ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 406, No. 1, pp. 12–14. © Pleiades Publishing, Inc., 2006.
Published in Doklady Akademii Nauk, 2006, Vol. 406, No. 2, pp. 221–224.

GEOLOGY

Intensification of Deep Hydrocarbon Inflow[1]

A. A. Barenbaum, S. N. Zakirov, E. S. Zakirov, I. M. Indrupskii, and A. R. Lukmanov

Presented by Academician A.N. Dmitrievskii April 26, 2005

Received May 6, 2005

DOI: 10.1134/S1028334X06010041

1. Owing to its long history, Russian and world oil and gas production has accumulated a great deal of diverse information about the specifics of fluid flow processes during oil and gas field development. Data on mature fields undergoing the final stage of exploitation are of significant interest.

Several fields in Azerbaijan that have long been developed are characterized by high oil recovery factors [1]. Evidence indicating the presence of deep hydrocarbon inflows is today being published with increasing frequency by various authors [2–6].

2. The corresponding publications compelled authors to draw special attention to the analysis of Shebelinskoe gas-condensate field development indexes (Ukraine) [6, 7]. First, the amount of gas recovered from the field long ago exceeded the initial reserves of 430 bln m^3. But the field continues to undergo exploitation (Fig. 1). Second, the field is developed under the gas drive. This fact simplified the analysis of development indexes and increased the certainty of corresponding estimates and conclusions. In particular, it has been determined that the total amount of additional deep gas inflow throughout the history of the field's development (since 1956) is not less than 80 bln m^3 [7].

In other words, the process of gas reserves compensation is apparent. The analysis reveals a potential for the endless development of the Shebelinskoe gas-condensate field in the case of an annual 2–2.5 bln m^3 gas recovery, because these production rates are compensated by additional deep gas inflows.

3. The problem of the feasible intensification of deep hydrocarbon inflows into deposits becomes natural in this relation. This possibility, as applied to the Shebelinskoe gas-condensate field, is investigated in the present paper by means of an equivalent mathematical model of a "supply channel."

The supply channel is considered to be a weak zone in rocks with a permeability value determined from calculations. Taking the tectonic structure of the field [8] into consideration, the depth of the channel is assumed to equal 5500 m from the bottom of the productive stratum. The cross section of the channel is represented by a square, with side lengths varying from 50 to 600 m. The required value of permeability was determined for each alternative calculation in order to match the calculated and actual dynamics of cumulative gas production for the whole period of Shebelinskoe field development.

The problem was solved numerically using a 3D single-phase formulation. Unsteady gas flow in the channel is described by a corresponding nonlinear parabolic differential equation, with account for gravitation [9]. The assumption of the zero rate of additional flow before the development of the Shebelinskoe field served as an initial condition. This admission allowed us to determine the value of pressure at the lower surface of the supply channel. Further, this value was kept

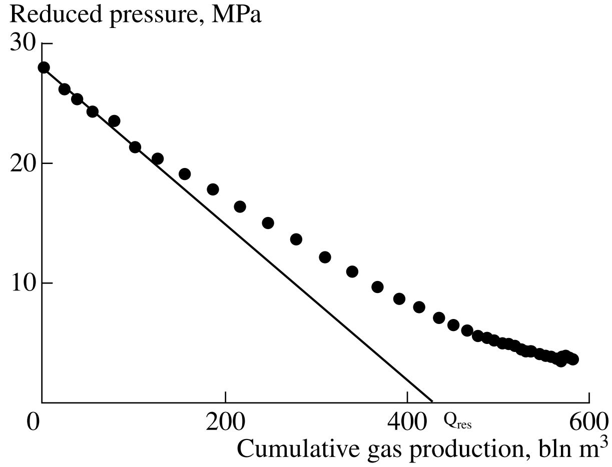

Fig. 1. Reduced average pressure vs. cumulative gas production for the Shebelinskoe field.

*Institute of Oil and Gas Problems,
Russian Academy of Sciences, ul. Gubkina 3, Moscow,
119991 Russia; e-mail: AntonLukmanov@mail.ru*

[1] The article was translated by the authors.

