Several Important Issues for Complex Strata Correlation

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Abstract. Geological work is the basis for oilfield development, if there is no reliable geological basis, other works are not reliable. In oilfield geology, strata correlation is the basis of it, especially for complex strata oilfield. The work is not well done in some oilfields now, resulting in unclear underground geology, blinding follow-up work, restricting oil production. So doing this work better is important for increasing oil production and improving economic efficiency for a company.

1. Introduction
Strata correlation is the foundation for oilfield development. It is very important, the aim is to recognize the connectivity of reservoir, and the connectivity of the reservoir layer plays an important role in understanding the characteristics of oil reservoir, the preparation of oilfield development plan and the stimulation of potential production. There are many methods of strata correlation, such as logging curve correlation, field outcrop observation, core description, seismic data interpretation, sedimentary face research, ancient fossils and so on. For oil field strata correlation, it has specialty, which is to divide strata to single sand body for correlation, therefore the most realistic, detailed, reliable, and important method is the logging curve correlation method, which applies the principle of "cycle correlation, hierarchical control" plus the mark layer. For large and complete cycle, it is feasible, but for complex strata, the application of the principles is very difficult. In this paper, the author summed up 6 main points for such strata correlation, in particular, put forward the concept of "combination characteristics"; it is well used in such strata correlation. Otherwise, using seismic data to verify the correctness of the correlation results is important for correlation. The article points out that the aim of strata correlation is to research the connectivity of reservoir layer, and gives out the method for such research and verifying the correctness of correlation also. This method is of great guiding significance for the correlation of complex strata in other similar oilfields.

2. The concept of complex strata
Here the complexity is mainly for strata division and correlation. For simple strata, the sedimentary profile of continental rocks is obviously characterized by cyclic nature and particle size gradient, similar rock appears repeatedly, the characteristics of the cycle is obvious, the strata marker is clear, easy for cycle correlation, such formations are called simple strata, and vice versa, is called complex strata (figure 1). In the upper strata of DK oilfield, the sandstone-mudstone appearing alternatively is the main layer, there is no large sedimentary cycle, and many sandstone layers have...
similar logging curve characteristics, and same as mudstone layers. There is a great uncertainty in strata correlation compared with simple strata.

3. The issues for correlation

Same time and same sedimentary environment deposits same strata. The logging curve characteristics of the same strata are the same, the oily quality of a layer only changes the size of resistivity. The similar logging curve shape guarantees the same layer, that’s the principle of strata correlation.

In detail correlation, there are 6 points needed to pay more attention.

3.1. Using a variety of logging curves as much as possible in the correlation of curves

The types of logging curve mainly include SP, GR, CAL, CON, RLLD, RLLS, AC, DEN, CNL; different curves reflect different information of strata and should be judged synthetically. For sand-shale series strata, it is basically sufficient to differentiate permeability layer by SP, to distinguish the content of shale or rock type by GR, and to distinguish the oil-bearing property with resistivity curve, this three basic curves are also used in the strata division and correlation.

3.2. Grasping the whole characteristics of logging curve

Find the representative complete well logging curve in the research region, and analyse the characteristics of SP curve shape from bottom to top, from old strata to new one. Different logging curve shape represents different rocks and different rock is deposited in different environment, such as shallow water, deep water, water inflow or retreat etc. In the process of analysis, we should grasp the whole, the essence change and eliminate the local interference. For example (figure 2), the SP curve shape of DK oilfield reflects a water retreat process in generally. The bottom strata is composed of shale, and it is formed in deepest water, the content of sand becomes more and more from bottom to top, it means the depth of basin water becomes shallower and shallower, the basin water retreat until extinction. Although there are several times of deep water in the process with fine grain deposition, but it is short period, does not affects the overall change in the general trend.

3.3. Grasping the detail characteristics

Here the detail refers to a single thin layer. It may be composed of special minerals or rocks, such as pure clay, carbonate, coal, organic skeleton, weathering surface, resulting in a special shape of the logging curve. This single layer distributing steady in the researching area is called a marker; it is used in strata correlation.

For example, in DK oilfield, there are 3 markers (figure 2). Marker 1 is the weathering denudation surface, natural potential and resistivity curve shape mutate up and down the surface, and the upper
part of surface is a stable mudstone. Marker 2 is located in the middle of the strata profile; it is mudstone layer with thickness of 2m approximately. Marker 3 is the abrupt surface of clay deposited in deep water deposit to sandstone formed in shallow water. Every marker distribute stable in the area of 30 km². They divide the strata profile into 3 parts, and are very useful in the division and correlation of strata.

3.4. Grasping the circle characteristics

Due to crustal movement, riverbed change or climate change, sedimentary rock changes regularly. It is generally characterized by regular changes in rock types and grain size, such as gravel-sand-silt-mudstone series, similar rocks repeat regularly, this series is called sedimentary cycles. The gravel-sand-silt-mudstone series is called normal circle, and reverse circle for mudstone-silt-sand-gravel series. The SP logging curve shape is described as “bell” for normal circle, and a “funnel” for reverse circle. Every circle has characteristics, so we can recognize each circle for strata correlation. A large circle can be divided to small circles, a small cycle to a smaller one, and so on; finally, single layer is obtained.

