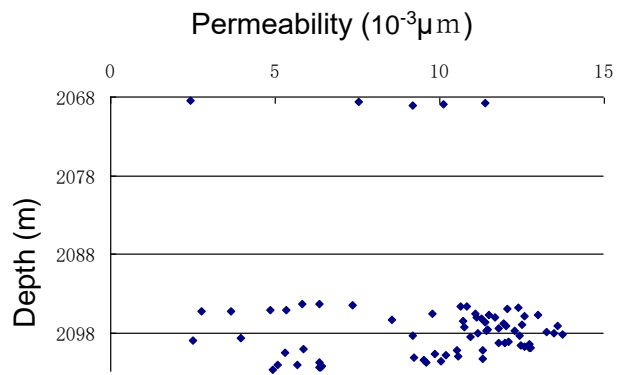
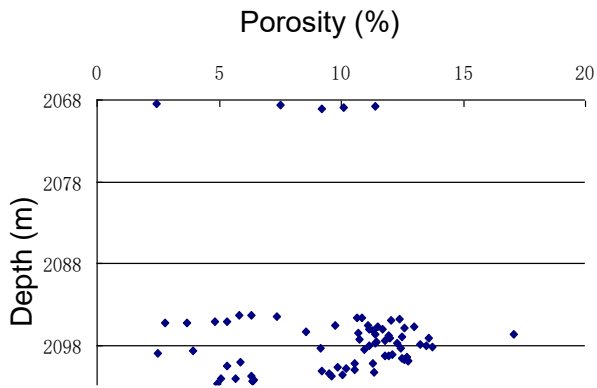
d. Yuan118 well porosity and permeability with depth cross-plot



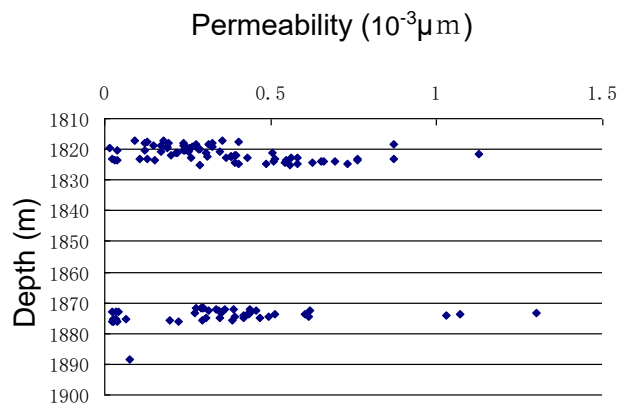
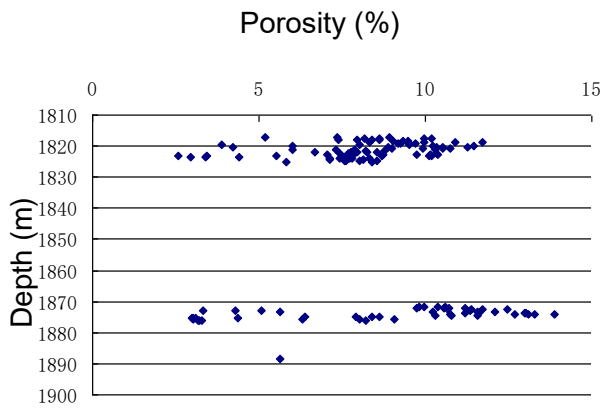
e. Yuan59 well porosity and permeability with depth cross-plot



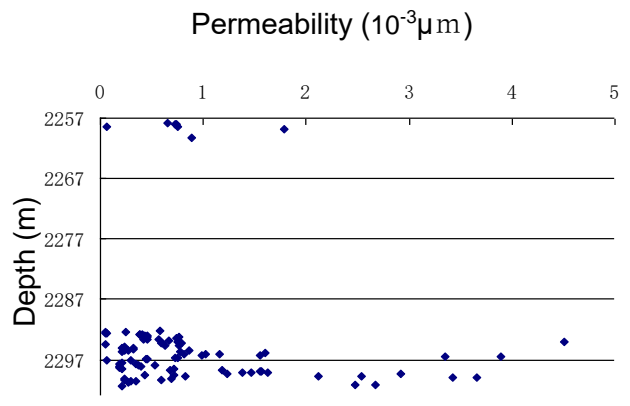
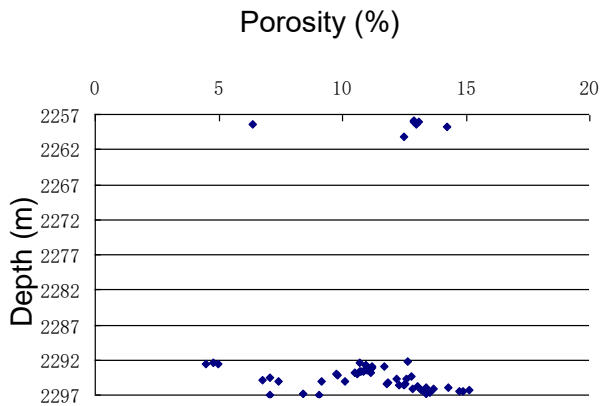
f. Yuan228 well porosity and permeability with depth cross-plot



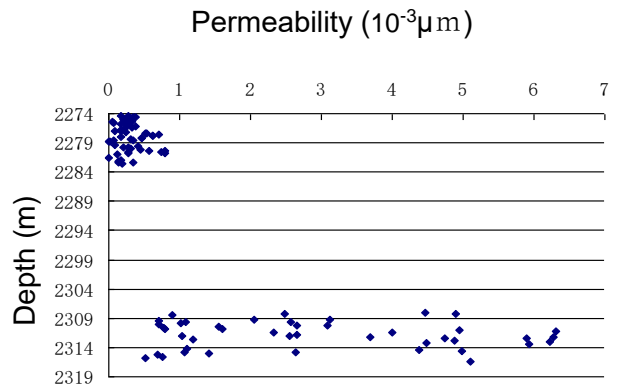
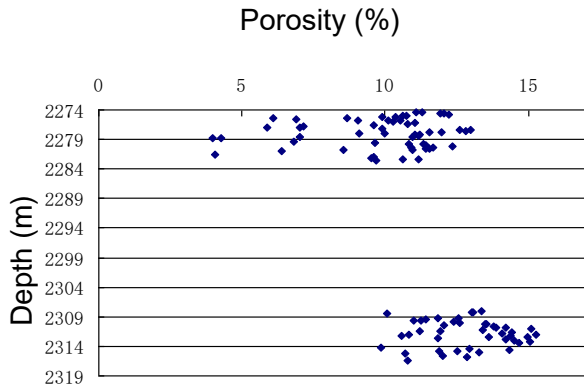
g. Yuan62 well porosity and permeability with depth cross-plot