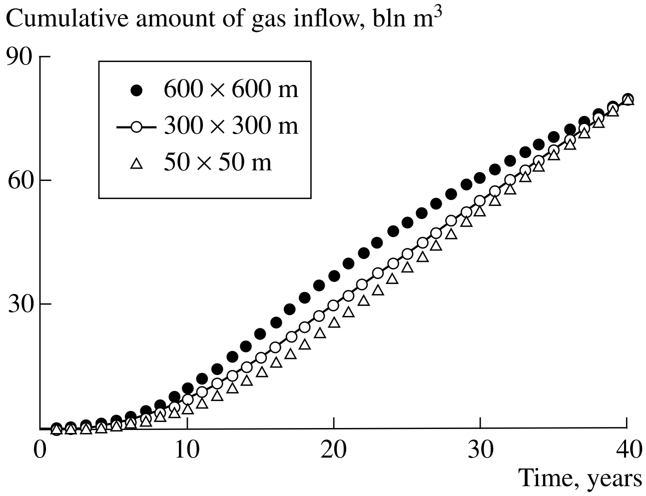

Fig. 2. Dynamics of cumulative gas production for different cross-section sizes of the supply channel.

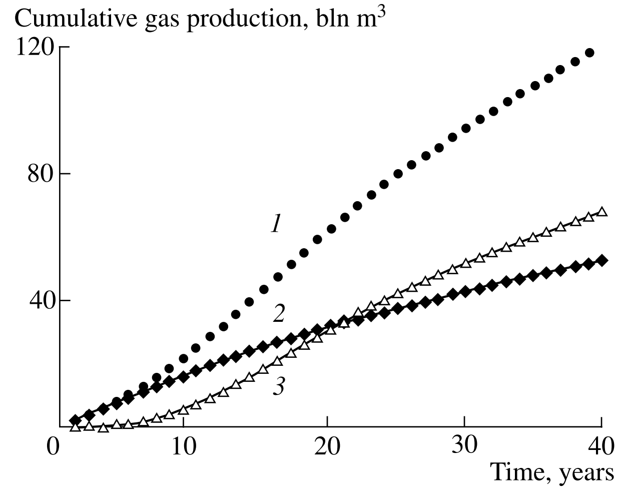

Fig. 3. Effectiveness of drilling the intensifying well with the 600 × 600 m channel size. (*1*) Total cumulative gas production, bln m^3; (*2*) Cumulative well production, bln m^3; (*3*) Cumulative deep gas inflow to the field, bln m^3.

constant as a boundary condition corresponding to the supposition of unlimited resources of gas inflowing to the field.

The boundary condition at the top surface of the supply channel is based on the actual dynamics of average formation pressure in the Shebelinskoe field. This information is known according to the field data.

The iterative reproduction of the history of the Shebelinskoe field's development allowed us to determine an equivalent value of permeability for each version of the supply channel. In particular, for the square with a side of 600 m the permeability was found to be equal to 3 millidarcy. This value provided 80 bln m^3 of total gas inflow.

As an example, Fig. 2 shows the dynamics of the cumulative amount of supplied gas as a function of the supply channel cross-section size and, accordingly, different values of the channel permeability. Differences between the displayed curves over time are explained by different values of initial gas reserves in the channel. Due to a decrease over time of the average pressure in the field, these reserves also begin to participate in the compensation of its resources.

Supply channels with other sizes of the cross section were also examined. For example, the equivalent permeability value is 227 millidarcy for the 10 × 600 m cross-section. The channel with the mentioned parameter values also provided 80 bln m^3 of gas cumulative production at the end of the field development.

4. The created model of the supply channel made it possible to investigate the possibility of hydrocarbon inflow intensification for the field examined. The essence of the approach consists in the "interception" of the upward gas stream at different depths by using drilled wells and thus reducing the channel resistance to the flow of gas.

The following results of calculations are given as an example to justify the mentioned idea. An intensifying well is drilled to a depth of 2750 m from the bottom of the productive stratum, and an interval of about 100 m in the lower part of the borehole is perforated. The well bottom-hole pressure in the calculations was set to 10 Mpa, which is dictated by the necessity of overcoming the hydraulic resistance of the borehole and providing the required characteristics of the field gas gathering facilities. The calculations were performed for the supply channel 600 × 600 m in size on the assumption that well exploitation began at the commencement of the Shebelinskoe field development.

Modeling showed that drawing top parts of the perforation interval near the bottom of the productive stratum intensifies gas recovery from the field. Maximum intensification of the deep gas inflow takes place under the largest possible offset of the perforation interval from the bottom of the productive stratum. In this case, the total volume of gas inflow over 40 years of Shebelinskoe field development amounts to 68.1 bln m^3, and the volume of gas collected from the well amounts to 52.8 bln m^3. Thus, the cumulative volume of collected deep gas equals 120.9 bln m^3. This means that drilling the intensifying well makes it possible to increase the total amount of recovered gas by 40.9 bln m^3.

