

On the Reason for the Inconsistence of Deposits Geological Models to the Results of their Development

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Abstract:

By combining data from seismic surveys, hydrodynamic studies, and the dynamics of development indicators, a fluid dynamic model of the South Field has been established. Taking into account a substantiated filtration-capacitive and hydrodynamic model of the reservoir SE1/1, which contains the main reserves, allowed us to identify the optimal rate of selection, which helps to achieve a higher oil recovery coefficient and reduce the formation of hard-to-recover reserves in areas with low permeability reservoirs.

Keywords: oil, fracturing, reservoir, reservoir model, development, water flooding, hard-to-recover reserves, South Field.

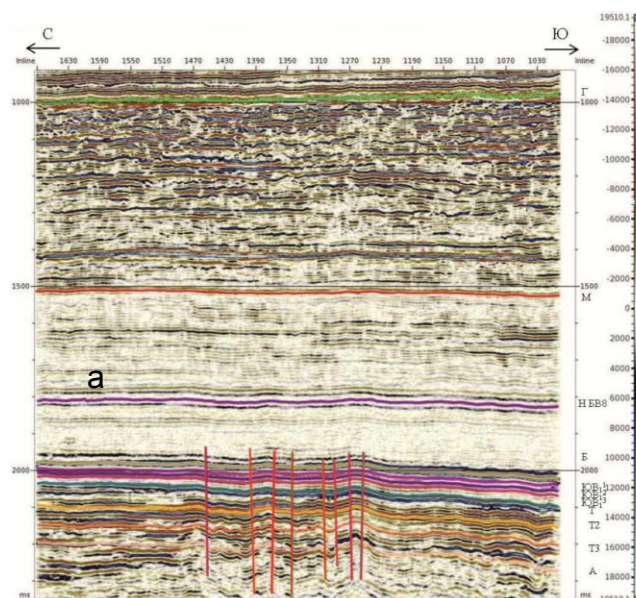
1. Introduction

At present, geological modeling is mainly associated with lithofacial characteristics of productive sediments, which are considered as the main factor in the heterogeneity of natural reservoirs [1]. However, low oil recovery rates and the formation of significant volumes of hard-to-recover reserves indicate that the standard geological models do not match the real, reasonable combination of seismic data, geological exploration studies and the dynamics of development indicators. Let us consider this as an example of the Southern oil field, located in the Nizhnevartovsk administrative district of the Khanty-Mansi Autonomous Okrug-Ugra of the Tyumen Region, 50 km south-west of the city of Nizhnevartovsk.

In tectonic terms, the field is confined to the southern part of the Nizhnevartovsk arch. Oil content was established in sediments BV10 (off-shore part of the complicated subcomplex of Neocomian oil and gas condensate) and SE1/1 (Vasyugan oil and gas condensate). The main object of development is the SE1/1 layer, 96% of the approved reserves of the entire field are concentrated in it [1].

According to the results of the MOGT 3D

seismic survey at the Southern field, the inheritance of the structures formation due to the block structure of the foundation was confirmed. Analysis of the wave pattern of time sections (Fig. 1, 2) indicates a significant number of discontinuous disturbances and complex tectonics of the structure.



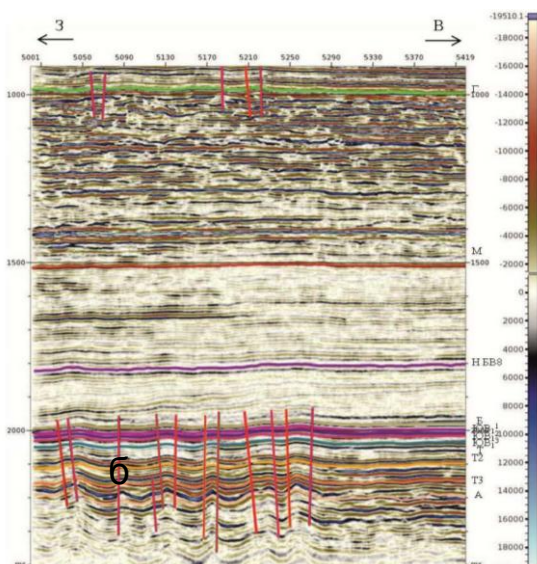


Figure 1. Fragments of temporary sections along the lines N - S (a) and E - W (b) of the South field

On the seismic section, two types of faults are noted: decaying in sediments of the Middle Jurassic and penetrating the Upper Jurassic (Bazhenov Formation). The initial seismic cube made it possible to identify non-amplitude faults and other heterogeneities in the seismic data (Fig. 2), indicating the decompression development.