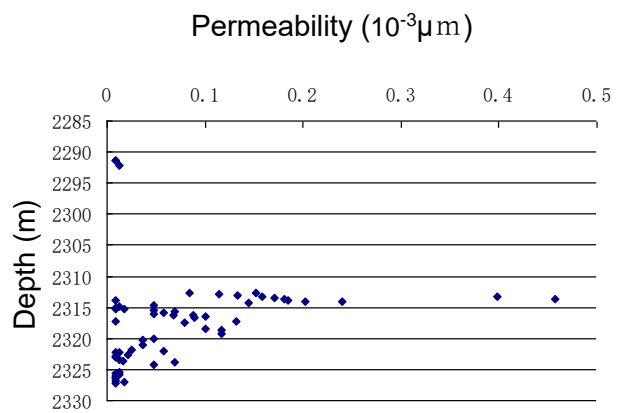
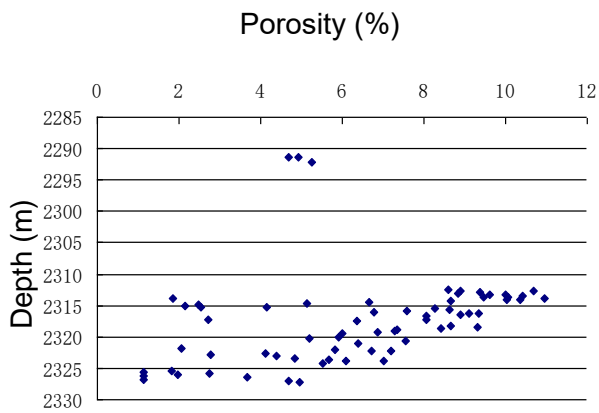
h. Geng35 well porosity and permeability with depth cross-plot



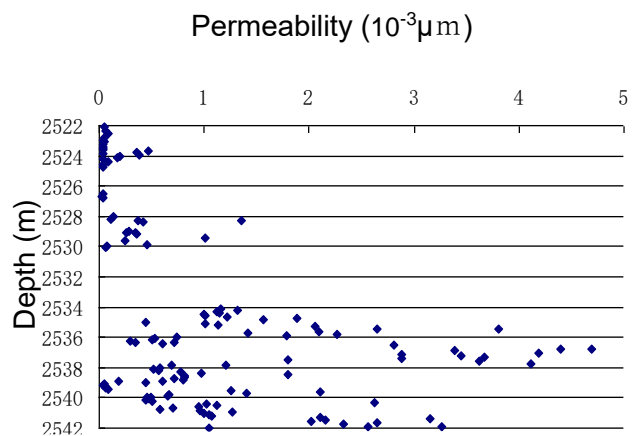
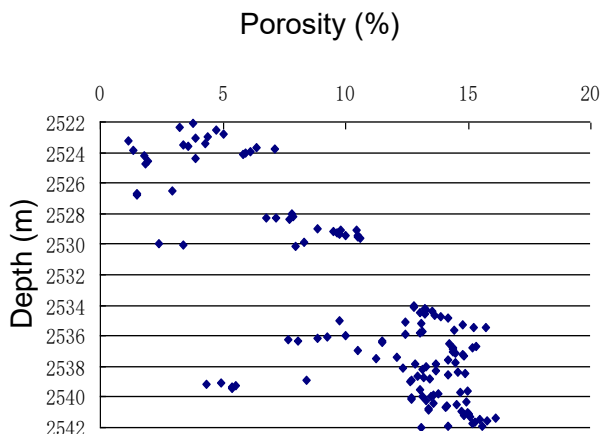
i. Geng61 well porosity and permeability with depth cross-plot



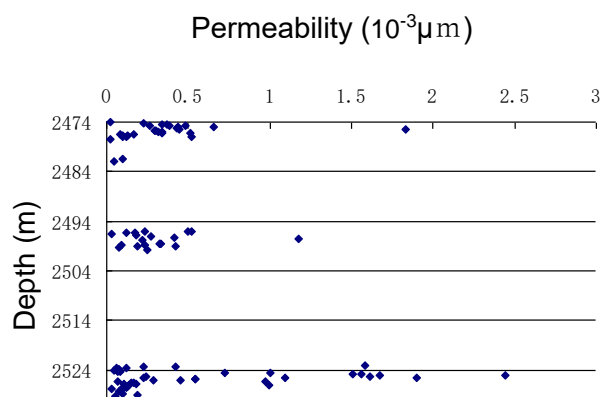
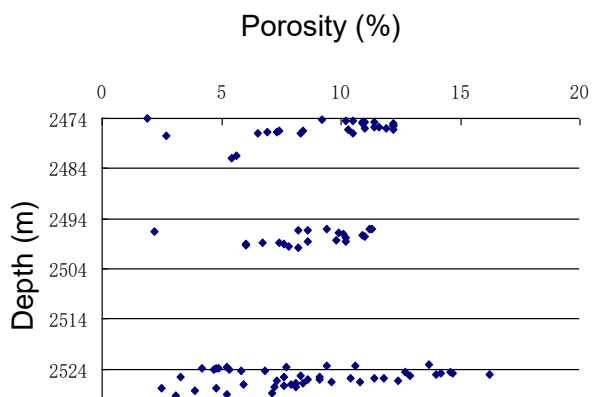
j. Geng44 well porosity and permeability with depth cross-plot



