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The method of evaluating the sealing ability of caprock

Zhang Qingyong
Northeast Petroleum University School of Geosciences, Daqing, Heilongjiang, China, 163318

Abstract: The thickness is the most direct parameter to evaluate the sealing capability of caprock. The percent of clay in the segment of caprock is an important parameter for the sealing ability in the case of the same thickness. In order to study the sealing ability more comprehensive, the damage of caprock caused by faults in the movement in the geology period has been considered. After deep study of sealing ability of caprock which is destroyed by faults, we find that the displacement pressure is the most effective parameter in controlling the sealing ability of caprock. In order to meet the requirement of the reality work of geology exploration, summing up the thickness of the caprock, the clay percent in the segment of caprock, the damage situation of caprock caused by faults movement and the displacement pressure in the stage of caprock is needed, and we get the comprehensive evaluation parameter of the sealing ability of caprock after that. The comprehensive evaluation parameter can reflect the sealing ability of capraock more exactly.

Key words: *mudstone caprock, the thickness of caprock, clay content in the caprock, match between fault and caprock, displacement pressure, comprehensive evaluation*

Caprock is a formation located above the reservoir which has some sealing ability. It's one of the important reasons that oil and gas can be saved. The evaluation of sealing ability of caprock is being widely valued in many years, in the start point scholars only evaluate the thickness of the caprock to predict the sealed region[1], and now we evaluate the sealing ability by capillary sealing ability and the match between faults and caprock[2]. The work of evaluation of caprock is more and more detailed, but it still couldn't match the need of the exploration of oil field. The result of prediction which is gotten by a single method is not well enough, so this way of predicting the sealing ability couldn't guide the work of exploration effectively.

I. IMPACT OF SEALING ABILITY FROM CAPROCK THICKNESS

When the thickness of caprock is greater, the continuity of caprock in the range of depression will be better, and the capillary seal ability in vertical will be stronger. On the other side, water discharge will be blocked in the case of compaction when the thickness of mudstone caprock is very thick. And there will be overpressure stratum in the mudstone caprock, it's good for the conformation of the pressure sealing effect. The pressure sealing effect can increase the sealing ability of mudstone caprock[3]. In summary, the greater the thickness of caprock is, the sealing ability of caprock will be stronger, and the trap is more conducive for oil and gas gathering in it.

In the course of actual data process, using the geological logging results from the drilled wells, we can demarcate the caprock. By demarcating the regional caprock in the study zone, we can make sure the formation where oil and gas stay in generally. On the base of the standard caprock from the single well data, compromised with the seismic data, we can demarcate the caprock from different formations meticulously in the help of seismic reflection signal. As there will be many different profiles in the course of explaining by seismic, so we can predict the distribution of caprock in the whole study zone. The prediction of caprock thickness will be more exactly, in another word, we can predicate the sealing ability of caprock more accurate.

II. IMPACT OF SEALING ABILITY FROM CLAY CONTENT IN THE STAGE OF CAPROCK

In consider of microscopic pore structure, there is a big gap between the throat radius of mudstone caprock and the reservoir because that the throat radius of mudstone is relatively small, as a result, it is possible to form a strong capillary sealing ability. Therefore the clay content in the caprock segment can influence the physical sealing ability of caprock. When the thickness of caprock is same, the higher the clay content in the caprock segment, the stronger the sealing ability of mudstone caprock will be, still it is easier for oil and gas to accumulate under the caprock. On the other side, oil and gas will be harder to gather in the trap under the caprock.

In the practical work, we couldn't make core-taking observation for all of the caprock from different wells and different depth. So it is impossible for us to determine the clay content of the caprock from the microscopic structure in the way of experiment. In order to indicate the clay content in the cap segment approximatively, we believe that the porosity in the mudstone is all the same, and then we can count the specific value between mudstone thickness and caprock thickness. Furthermore we make the specific value as the clay content in the mudstone caprock, and we can use it to evaluate the sealing ability of mudstone caprock.