For example (figure 3), in DK oilfield, there is a large normal circle C. According to the SP and resistivity curve, it can be divided into three small cycles: C1, C2 and C3. C3 can also be divided into smaller cycles: C3-1, C3-2, and C3-2 can be divided into single layers as C3-2-1, C3-2-2......C3-2-6, and so on for other circles for detail partition. Each circle has its characteristics.
3.5. Grasping combination characteristics

The combination characteristic is relative to a single marker. For many sand-mudstone interbedding, sandstone and mudstone alternately recur, up to dozens of layers. For such strata, the electrical characteristics of a single layer are not obvious and difficult to distinguish. But, the characteristics of multi-layer combination are obvious and easy to correlate, and a large combination may be composed of small ones of different grade. So, the combination can be used to control strata correlation from large grade to small grade until a single layer.

In strata correlation practice, layer I of well 1 may correlate to layer II₀ or II₁ or II₂ of well 2, it does not make sure of the correctness. But I only can be correlated to one of II₀, II₁ and II₂, if using combination characteristics, the problem may be solved easily.

For example (figure 4), in DK oilfield, the combination I is composed of numerous sand-mudstone interbedding, up to 30 layers. The logging curve shape of single layers is similar almost; it is difficult to distinguish each of them. When put them together, they present with characteristic. The SP curve like a vertical straight line generally, and resistivity curve a bow with small value in top and bottom and big value in middle. The thin layer limited in this combination, can only be compared with layer in the equal combination of other wells. A large combination can be divided to small combinations of different grade until a single layer. Large grade limit small ones; that is to say, a single layer is limit by several grade combinations. The combination position is definite in the strata profile, and it guarantees the correctness of the correlation. For example (figure 4), combination I is subdivided into 2 small combinations: I-1, I-2, each group has characteristics. For detail, I-1 can be divided into I-1-1, I-1-2, I-1-3, I-1-4 and I-1-1 can be divided to single layer: I-1-1-1, I-1-1-2, and I-1-1-3, and so on for other combinations. I-1-1-1 is limited by larger grade combination I-1-1, I-1, and I.

3.6. Grasping the sequence of each segment

The sequence here refers to the appearance position of each layer or layer combination, called segment. The arrangement order can be used in strata correlation, that is to say, if a segment appears at the bottom of a profile of a well, it can only be correlated to the one at the same position of another well. For example (figure 2), the four large segments arrange in the order of IV-III-II-I from bottom to
top, IV is the lowest part, and it would not be compared with the parts of other positions. Each segment has its char (table 1).

Table 1. The characteristics of each segment.

| Segment | I     | II    | III   | IV    |
|---------|-------|-------|-------|-------|
| position| top   | middle| middle| bottom|
| SP shape| vertical | normal circle | normal circle | vertical |
| RT shape| arc | hook | reverse hook | vertical |

Another meaning of the sequence is that the large scale segment includes small ones and small one includes smaller ones and so on.

The characteristics and sequence of logging curve are combined for strata correlation to obtain better result, especially for complex strata.

4. Checking the correlation results
The complex strata changes fast from sand to clay, and the correlation result using only logging curve has certain error, so, to validate the result is necessary. The most practical and intuitive verification method is to use seismic data. It projects wells and strata correlation result onto seismic section, if the same layers are labelled on the same coaxial axis of the seismic profile, the result is reliable (figure 5). In practical work, all the wells in the research region and correlation result should be projected into seismic section to verify it.

5. Analysing the connectivity of the same layer
The result of strata correlation shows a layer of different wells may be connected. But because of the fault, the pinch out of layers between wells, the same layer may not be connected. It directly affects the development of oilfield, and it may be the main limit factor, for some oilfield, the problem has not been solved better. So, based on the strata correlation result, to analyse the connectivity of a layer is very important, especially for complex oilfield. There are some methods of connectivity analysis, which can be divided into two categories: static and dynamic. Static method includes fault property analysis, lithological matching on both sides of a fault, sand body distribution, reservoir pressure system, oil-gas-water system, dynamic methods includes trace test, water injection effect analysis, etc., for this topic, the author has written an article (refer to 2017 IOP, conference series: Earth and Environmental science, 100.012008), discussing on the methods of determining reservoir layer connectivity.
6. Conclusion

Grasping the issues for complex strata correlation helps us on the geological study on DK oil field, its strata changes frequently. It is difficult to correlate strata to single layer only using the traditional method (circle, marker), because the circle and marker are not efficient for most parts of the strata. The oil-gas-water relationship is indistinct for several decades, and limits the production, oil production rate decrease for 20 years. That shows geological research is very important. Using the new comprehensive method, especially the combination characteristics, the strata of 870 wells was divided and correlated to single layer. Based on the correct strata, which is satisfied to answer why this layer contains oil and that one is water, the reservoir is clear, a correct fundamental result is achieved. It is used in the oil field development, the oil production increases in recent years.

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