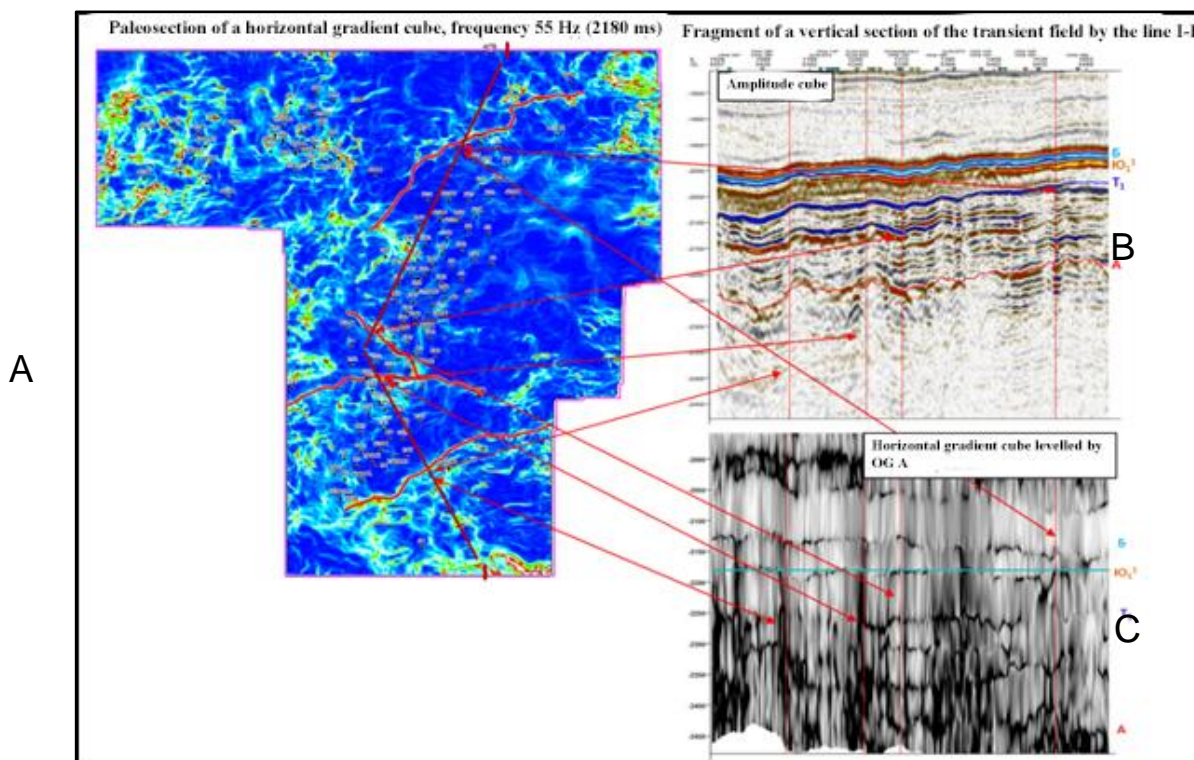


Figure 2. Paleosection of a horizontal gradient cube (a), a fragment of a vertical section of the transient field by the line I-I (b) and horizontal gradient cubes (c)

The presence of decompression sites in productive sediments proves the low core removal (not exceeding 60%), and, as a result, obtaining information on it based on reservoirs with underestimated filtration-capacitive properties (FES). However, the formation of a deep zone of drilling fluid penetration during drilling and low information content of the section geophysical studies are characteristic of fractured reservoirs.