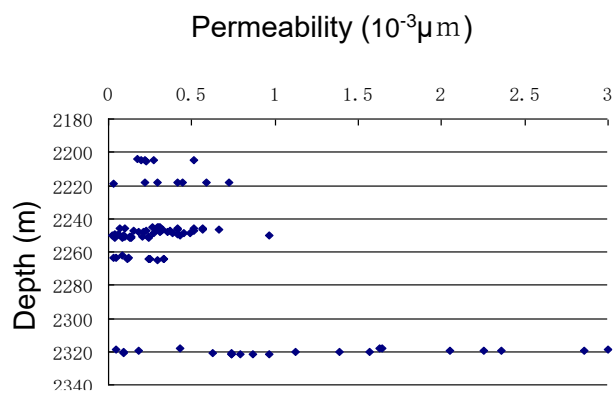
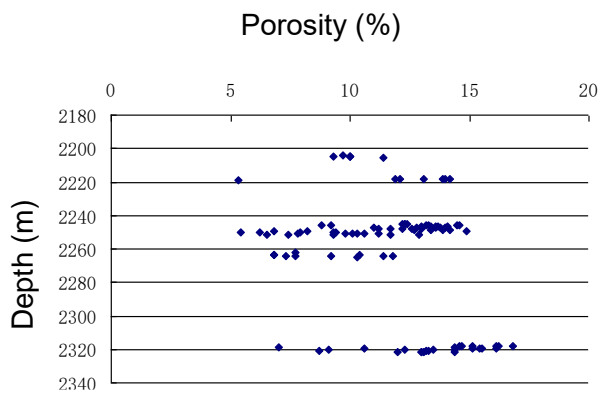
k. Geng124 well porosity and permeability with depth cross-plot



l. Geng137 well porosity and permeability with depth cross-plot



m. Geng130 well porosity and permeability with depth cross-plot

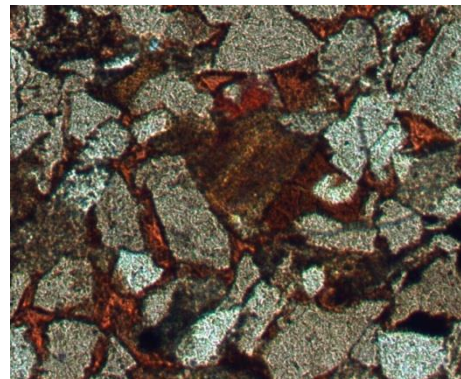


n. Geng43 well porosity and permeability with depth cross-plot

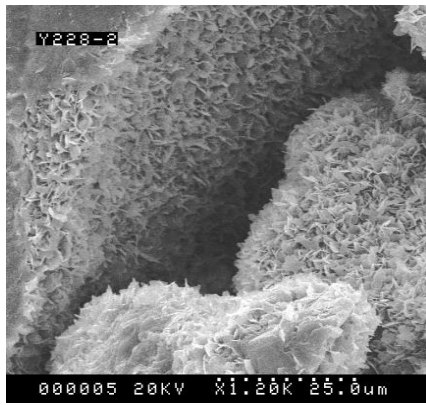
Figure 3 C type porosity and permeability with depth cross-plot



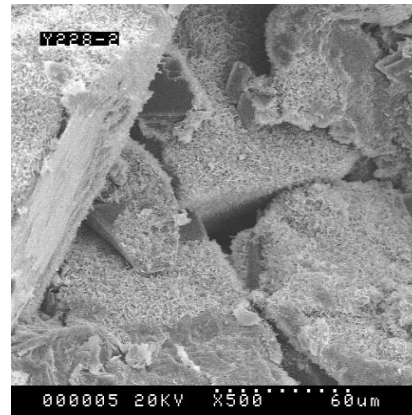
a. Yuan228well, Chang 6₁: the residual intergranular pore, throat connectivity is well



b. Yuan228well, Chang 6₁: the residual intergranular pore and Iron argillaceous cement



c. Yuan228Well, Chang6₁: Chlorite films filling rest intergranular pore



d. Yuan228Well, Chang6₁: Chlorite films filling rest intergranular pore

Figure 4 Yuan228well Reservoir space microscopic photographs

As can be seen from the above pictures, due to different sedimentary facies and diagenesis, the porosity and permeability with buried depth have different relative. However, it was mainly controlled by diagenesis, such as Yuan22well. Normally, the porosity and permeability will decrease with the increasing of depth and compaction. However, Chang6₁, sand body is thicker, the residual intergranular pore development, so the porosity and permeability it expressed is much stronger than Chang4+5. For example, Geng 35well and Yuan228well, the porosity and permeability parameters of both are clearly negative correlation with formation buried depth. Facts show that compaction is not the only factor caused the physical vertical change of the study area, The different sedimentary facies of well area also has a larger effect on porosity and permeability parameters.

Examples

Chang 4+5₁ intervals Sandstone reservoir petro-physical characteristics

All in all, Chang4+5₁ porosity (Φ) is 5-9%, mainly about 7-9%, permeability (K) is about $0.3 \times 10^{-3} - 0.9 \times 10^{-3} \mu\text{m}^2$, mainly about $0.7 \times 10^{-3} - 0.9 \times 10^{-3} \mu\text{m}^2$, low porosity, medium-low permeability.