III. IMPACT OF SEALING ABILITY FROM FAULTS

In the process of oil moving from the source to the trap, the moving distance and gather formation is influenced not only by the length of faults and the throw of faults, but also by the damage degree between fault and caprock and still other factors. In order to express the extent of damage to the caprock fracture, precious scholars proposed the concept of connected thickness, the concept means that the connected thickness equals to the divergence of caprock thickness and fault throw[4]. We can divide the situation of caprock destroyed by fault into three types on the base of the relationship between fault throw and caprock thickness (as Fig.1). The first type is that fault throw is bigger than caprock thickness, in this case the caprok is destroyed entirely by fault, and it loses all of the sealing ability, so the petroleum can move up along the moving faults. The second type is that the thickness is bigger than fault throw and the connected thickness is smaller than a certain value, in this case the caprock is destroyed partly by fault, petroleum can move along the moving fault over the cap partly. The last type is that the connected thickness is bigger than the certain value, although the caprock is destroyed, it could still have the efficacious sealing ability.

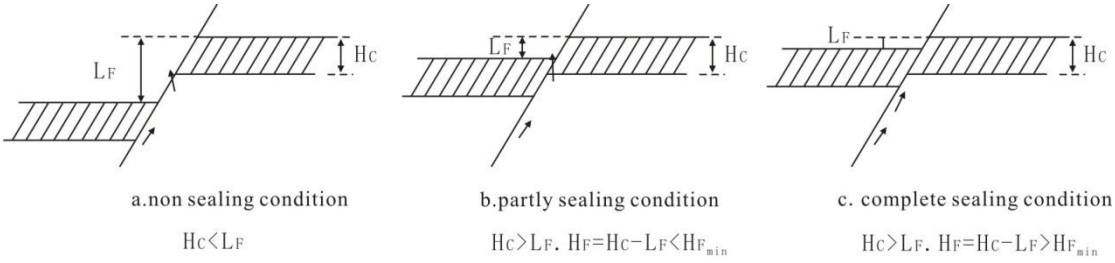

Fig.1 The situation of caprock destroyed by fault

In the process of using the connected thickness, in the first place we standardize the thickness of caprock from the single well diagram, and then combine with structure map of the formation in which the caprock is, in this way we can make sure the position of the well. Combined with the structure map we can read the nearest throw of the fault which is always in the downdip direction to the oil well. By the way of reading the value of throw of faults and the thickness of caprock, it is possible for us to make sure the connected thickness of the caprock of all hydrocarbon show wells, and combined with the formation of the hydrocarbon lives, we can define

the effective connected thickness which means that there is no hydrocarbon shows when over the certain value. So we can use this certain value as a boundary to range the area where the connected thickness is bigger than the certain value, in another word we can fix the range as the effective sealing zone of mudstone caprock.

IV. USING DISPLACEMENT PRESSURE TO EVALUATE THE SEALING ABILITY OF CAPROCK

The main mechanism of sealing hydrocarbon by mudstone caprock is physical property sealing, physical property is the capillary difference caused by the different physical parameter between caprock and reservoir, the existence of the difference of capillary pressure can seal the oil and gas under the caprock and still can prevent hydrocarbon from moving upword. Displacement pressure is the minimum pressure that wetting phase liquid displaced by unwettng phase in the hole of the rock, it equals to the maximum connected capillary pressure of the connected hole in the rock. Only in the way that the upper energy is weaker than the difference of the capillary pressure of caprock and reservoir, the mudstone caprock can stop the hydrocarbon from moving over it. Because that the capillary pressure of reservoir is too small to ignore it, so we overlook it in the process of calculating[5]. Therefore, we can use the capillary pressure of caprock to stand for the difference capillary pressure of caprock and reservoir, and this is the most effective method to evaluate the sealing ability of caprock.

