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Study on Flow Unit Division Approaches of Continental Reservoir

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Abstract： - This paper defines flow unit as the same reservoir unit owning equal percolation characteristics and argues that flow unit is relative and graded with different scales. After analyzing the basic features of continental reservoir flow units, this paper divides the flow units of pilot site in the East of the Second Region in the North of Daqing Saertu Oil Field, according to the geological factors influencing percolation characteristics.

Keywords： - flow unit, percolation characteristic, reservoir description, reservoir heterogeneity, residual oil

I. INTRODUCTION

Practice in oil and gas field's exploration and development shows that the key of effective exploration and development lies in whether the awareness to oil and gas reservoirs is consistent with objective geology condition. This requires petroleum geology engineers and reservoir engineers to master various parameters and spatial distribution regularities of oil and gas fields as possible as they can, to build a reservoir geological model accurately reflecting reservoir heterogeneity of oil and gas reservoir so as to guide its exploration and development and to improve success rate at exploration stage and recovery efficiency at development stage. Currently, we are still faced with two difficult questions, how to successfully develop new fields and to further tap the potential of old oil fields and enhance oil recovery. Research data shows that only relying on secondary oil recovery, the average recovery ratio is about 35% which still has great potential. It is generally estimated that 20% of the movable oil is due to that the heterogeneity of reservoir hasn't being affected by water injection [1]. This part of movable oil can be completely mined by deepening understand the heterogeneity of reservoir and improving secondary recovery technology. The economic benefit of further improving the recovery of mature oilfields far outweighs that of exploration in remote areas. However, all various adjustment measures taken to improve the recovery must base on the clear master of remaining oil's distribution status.

In order to know the distribution of residual oil, it is necessary to start from specific geological conditions of continental field, to correctly understand the heterogeneity of reservoir and to quantitatively describe and characterize various parameters of reservoir in three-dimensional, namely, to establish a fine three-dimensional geological model [2] accurately reflecting structure, deposition, diagenesis, fluid and other characteristics of the reservoir. During the period of developing the oil field, the task of reservoir description is to correctly describe the development geological characteristics of the reservoir, which is defined as "all geological characteristics the reservoirs own to control and influence the process of oil and gas development so as to affect the develop measures." Flow unit is the key and basic unit concerning the fine description of future reservoir [3]. The research on flow unit provides effective means to understand the heterogeneity of reservoir, being an important development trend and research objectives in future's reservoir description. Therefore,

carrying out research on flow units and finding out the distribution of residual oil have great theoretical and practical significance.

In this paper, the research process is as follows：

1、Purpose and Significance of division of flow unit

2、Concept and basic characteristics of flow unit

3、Flow unit division approaches of continental reservoir and division of flow unit in study area

4、Conclusions and Recommendations

II. CONCEPT AND BASIC CHARACTERISTICS OF FLOW UNIT

2.1 Concept of flow unit

Flow Unit, also known as hydraulic unit, is an emerging reservoir research method in middle and late 1980s. Researchers both as home and abroad, due to different research angles and objects, possess slightly different understanding and research methods to flow cell. Hearn argues that flow unit is a horizontally and vertically continuous reservoir stratum, owning similar lithology characteristics in various parts and parallel petrophysical properties affecting fluid flow [4]; Ebanks considers that flow unit is the rock mass that further broken down based on the change of geological and physical properties affecting the flow of fluid in rock [5]; Amaefule believes that flow unit is the intervals having similar hydraulic characteristics in given rock [6] and he thinks that flow unit is the representative base volume affecting fluid flow's physical properties of reservoir to be constant and can be distinguished from other rock volume in total rock volume of the reservoir; while Jiao Yangquan and Li Sitian believe that flow unit is the building blocks divided by hydrodynamic conditions within deposition system [7,8], which shares similar concepts with structural unit (structural elements); Qiu Yinan considered that flow unit is the fluid flow channel formed naturally and featuring certain degree of oil displacing created through injection water passing geological structure due to a variety of heterogeneity in reservoir, barriers and bypass channeling conditions [9]; Mu Longxin argues that flow unit is, when an oil sand and its inner part are limited by boundary, the reservoir units with similar permeability and water flooding characteristics formed under the influences of discontinuous thin barrier layer, various deposition micro interfaces, minor faults and permeability differences and other factors [3].

It is not difficult to find out from the above definition that flow unit mainly emphasis on reservoir unit, being further subdivision of the reservoir layer. In this reservoir unit, the petrophysical properties effecting fluid flow are the same, or similar percolation characteristics are possessed. Therefore, flow unit can be defined as reservoir unit having parallel flow characteristics.