This position confirms the dependence of well production on the distance to the decompression zones (Fig. 3). With distance, the fracture dams and capillary channels are developed that are comparable with the pores, which leads to low flow rates. Therefore, the reservoir capacity determines the tectonic factor [2].

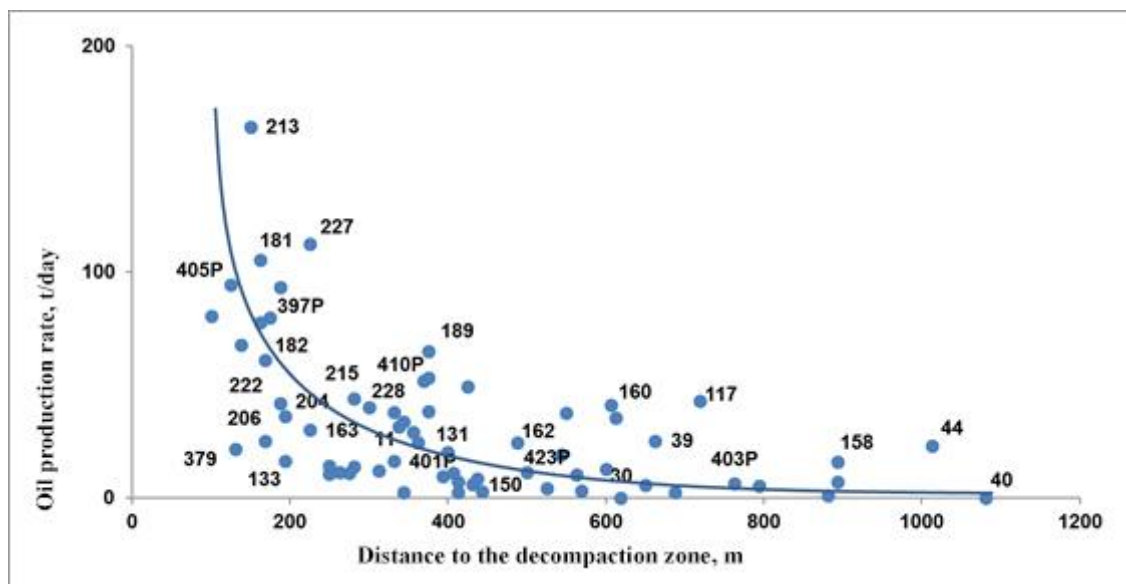


Figure 3. The dependence of oil production in wells on the distance to the decompaction zone

Using the dependence of geological and production parameters on the skin effect and the skin effect on depression (IP Popov's method [3]), it is possible to evaluate reservoir properties from indicator diagrams (ID) - Fig. 4). The convex nature of the curve (well 397) shows that lateral drainage and cracks (T) experience underflow from reservoirs with poorer properties (PT — pore-crack, TP — crack-pore and P — pore). The concave or S-shaped character of the ID (well 405) indicates a decrease in the permeability of the bottom-hole zone (PT collector) and the difficulty of the hydrodynamic connection with the main crack capacity (collector T). For other wells (410, 401 and 413) using the principle of parallelism of the classical ID (well 397), it is also

possible to determine the differentiation of the reservoirs by the reservoir properties. Thus, the presence of exchange processes between cracks and pores makes it possible to distinguish four types of reservoirs, which confirms the ID spectrum (arrow).

Since the T, PT, TP reservoirs are characterized by negative values of the skin effect, they constitute a group of fractured reservoirs whose geological and production parameters depend on depression, and therefore, before stabilization at a low level (p. A), the productivity coefficient is typical of a fractured reservoir, and after p. A - pore (Fig. 5). The geological production model is confirmed by the analysis of the development of the SE1/1 formation (Fig. 6).