Similar calculations for the supply channel 10 × 600 m in size show that, due to the formation of the depression cone, 21.2 bln m^3 of gas comes from the field to the perforation interval. Thus, the volume of gas collected by the well equals 256.8 bln m^3. Hence, the cumulative volume of produced deep gas amounts to 235.6 bln m^3, which exceeds the amount of inflow gas collected without drilling the intensifying well by 155.6 bln m^3.

Thus, calculations testify to the feasibility of increasing the cumulative gas production from the She-

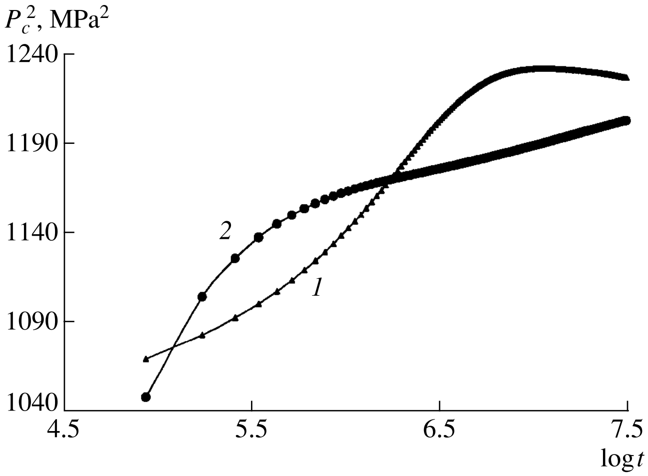

Fig. 4. Pressure buildup curves in semilog coordinates for the supply channels with different cross-section sizes. (*1*) 10 × 600 m; (*2*) 600 × 600 m.

belinskoe field by using intensifying wells. There are obviously many ways to optimize the technological parameters and solutions in the problem considered. Variables to optimize include the depth of intensifying wells, their completion intervals, total number, and type.

5. Significant attention during oil and gas field development is drawn to well testing. The latter makes it possible to determine the parameter values necessary for field development planning. This is why the problem of developing an interpretational theory of measurements in intensifying wells is apparent. The issue arises due to the specificity of the geometric sizes and parameters of supply channels, which are noticeably different from those common to the practice of oil and gas field development. In particular, varying pressure along the supply channel is observed. Also, flow of gas along the channel exists no matter if the well is exploited or not. In other words, we are addressing a new type of underground fluid flows.

The process of the well bottom-hole pressure (P_w) buildup was simulated for the two examined types of supply channels. It is assumed in both cases that the well is exploited with a constant flow rate until it is shut at the bottom hole. The pressure buildup curves are shown in Fig. 4 in semilog coordinates. In the case of homogeneous oil- or gas-bearing formations, pressure buildup curves usually represent straight lines. However, they are characterized by some specific features in the case of intensifying wells. This fact confirms the necessity to develop a corresponding interpretation methodology for well test measurements in supply channels.

It follows from the previous discussion that the issue of increasing the resources of oil and gas fields by deep hydrocarbon inflow intensification is urgent. New theoretical and applied problems must be investigated in this connection. The expediency of such an analysis has been addressed in the present paper.

REFERENCES

1. S. T. Ovnatanov and K.A. Karapetov, *Oil Recovery upon Development of Oil Fields* (Nedra, Moscow, 1970) [in Russian].
2. *Degassing of the Earth: Geodynamics, Geofluids, Oil, and Gas* (Geos, Moscow, 2002) [in Russian].
3. V. A. Trofimov and V.I. Korchagin, Georesources, No. 1 (9), 18 (2002).
4. A. N. Dmitrievskii, B.M. Valyaev, and M.N. Smirnova, in *Mechanisms, Scales, and Rates of Reimbursement of Petroleum Pools in the Course of Their Development: Genesis of Oil and Gas* (Geos, Moscow, 2003), p. 106 [in Russian].
5. R. H. Muslimov, Neft. Khoz-vo, No. 4, 11 (2003).
6. A. A. Barenbaum and S. N. Zakirov, Neft. Khoz-vo, No. 3, 32 (2003).
7. A. A. Barenbaum, V. S. Grigor'ev, S. N. Zakirov, R. M. Kondrat, and A. R. Lukmanov, *New Technologies of Oil and Gas Field Development* (Moscow, 2004) [in Russian].
8. Yu. P. Korotaev, G. A. Zotov, and K. D. Kichiev, *A Procedure for Gas and Gas-Condensate Field Development Planning (with Shebelinskoe Field as Example)* (Nedra, Moscow, 1966) [in Russian].
9. S. N. Zakirov, B. E. Somov, V. Y. Gordon, *et al.*, *Multidimensional and Multicomponent Underground Fluid Flow* (Nedra, Moscow, 1988) [in Russian].