The definition of flow unit reflects not only the basic features of internal fluid flow of reservoir, but also the changes of petrophysical properties in reservoir. In general, similar percolation characteristics indicate the petrophysical properties effecting fluid flow are the same. Different flow unit reflects different physical properties of rock.

2.2 The basic characteristics of flow unit

Development characteristics and spatial distribution of flow cell are mainly controlled and influenced by the original sedimentary, tectonism and diagenesis or even by various measures taken during oilfield development (for example after water-flooding, physical properties of reservoir will change, etc.) Thus, flow unit is a comprehensive reflection of physical properties of reservoir rock. A reservoir can be divided into a number of flow unit blocks owing different petrophysical properties. Within the same flow cell, the geological factors effecting fluid flow are same with identical hydrodynamic characteristics and percolation characteristics. For water-flooding development oilfield, the same flow unit should have the same flooding characteristics and residual oil distribution regularity; difference flow units exhibit different petrophysical properties featuring

various hydrodynamic characteristics and percolation characteristics as well as diverse flooding situation. Some may be residual oil and some have been washed by water while some are still movable oil.

Flow unit is objectively existed in reservoir. In space, many different characteristics' flow units inset and fold to form a complete reservoir. Boundaries of various flow units should correspond with the location, lithology and petrographic zone of each fault and the type distribution of diagenesis cements. A single sand body can be composed of a flow unit or a couple of flow units.

Due to the heterogeneity of reservoir is graded with different scales [10], flow unit is just the same. However due to the restrictions of exploration and development stage as well as the reasons such as the complexity of research object, the mastery of information and research means, people have limited knowledge about flow unit. At various stages of oilfield exploration and development period or under different research purposes, flow unit can be understood differently. If a study area has less complex geological conditions, under dense well pattern, both static and dynamic data are extremely rich then the awareness level to flow unit is higher. With the increased awareness of reservoir heterogeneity, the understanding of flow unit increases. In this sense, flow unit is a relative concept. For various exploration and development stages, different research purposes or different causative flow cell, the range and research methods of flow unit's definition vary. The division of flow unit is concerned with the current technical level and geological problems need to be solved.

III. DIVISION OF FLOW UNIT IN STUDY AREA

3.1 Flow unit division approaches of continental reservoir

The division of flow units in continental reservoir should be based on the differences of geological characteristics and percolation characteristics in continental reservoir. The difference of percolation characteristics are not only reflected in vertical profile, but also in plane. So that the division of flow unit needs to consider the differences both in vertical and plane percolation characteristics, so as to determine the spatial distribution of flow unit.

The differences in vertical percolation characteristics should be based on faults, fractures, compartment, mezzanine, the rhythm of permeability, bedding structure and the distribution features of pore structure to further subdivide the reservoir. The subdivision level should consider the purpose and need of the research. As for high water-cut stage fine geologic research, it should be divided further for currently divided sublayer in accordance with the distribution features of mezzanine and other signs reflected by well log such as rhythm nature, lithological association and contact relations. If possible, it should conduct further division in accordance with bedding structure and pore structure and the reservoir units after dividing is the division of flow unit in vertical profile.

Differences in plane percolation characteristics should be in line with the closure of faults and the geologic features such as the distribution of sand body and the spread of sedimentary microfacies, based on analysis of reservoir percolation characteristics and flow unit representations, to determine the boundaries of flow unit.

3.2 The division of flow units in study area

The study area is the well patterns test area.In the East of the Second Region in the North of Daqing Saertu Oil Field, located in the north of Daqing Changyuan Saertu structure in Songliao Basin, which is the pilot test area designed for further developing the three encryptions in Daqing Oil Field. With an area of about 0.835km^2, this test area has 89 oil wells after the three encryptions and also a sealed coring wells, and its density of well patterns has reached 90.4 / km^2. The static and dynamic data is abundant in study area, which lays a solid foundation for the carrying-out of elaborate geological research and the division of flow units.