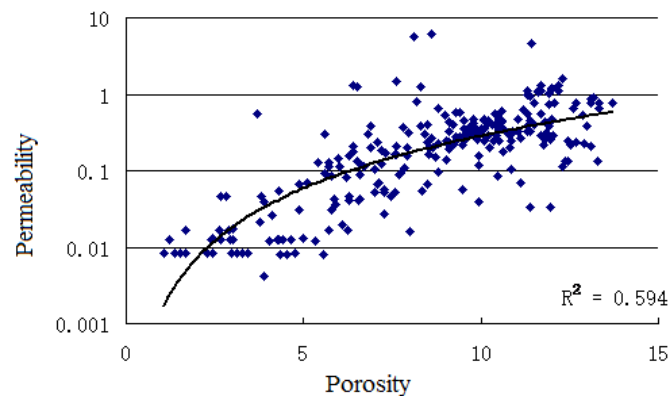


Figure 3-1 P-K cross-plot at Interval 4+5₁ in Wangpanshan-West

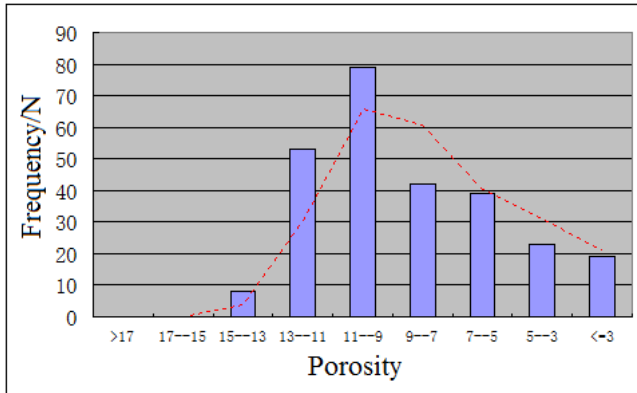


Figure 3-2 Porosity vs. frequency at Interval 4+5 Wangpanshan-West area

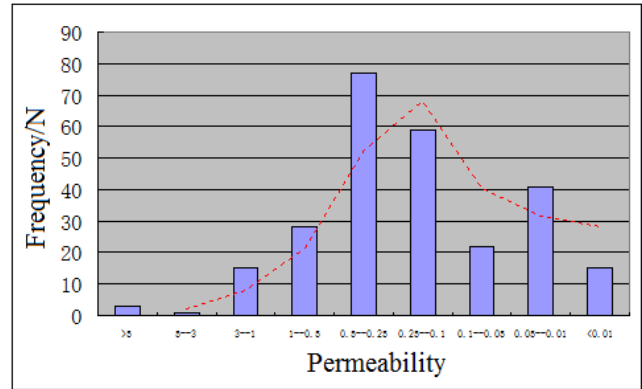


Figure 3-3 Permeability vs. frequency at Interval 4+5 Wangpanshan-West area

From Geng 59 well (figure3-4), Chang4+5₁ depth is 2248m-2260m. When the pore-permeability is relatively high, sedimentary facies mainly consist of sandstone and argillaceous sandstone, oil saturation and water saturation both are pretty high. By contrast, logging data interpreting result show that the layers are oil-water layers or tight oil layers. Geng 59 well porosity is 8.54%, permeability is $0.77 \times 10^{-3} \mu\text{m}^2$, variable coefficient (Kv) is 2.63; overall, this area porosity and permeability is poor, heterogeneity is strong.