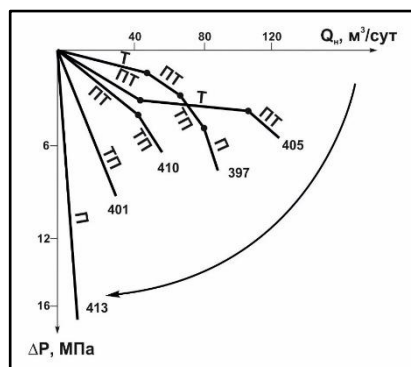


Figure 4. Indicator charts for exploration wells in the South Field

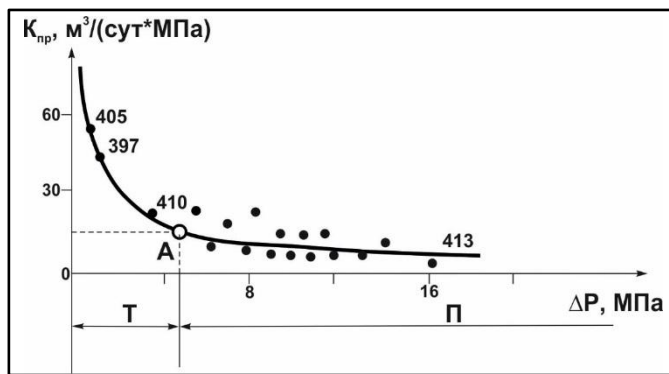


Figure 5. The dependence of the coefficients of productivity from depression in the wells of the South field