Experimental method is the major method to calculate the displacement pressure, and there are three methods mostly used, they are adsorption method, mercury porosimetric method and direct displacement method. The results are partly different by these methods, and mercury porisimetric method is the most widely used in this three methods. However in the piratical work we could not use experimental method to test every caprock. There are mainly two reasons, the first reason is that there will be so much work that we couldn't finish it; the other reason is that we could not forecast the distribution of displacement pressure because that there is no well in much of the region. But using the relationship between interval transit time and the test simple, we can fit the formula of displacement pressure and interval transit time, shown in Fig.2. By picking up the interval transit time from seismic data, we can predict the distribution of displacement pressure in the whole area. Studies show that the caprock can effectively seal the under hydrocarbon when the displacement pressure is over 1 MPa. Combining with the forecast consequence, we can delineate the effective sealing area.

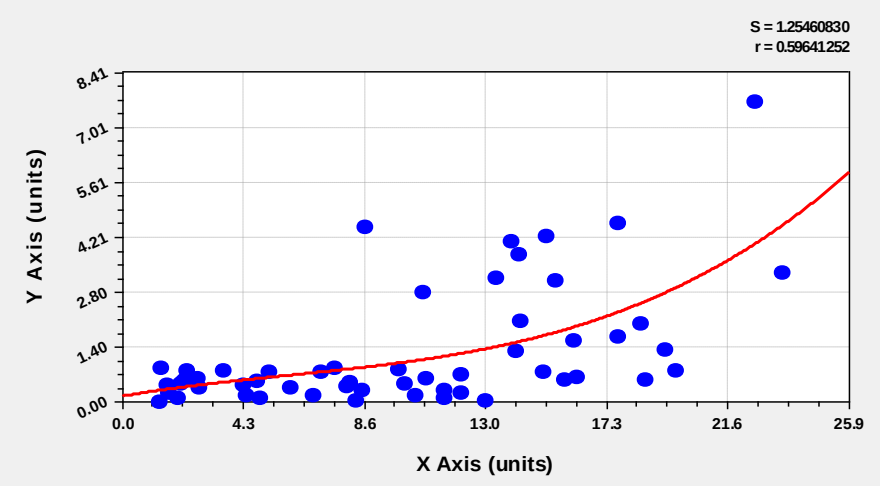

Fig.2 The fitting curve of displacement pressure(Pd-Y) and depth and clay content(Vsh*Z) in Nanpu Sag

V. COMPREHENSIVE METHOD IN EVALUATING THE SEALING ABILITY OF CAPROCK

Formation is influenced by many factors in the geological processes, in the process of evaluating the

sealing ability of caprock we need to consider the influence from not only the sedimentary environment but also the damage caused by structure movement. So when we only consider one factor, the forecast results of sealing zone of caprock cannot match the exploration situation very well. In order to increase the accuracy of forecast the sealing zone of caprock, we analysis the influence of four main factors, they are the thickness of caprock, the clay content in the caprock segment, the damage situation of cap rock caused by the movement of fault and the displacement pressure[6]. By the way of value assignment from experts, we can clear the weights of each factor, and it is convenient for us to analysis the sealing situation of caprock. After comprehensive analysis, the results are defined in four degrees, they are bad, medium, good and preferable. Using this method to evaluate the effective sealing zone distribution in Nanpu Sag in all the areal caprock, the results match the exploration situation pretty well, and the results indicate workers to find more hydrocarbon.

VI. CONCLUSION

The sealing ability of caprock is influenced by formation physical properties and structure movement. The structure movement mainly cause fault move to destroy the integrity of caprock. And the physical properties can influence the thickness of canrock, the clay content in the caprock segment and the displacement pressure. Compromise analysis all of these factors we propose the weighted average method to evaluate sealing ability of caprock. The method can combine the two aspect factors perfectly, let us can make a more accurate forecast of effective sealing zone and prospect the gathering area of hydrocarbon.

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