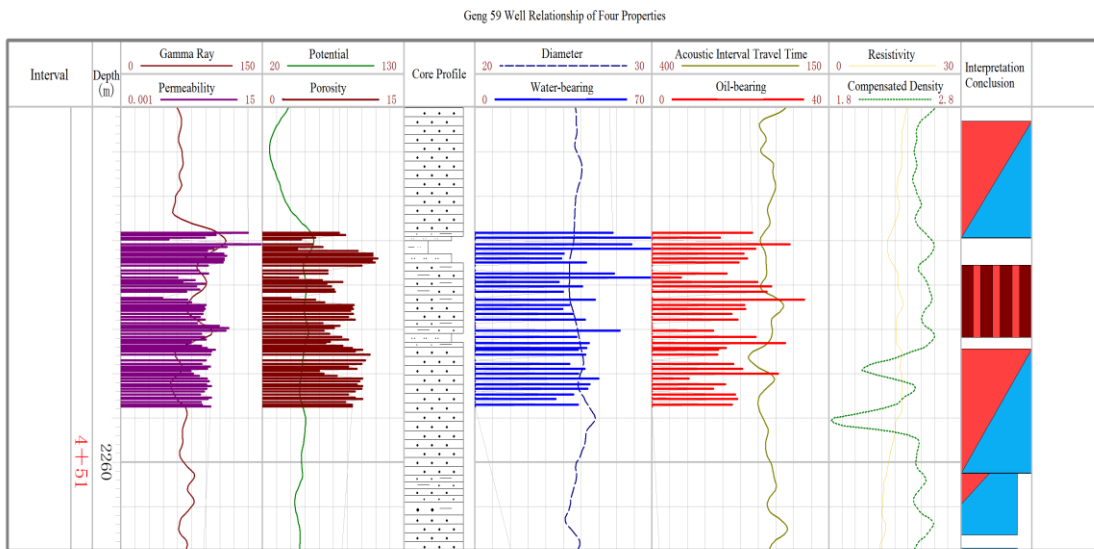


Figure 3-4 Geng 59 well relationship of four properties at Interval 4+5₁

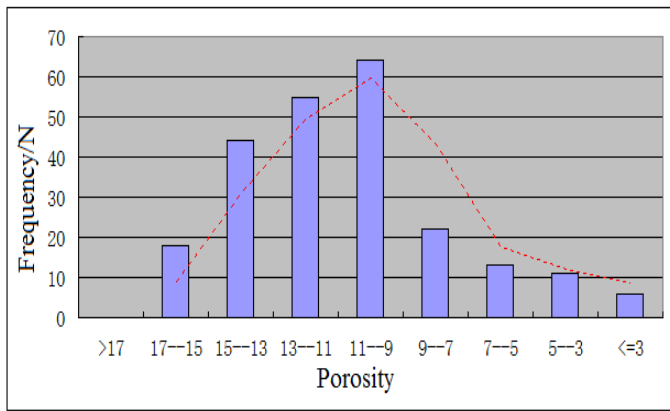


Figure 3-5 Porosity vs. frequency at Interval 4+5₁ in Wangpanshan-East area

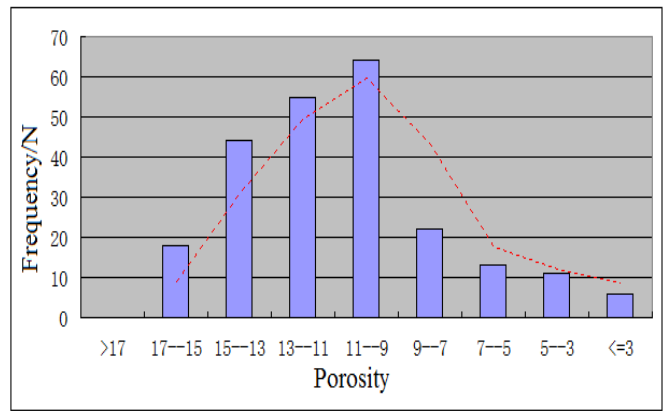


Figure 3-6 Permeability vs. frequency at Interval 4+5₁ in Wangpanshan-East area

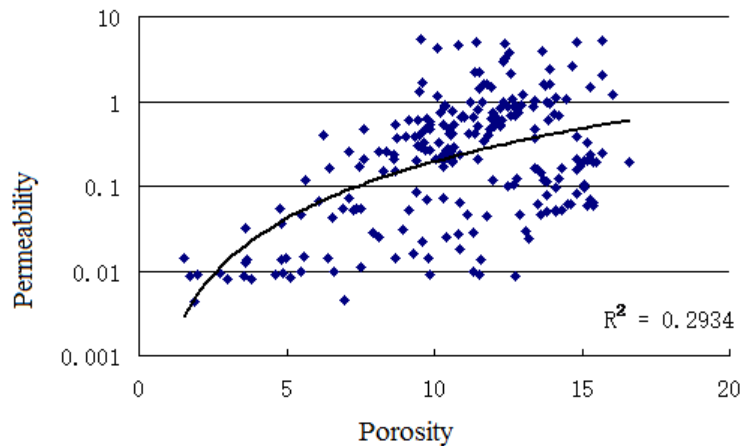


Figure 3-7 P-K cross-plot at Interval 4+5₁ in Wangpanshan-East area

From 3-7, it reflected that the pore-permeability relative rate is 0.2934, under a same porosity, the permeability changes a lot, especially porosity which is during 10%-17%.

From Geng33 well and Yuan69 well relationship of four properties at Interval 4+5₁ in Wangpanshan East area (Figure 3-8), large lithology changes in the region. It has many depositional cycles. Median size of sandstone is about 0.2mm. The carbonate content of the sandstones is commonly high, some intervals are higher than 30%. In Geng33 well bottom segments, carbonate content is higher and most of them filling with calcite, formed dry layer. Geng33 well porosity is 4.36%, permeability is $0.04 \times 10^{-3} \mu\text{m}^2$, in total pore-permeability is poor, but heterogeneity is strong. Yuan69 well porosity is 11.68%, permeability is $1.01 \times 10^{-3} \mu\text{m}^2$. From lithologic description and thin section authentication, macro and micro cracks both are development very well. Crack is an important reason for this area strong heterogeneity.