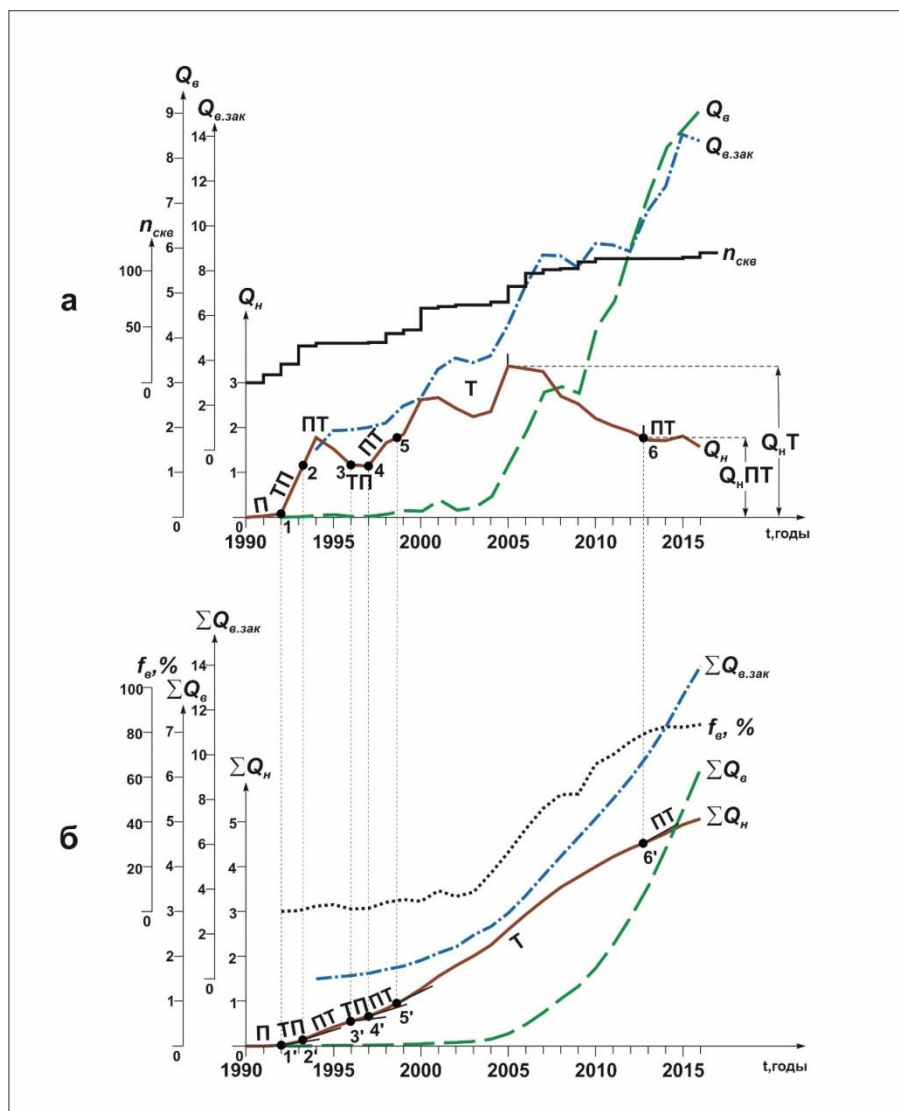


Figure 6. Dynamics of the average (a) and total (b) by years indicators of development of the SE1/1 facility of the South Oil Field:

$Q_o, \Sigma Q_o$ – oil probe; $Q_{pumpw}, \Sigma Q_{pumpw}$ – pumped water; $Q_w, \Sigma Q_w$ – selection of turbid water, all in conv. units; N_{well} – operating well stock; f_w – water cut, %

In the initial period, due to the mudding of the PZP cracks, the production level corresponds to the pore P (the origin is point 1'), fracture-pore TP (points 1'-2' and 3'-4') and pore-fissure PT (points 2' -3' and 4'- 5') to the collectors. After complete cleansing of the cracks (1999, points 5, 5''), the collector is drained as a uniform-non-cracked T and piston displacement of oil by water occurs, which confirms a high increase in water cut to 10% in 2004-2005.

These curves' character ΣQ_o , $\Sigma Q_{pumpw.}$, ΣQ_w proves that the injected water fully controls the highly permeable fractured T-collector and in 2013 the development and flooding of the fractured reservoir is completed, TPH is formed in areas with worse reservoirs. Consequently, the injection of large volumes of water and the creation of a pumping pressure that is significantly higher than the reservoir pressure eliminates oil inflow from the pores, determines the separate production of reservoirs, violates the unity of the hydrodynamic system of deposits and ultimately leads to the formation of hard-to-recover reserves [4].

The analysis of dynamics indicators development indicates that the main recoverable reserves

are contained in the fracture reservoir (T, PT, and TP reservoirs). As follows from fig. 6, the Q_{oPT} sampling rate, at which the unity of the hydrodynamic system is not violated and the selection from cracks, is replenished by replenishment from the pores, approximately two times less than the Q_{nT} level, i.e. $Q_{oPT} \approx 0.5Q_{oT}$, and this corresponds to 2% of the balance sheet reserves. The revealed pattern is characteristic of both oil and gas fields [5]. In this field, the sampling rate during the development of a uniformly fractured reservoir T reached 2.9% (2005, Fig. 6a). When the reservoir is drained at the Q_{nPT} level, the water cut is slowly growing (Fig. 6b), therefore, the balance between oil withdrawal and the volume of injected water is not upset, and a higher oil recovery coefficient is achieved.

Confirmation of the presence of a clogged fractured reservoir in the field during the initial development period is an indicator of the change in piezoconductivity. So, in 1998, the average piezoconductivity of the SE1/1 formation was 0.2 m²/s, and according to research by the method of hydraulic listening in 2003 and 2005. between pairs of wells No. 215-No. 222 and No. 190-No. 169b - above 1 m²/s, a good hydrodynamic relationship was revealed (Table 1).

Table 1

The results of studies of the piezoconductivity of the SE1/1 formation by the method of hydro-listening

Well No		Distance between wells, m	Pressure, atm			Piezo conductivity, m ² /s
Perturbing	Reacting		before	after	ΔP	
215B	222	575	107	105,9	-0,8	1,6
190	1696	1513	48,7	48,6	-0,1	0,8-1,2

The hydrodynamic connection between the wells (lateral), due to the presence of decompression zones and channels of ultrahigh permeability (100 ... 1000 times higher than in the pore reservoir), is confirmed by tracer studies. So, when in-

jecting a urea solution into the input well 327, tracer was discovered in producing wells 75, 235 and 243. The progression speed of the indicator was up to 1977 m/day, water permeability - up to 22.8 D (Table 2).

