Annual of the University of Mining and Geology "St. Ivan Rilski"
vol.45, part I, Geology, Sofia, 2002, pp. 101-103

PHYSICAL ASPECTS OF OIL-RECOVERY IN SELANOVTSI TYPE OIL FIELDS

Vassil Balinov, Efrossima Zaneva-Dobranova

University of Mining and Geology "St. Ivan Rilski", Sofia 1700, Bulgaria, E-mail: geoenergy@mail.mgu.bg

ABSTRACT
The Middle Triassic section in the eastern part of Lom depression (Selanovtsi, Marinovgeran) contains oil accumulations related to a specific type of natural reservoir. It was defined as "Selanovtsi" type. A typical representative is the homonymous Selanovtsi oil field. The general principles which characterize the mechanism and kinetics of oil extraction from fractured media are valid in the conditions of the "Selanovtsi" type oil field. There are a number of specific features arising from the particular geological setting and the characteristics of the stratified system; the model of the host space; the fluid saturation of different types of cavities and their communication; the behavior of bed energy; the expected phase transformations of the hydrocarbon system; the molecular nature of the hard surface, etc. The recovery of oil from the fracture system is controlled by the pressure gradients. The main driving forces in the matrix system are related to capillary phenomena, interbed depressions, the elastic properties of the fluids and the separation of gas from the oil. The possibilities to recover oil from "Selanovtsi" type oil fields are extremely limited and are controlled exclusively by the fracture system. The analysis and conclusions inferred from Selanovtsi field attain a more general significance and may be used for prognostication purposes.

INTRODUCTION

The Middle Triassic section in the eastern part of Lom depression (Selanovtsi, Marinovgeran) contains oil accumulations related to a specific type of natural reservoir. It was defined as "Selanovtsi" type (Balinov et al., 2002) on the basis of characteristic lithogenetic and petrophysical features which determine a considerable capacity and filtration potential of the reservoir (Balinov et al., 2002). Since the hydrocarbon accumulations are of industrial significance, the recovery efficiency of the petroleum resources in the "Selanovtsi" petroleum reservoir is of great practical interest. From this point of view, the physical aspects of the mechanism and the kinetics of the processes, which accompany the exploitation of the oil field, are of essential importance. The prognosis of these processes is based on detailed knowledge of important characteristics related to the particular geological setting and to a number of factors that control the stratified system.

The Selanovtsi oil field is a typical representative of hydrocarbon accumulations related to natural reservoirs of "Selanovtsi" type. It may be assumed that the mechanism of the processes, related to the recovery of oil, will in principle not differ from other fields which were formed in analogous or close geological setting. From this point of view, the analysis and conclusions inferred from Selanovtsi filed attain a more general significance.

SHORT NOTES ON THE SELANOVTSI OIL FIELD

The Selanovtsi oil field is located in the eastern part of Yarlovo-Selanovtsi swell and is related to a horst-brachianticline. The productive horizon is a complex, 20-25 m thick stratified body located in the upper part of Opletnya Formation (Anisian). This body comprises beds, interbeds and lenses of dominantly pelleted, pelleted-biodetrital and locally micritic limestones in complex spatial interrelations. The considerable lithogenetic diversity and specific development of post-depositional processes control the formation of cavities of diverse genesis, morphology and dimensions. They form two relatively autonomous fluid-saturated systems: fracture and matrix system (Balinov et al., 2001).

The fracture system is of general occurrence within the productive horizon. It is formed of micro- and macro-fractures of different generations, orientation (dominantly vertical) and scale (short, medium and long). Commonly, the fractures are complicated by open or partially mineralized irregular extensions. They form the filtration potential of the productive horizon (the permeability grades to several tens of md) but their capacity is relatively low. Their effective (oil-saturated) volume is estimated to be approximately $1{,}6.10^5$ m^3.

The matrix system comprises intergranular, fragmentary, intercrystall, relictic-peletted (moldic), relictic-fragmentary (vagues) cavities (pores and caverns) that link subcapillary pore canals and microfractures (partially or totally mineralized). They show irregular spatial distribution and specific relations to different rock types. Their capacity varies in a wide range ranging to 26% and more. At the same time, the matrix system is characterized by extremely low filtration properties (the permeability is rarely over 0,1 md). This indicates that there are no effective links between the matrix cavities and the filtrating fracture system (Balinov et al., 2001). The matrix forms the basic capacity potential of the productive horizon. Its effective (oil-saturated) volume is approximately $2,05.10^6$ m^3.