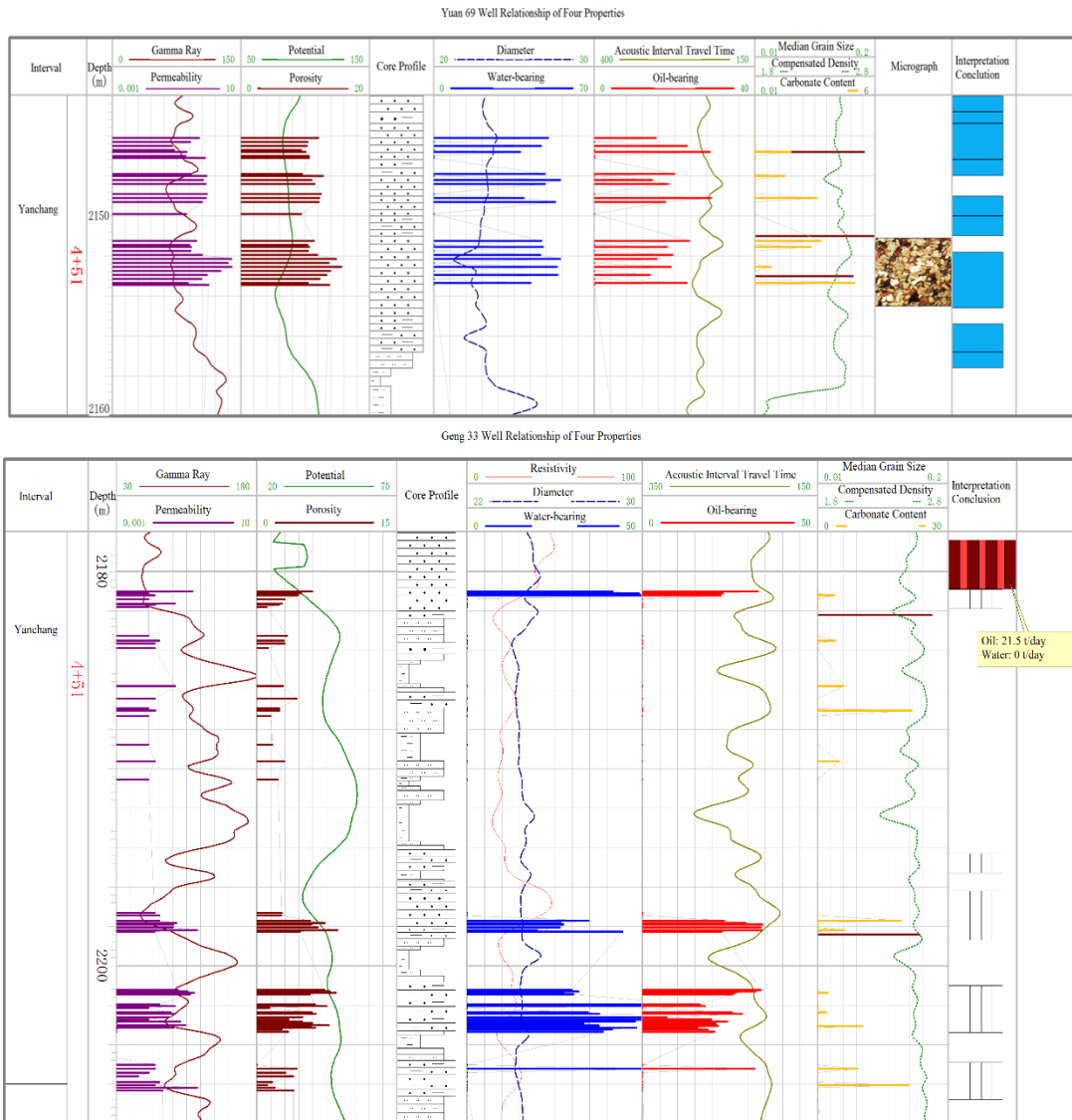


Figure 3-8 Geng 33 well and Yuan69well relationship of four properties at Interval 4 + 5₁ in Wangpanshan-East area

Chang4+5₂ intervals Sandstone reservoir petro-physical characteristics

All in all, Chang4+5₂ porosity is 7-11%, it mainly about 9-11%, permeability(K) is about $0.7 \times 10^{-3} - 1.1 \times 10^{-3} \mu\text{m}^2$, mainly about $0.7 \times 10^{-3} - 0.9 \times 10^{-3} \mu\text{m}^2$. Therefore, it is low and medium-low porosity, medium-low permeability (Figure 3-7、Figure 3-8) .

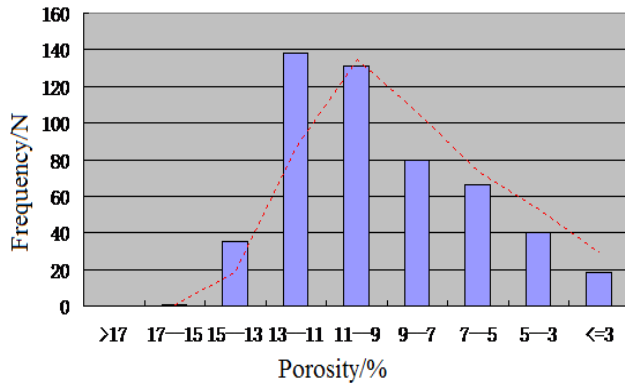


Figure 3-9 Wangpanshan area
Chang4+5₂Porosity distribution histogram

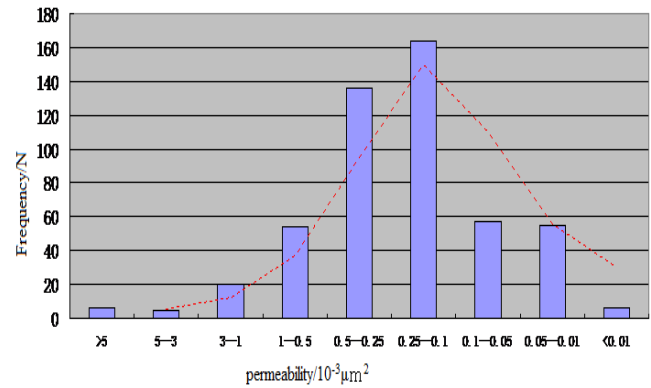


Figure 3-10 Wangpanshan area
Chang4+5₂Permeability distribution histogram

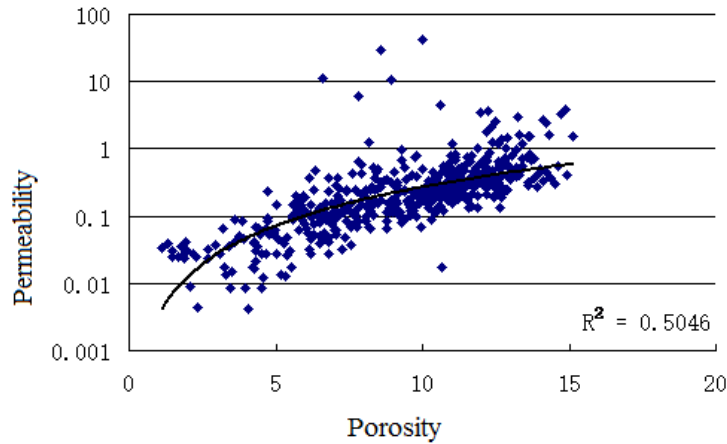
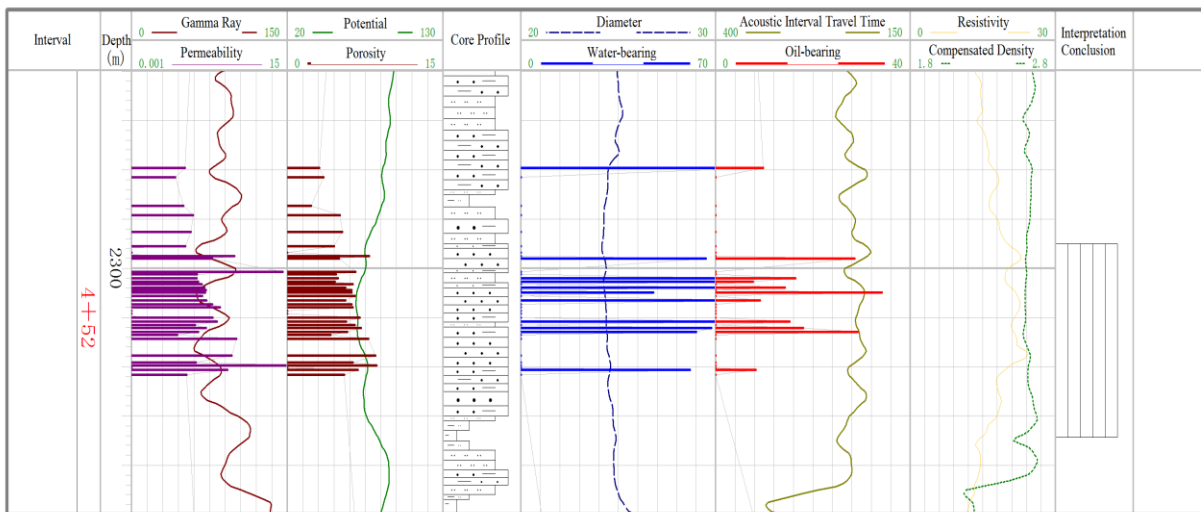