Table 2
Results of tracer studies of the SE1/1 reservoir

Input Well No	Control well No	Distance from input well	Maximal progression speed of the indicator, m/day	Indicator mass, %	Water permeability, D
327	75	1288	1977	2,8	16,967
	235	870	1336	1,8	22,807
	243	930	1417	4,7	6,405

The tracer flow to the producing wells is uneven. This fact indicates that the tracer agent moves along channels that differ in length, volume and permeability.

The speed of the input water portion labeled with an indicator exceeds the filtration rate of water in the pore reservoir by 2–3 orders of magnitude.

The stated regularities of the fluid dynamic reservoir model are confirmed by the analysis of waterflooding efficiency (Fig. 7). Around the same years (Fig. 7a) as in Fig. 6, production levels correspond to the laws $Q_{nPT} \approx 0.5Q_nT$. Moreover, with drainage of the reservoir as a uniformly fractured T, the production of associated water and the water cut of the deposit rapidly increase after 2005 (see Fig. 6b and 7b).

A straightforward relationship (Fig. 7c) indicates that from the very beginning of development, water enters only into a highly permeable reservoir. Deviation from the established pattern at high selections from 1993 to 2000 indicates the effectiveness of water flooding (collector PT), and in 2006-2011 at low liquid withdrawals (collector T) - to possible inter-reservoir flows or leaving input water into the marginal zone.

From fig. 7d it can be seen that when the collector works as a uniformly fractured T, the waterflooding efficiency index according to the

dependence $Q_{zh} / Q_{pump.w} = f(Q_{pump.w})$ is less than 1, and at the same time, when the collector is drained as a pore-crack FG, it can reach 1,8 (1995-2000). From this we can conclude that high rates are ensured while maintaining a balance between the rate of selection and the volume of injected water.

As practice shows, the main volume of production falls on high-yield wells, the fund of which in the fields does not exceed 10-15%. Therefore, the main recoverable reserves are contained in the fractured reservoir capacity [4]. In this field, 20% of the well stock accounts for more than 60% of all accumulated oil production. It is noteworthy that these wells are located near the destruction zones, which means zones with maximum fracture of the reservoirs (Fig. 3, 4, 5).

Creation of significant depressions or the intensification of production by water flooding violates the unity of the hydrodynamic system of deposits and excludes the feeding of hydrocarbon cracks from reservoirs with the worst reservoir properties (FES), which determines the inefficient separate production of media: first from cracks, and after their flooding from isolated areas with pore reservoirs. This leads to the formation of hard-to-recover reserves, requires additional drilling of wells, growth of unproductive costs.