The basic properties of the formation oil were estimated on the basis of the initial thermobaric conditions of the field: initial bed pressure – 29,63 Mpa and initial temperature – 95^0C. Under these conditions, the initial gas content (gas factor) is assumed to be 280 m^3/m^3; the saturation pressure – 265 Mpa and the volume oil formation factor – 1,88. Under the same conditions, the molecular weight is 215, the density – 596 kg/m^3, the dynamic viscosity – 0,520 cP, the compressibility factor – $3,3.10^3$ 1/Mpa.

According to molecular nature, the surface of the rocks, which form the productive horizon, is heterogeneous (Yordanov et al., 2001). The rocks with high oil saturation are dominantly hydrophobic and those with low saturation – dominantly hydrophilic. The high oil saturation of the fractures indicates that their walls are highly hydrophobic.

In hydrodynamic respect, the natural reservoir of the oil field is a closed system of relatively small dimensions. This controls its limited energy potential, the possible sources of bed energy and their interrelations in time. From this point of view, two periods of exploitation of the oil field may be conventionally divided: 1) a period of decreasing bed pressure, from the initial value (29,63 MPa) to the saturation pressure (26,5 Mpa); 2) a period of further decreasing bed pressure below the saturation pressure. During the first period, the bed energy is controlled by the elastic properties of the reservoir system. The regime of the oil accumulation is elastic-water drive controlled. During the second period, the gas dissolved in the oil contributes to the energy balance and the regime transforms into mixed.

MECHANISM OF OIL RECOVERY

The modern approach to appraise oil and gas recovery is based on the physical essence of the mechanism and kinetics of the processes which accompany the exploitation of the hydrocarbon accumulations. Their forecast suggests detailed knowledge of the specific features and characteristics of the reservoir systems as well as the role and significance of the diverse factors that control these processes.

These specific features, applied to the conditions of Selanovtsi oil field, are as follows: the model of the hosting space; the fluid saturation of the different types of cavities and their interlinks; the behavior of bed energy; the expected phase transformations of the hydrocarbon system; the characteristic molecular nature of the rock surface, etc. The model of the capacity volume (Balinov et al., 2001) is of decisive importance. According to this model, the productive horizon comprises two incorporated into each other, relatively autonomous and at the same time interacting systems – fracture and matrix system. In principle, the mechanisms of oil recovery from both systems is different and for this reason they will be discussed separately.

MECHANISM OF OIL RECOVERY FROM THE FRACTURE SYSTEM

During the first period of production, when the elastic properties of the bed system (elastic-water drive controlled regime) are the basic energy source, a process of displacement of the oil from the fracture system initiates as a result of the invading water. The limited capacity potential of the fractures creates conditions for a relative active inflow of sub-oil water into the oil accumulation. The process progresses with different intensity in fractures of different size (width). This creates favorable conditions for an dominate displacement into zones of higher filtration properties where macrofractures dominate (wells P-3, P-9, P-10, P-13, P-14). In other parts of the accumulation, where microfractures dominate (P-6, P-11), the rate of motion of the fluid system is lower. In this case, the capillary processes play a negative role due to the small width of the microfractures and their highly hydrophobic walls.

The oil recovery from the watered part of the fracture system, at optimum drainage conditions, is high and probably exceeds 90%. Some time later, depending on the hypsometric position of the well depth with respect to the oil/water contact and the specific features of the fracture system, conditions for water inflow may develop and later – the water content in the production of the wells may increase, including partial or complete watering. Consequently, in the end of the first period of exploitation of the oil field, the productive horizon will be irregularly drained due to the unequal displacement rate of the oil from different in size fractures.

The second period marks the beginning of gas breakout and transformation of the regime of the field into mixed. The gas, initially expanding in free space, is now in discrete state, under the form of gas bubbles. With increasing volume, they displacement part of the oil into the production wells. At the same time the displacement effect of the gas-containing water below the water/oil contact rapidly decreases due to the numerous capillary effects in the oil-gas dispersion system. This negative effect is very strong in microfractures in which the motion may practically stop. After the expansion of the volume of the gas phase, the latter becomes mobile and involves part of the less mobile oil in its dominate displacement motion to the production wells. The displacement effect of the oil-gas mixture from the water below the oil/water contact continues to be small due to the rapid decrease of the mobility of the fluid system under the conditions of three-phase filtration. The combination of unfavorable factors leads to worsening of the production characteristics of the wells, including water cut and as an end effect – to a decrease of oil production from the fracture system.