Figure 3-11 P-K cross-plot at Interval 4 + 5₂ in Wangpanshan-West area

From Geng59well and Geng130well relationship of four properties at Interval 4 + 5₂ in Wangpanshan West area (Figure3-12), variable coefficient followed the variation of sand body thickness on both sides gradually increase from 0.2 to 1. Heterogeneity is increased too. Geng130well porosity is 9.81%, permeability is $3.86 \times 10^{-3} \mu m^2$, variable coefficient is large. Heterogeneity is strong. Geng59well porosity is 5.99%, permeability is $1.70 \times 10^{-3} \mu m^2$, but heterogeneity is also strong, variable coefficient is 3.21.

Geng 59 Well Relationship of Four Properties



Geng 59 Well Relationship of Four Properties

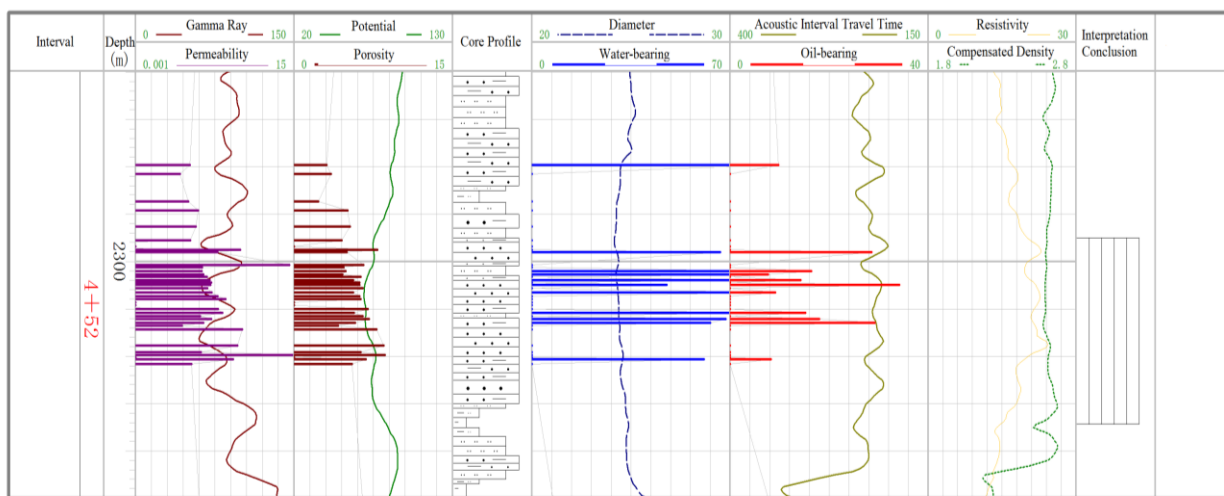


Figure 3-12 Geng59well and Geng130well relationship of four properties at Interval 4 +5₂ in Wangpanshan-West area