The division of vertical flow units

Due to the relativity and hierarchy of flow units, a oil layer group, a sandstone group or a small layer can be seen as the flow units of different levels. Since the dense well pattern test area in the East of the Second Region in the North of Daqing Saertu Oil Field has large-density well patterns and abundant data and the purpose of study is to investigate the distribution characteristics of remaining oil in high water-cut period, as for the division of flow units in study area, the current small layers should be further divided into smaller segments. Owing to the faults in study area, the extremely rudimentary fractures and shortage of coring wells' data, the division of vertical flow units in study area is based on the analysis of coring wells. According to the distribution characteristics of faults and interlayer, relying on the logging curve to reflect the sedimentary sequence, rhythm nature, lithological association, contact relationships and other signs, we divide the flow units in vertical. The flow unit that has been divided is the independent smallest sand body unit that can be divided and compared, which reflects the continuously changing process of the hydrodynamic conditions in the deposition course.

According to the division methods of flow units, in the S Ⅱoil layer groups, we divide from the current 9 small layers to 18 flow units (Table 1), and in the P Ⅰoil layer groups, we divide from the current 6 small layers to 10 flow units (Table 2). Each flow unit is the final unit after the subdivision of small layers, and it can be compared within the whole region.

TABLE 1 Flow Units Of S Ⅱ Formation

Sublayer	1+2		2+3		4		5+6		7—9		9—11			12	13+14		15+16	
Flow unit	1	2	3^1	3^2	4^1	4^2	5	6	7	8	9	10	11	12	13	14	15	16

TABLE 2 Flow Units Of P Ⅰ Formation

Sublayer	1	2		3		4		5+6		7
Flow unit	1	2^1	2^2	3^1	3^2	4^1	4^2	5	6	7

The division of plane flow units in study area

Since the faults in study area do not develop very well, the division of plane flow units in study area should be based on the distribution of sand body and the characteristics of sedimentary microfacies, and in accordance with the stored coefficients and formation coefficients, the flow units can be further divided into Ⅰ type, Ⅱ type , Ⅲ and Ⅳ type (Fig 1), among which the flow unit of Ⅰtype is best at the seepage capacity and storage capacity, while the flow unit of Ⅳtype is worst at the seepage capacity and storage capacity. According to the data analysis of water flooded layer, the flow units of Ⅲtype and Ⅳtype are the major enrichment part of the remaining oil-rich and are the main target of the encryption and potential tapping. Although the flow units of Ⅰtype and Ⅱtype have been washed, thickness of the water flooded layer is awaiting to be further expanded, so there is still a certain potential to tap.

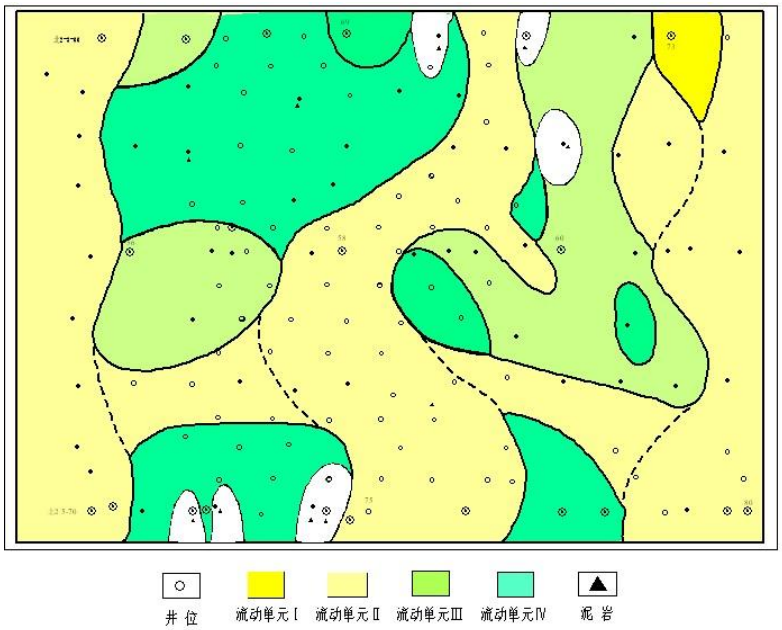

Fig. 1: Classifications distribution of the flow unit in S Ⅱ2

IV. CONCLUSIONS AND RECOMMENDATIONS

The correct knowledge and the reasonable division of reservoir flow units play an important role in correctly understanding the reservoir's heterogeneity and finding out the distribution characteristics of remaining oil. The division of flow units should consider not only the differences of the vertical flow's characteristics, but also the differences of the plane flow's characteristics, so as to determine the spatial distribution of flow units. The flow units reflect the basic characteristics of fluid flows within the reservoir, so carrying out the in-depth research on flow units and improving its theoretical system and research methods have a very important theoretical and practical production significance.

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