MECHANISM OF OIL RECOVERY FROM THE MATRIX SYSTEM

This mechanism is in principle different from that described for the fracture system. Due to the low conductivity of the matrix, the latter does not participate independently in the filtration processes but interacts with the fractures. In this interaction, lower rates of the pressure gradient in the matrix should be expected as compared to the fractures and as a result – late separation of gas from the oil in the matrix.

If we take into consideration the specific features of Selanovtsi oil field, it may be assumed that the main forces which provoke or hinder oil recovery from the matrix are: capillary processes; inerformation depressions; elastic properties of the fluids and the rock; separation of gas from the oil.

The processes of capillary displacement may develop after watering of the fluid system at high oil saturation of the matrix and dominantly hydrophilic hard surface. The possibilities to extract oil by capillary way are extremely limited for the following reasons: dominantly hydrophobic properties of the matrix in domains of high oil saturation and its relatively low oil saturation in domains with dominantly hydrophilic properties; different size of the cavities, forming a system of complex morphology in which the capillary displacement is not effective; negative influence of the expanding free gas phase.

The inerformation depressions are a result of higher rates of bed pressure drop down in the conducting fracture system as compared to those in the heavy-permeable matrix. For this reason, an increasing in time depression forms between the two systems. This creates conditions for "outflow" of part of the oil towards the fractures. Relatively better possibilities for this process exist in domains with high oil saturation of the matrix, the permeability of which is relatively higher or in case of the presence of linking local micro fractures. After the beginning of the liberated from saturated oil of gas from the formation oil, the process is hampered or impossible.

With decreasing bed pressure, the elastic energy of the matrix system becomes the main factor. The existing imperforation depression favors the outflow of additional quantities of oil corresponding to the elastic resource. Also in this case, the separation of gas from the oil has a negative influence on its mobility.

In the course of the development of the oil field, the above mentioned moving forces occur simultaneously, with different and variable intensity but as a final result they will not lead to extraction of considerable quantities from the matrix (the oil recovery coefficient hardly could exceed 10%). Due to the low conductivity of the matrix, the gas which separates from the oil hinders the processes of oil extraction to its full stop in the conditions of a three-phase fluid system.

Consequently, the major extractable quantities of oil from Selanovtsi oil filed are contained in the fracture system. The contribution of the matrix system is extremely limited and will come into effect within a considerable period of time during the development of the oil field, including also the period after the full drainage of the fracture system.

CONCLUSIONS

The general principles which characterize the mechanism and kinetics of oil extraction from fractured media are valid in the conditions of the "Selanovtsi" type oil field. However, there are a number of specific features arising from the particular geological setting and the characteristics of the stratified system. The above analysis leads to the following conclusions.

1. The fracture system forms a unified in hydrogeodynamic respect conductive medium of relatively low capacity. The displacement of the oil is a result of the influence of sub oil water and the existing pressure gradients. The behavior of the bed energy and the related phase transformations hinder the full realization of the capacity potential.
2. The matrix system has a high capacity potential which is controlled by the presence of cavities, commonly with large dimensions. Its realization, however, is insignificant due to the low effectivity of the bed energy, the hindered communication between the cavities and the fracture system, and the specific mechanism of oil extraction.
3. The possibilities to extract oil from oil fields of "Selanovtsi" type are extremely limited and are related exclusively to the fracture system. Consequently, taking into account the effective (oil saturated) volume of this system, the volume coefficient of the oil and the possible coefficient of oil recovery, the extractable quantities in the period of effective production will not exceed 50-60 thousand tons which is approximately one third of its effective volume.

REFERENCES

Balinov, V., E. Zaneva-Dobranova, Y. Yordanov, A. Atanassov, P. Mitov. 2001. Reservoir features of biogenic limestones in the Middle Triassic section of Selanovtsi area, Geology and mineral resources, September, 28-32.

Balinov, V., A. Atanassov, E. Zaneva-Dobranova, M. Doncheva, P. Mitov. 2002. Selanovtsi type natural reservoir in the Middle Triassic section of Lom depression. Mining and geology, 3, in press.

Yordanov, Y., V. Balinov, E. Zaneva-Dobranova. 2001. A new approach to divide oil-saturated intervals within carbonate sections (on the example of Selanovtsi area). Geology and mineral resources, September, 47-50.

Recommended for publication by Department of Economic Geology, Faculty of Geology