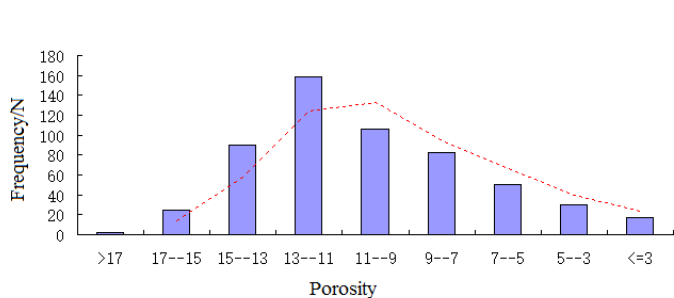


Figure 3-13 Wangpanshan-East Interval 4+5₂ porosity distribution histogram

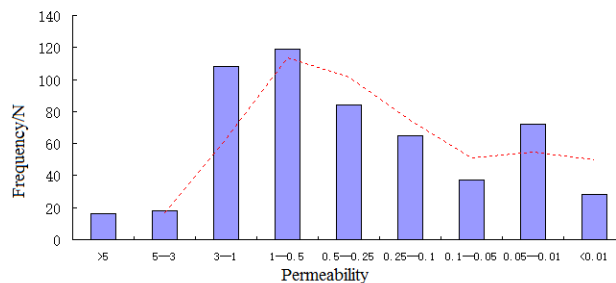


Figure 3-14 Wangpanshan-East Interval 4+5₂ permeability distribution histogram

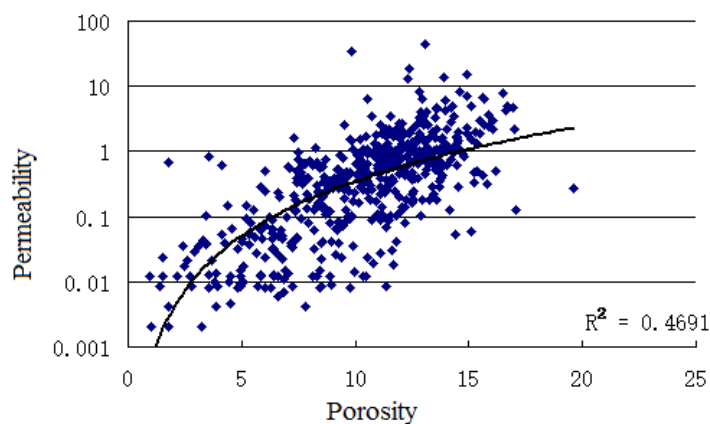
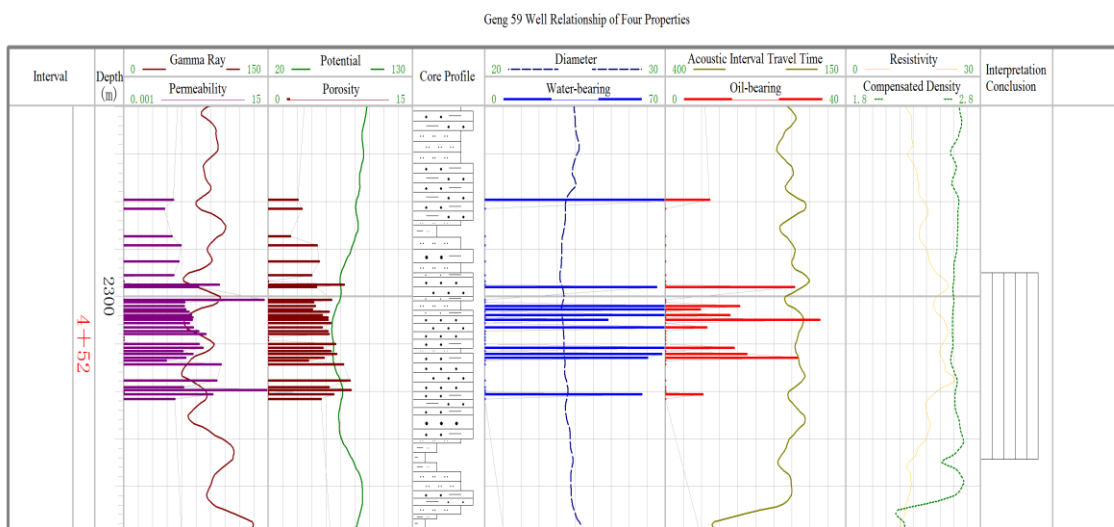


Figure 3-15 P-K cross-plot at Interval 4+5₂ in Wangpanshan-east area

From Geng34well and Yuan69well relationship of four properties at Interval 4+5₂ in Wangpanshan East area (Figure3-16), no large lithology changes in the region. It has only few depositional cycles, median size of sandstone is about 0.3mm, The carbonate content of the sandstones is commonly high, some intervals are higher than 30%, but most is 10%-20%. In some segments of Geng34well, carbonate content is higher and most of them filling with calcite, porosity is 10.17%, permeability is $1.94 \times 10^{-3} \mu\text{m}^2$. Pore-permeability is high and heterogeneity is strong. Yuan69well porosity is 11.68%, permeability is $1.01 \times 10^{-3} \mu\text{m}^2$, pore-permeability is well, but heterogeneity is not strong.



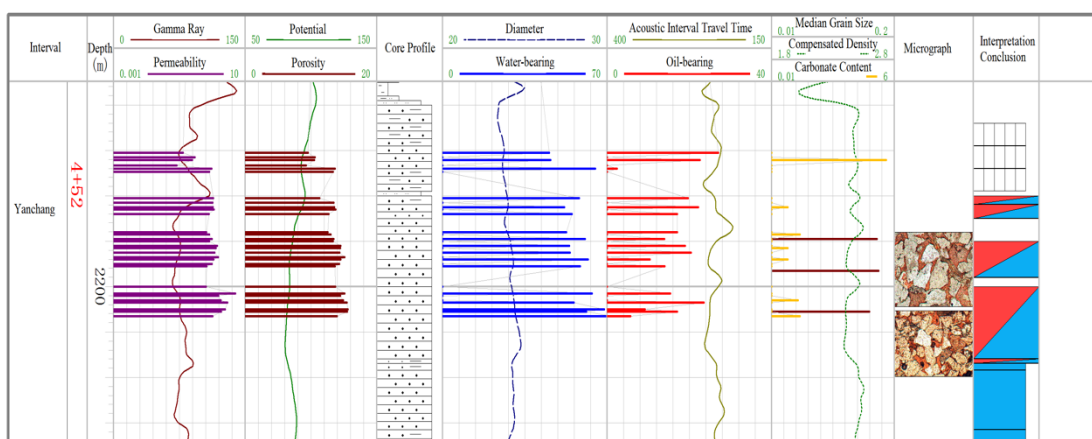


Figure 3-16 Geng34well and Yuan69well relationship of four properties at Interval 4 + 5₂ in Wangpanshan-East area

Conclusions

i: The porosity of research area: Triassic Chang 4+5 intervals of yanchang oil bearing formation interval is main range from 7% to 9%, permeability is main range during $(0.5-1.1) \times 10^{-3} \mu\text{m}^2$; they are belong to low porosity and low permeability reservoir; the parameter for porosity and permeability is no relatively large range between each small lay. Among all intervals, the parameter for porosity and permeability of Chang 61 is relatively better than others, Its average porosity is 10.33%, average permeability is $1.01 \times 10^{-3} \mu\text{m}^2$.

li: Reservoir porosity and permeability in the plane distribution is basically consistent with the distribution of sand body, the underwater channel development. On the contrary, the area of large thickness sand layer porosity、 permeability relatively high, however, underwater channel not develop well, The porosity and permeability of thickness thin sand layer area is comparatively low. Overall, Chang4+5 oil-bearing intervals is low porosity and low permeability lithological hydrocarbon reservoir, porosity and permeability have a well related. As the porosity increases, the permeability increase, demonstrated the pore type reservoir characteristics. When a certain porosity, a wide variety in permeability, it means the permeability not only relate with porosity, also may relate with hole porosity structures and throats shapes.

lii: The factors affecting the property of reservoir were as follows. (1) Environment of sedimentary, (2) paleoclimate, (3) diagenesis, (4) tectonic movement, (5) clay minerals. The main influences on this study area reservoir are deposition, a tectonic movement, and diagenesis. Deposition on the macro controls the planar distribution of reservoir the original permeability and porosity of the sand body and it have a certain influence on the later diagenesis. Tectonic action on the properties of reservoir in this area mainly reflects in the rock failure fracture formation of cracks.

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