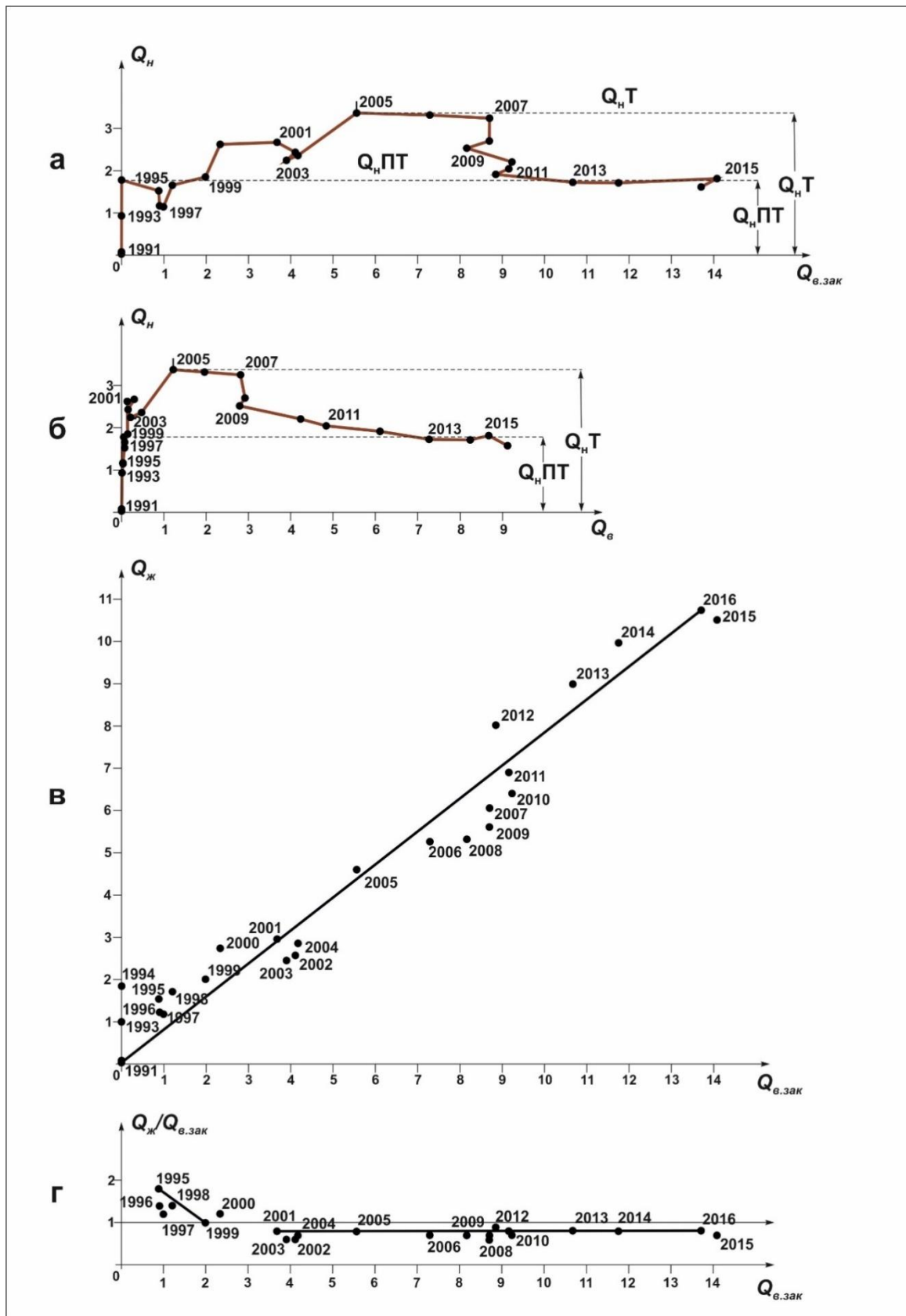


Figure 7. Waterflood efficiency analysis by dependency:

$a - Q_o = f(Q_{pump.w.})$; $b - Q_o = f(Q_c)$; $c - Q_{zh} = f(Q_{pump.w.})$; $d - Q_{zh}/Q_{pump.w.} = f(Q_{pump.w.})$, all in conv. units

The above allows us to draw the following conclusions:

1) The natural reservoirs of the Jurassic deposits are confined to deep faults, zones of rock deconsolidation and contain hydrocarbons in cracks and capillary channels commensurate with pores, which determines the presence of fractured, pore-crack, fracture-pore and pore reservoirs in the productive strata. This is confirmed by MOGT 3D seismic studies, hydrodynamic studies using methods of tracer injection and hydraulic listening, a range of indicator diagrams and differentiation of production wells by production rates.

2) The excess of the permeability of the fracture capacity in comparison with the pore matrix is 2-3 orders of magnitude. The main recoverable reserves are concentrated in the fractured reservoir.

3) Operation of wells at high depressions or increased volumes of injected water disrupt the exchange processes, which leads to the priority production and flooding of the fracture tank and, as a result, the formation of hard-to-recover reserves in areas with pore reservoirs.

4) The rate of annual withdrawals, not exceeding 2% of the balance reserves, ensures the simultaneous production of two environments (cracks and pores), low water cut growth and the achievement of higher oil recovery.

5) The neglect of the reservoir model and the need to drill tightening wells due to the formation of TPH in areas with pore reservoirs, as well as measures to increase oil recovery lead to an increase in the cost of produced oil, which eliminates the use of the fluid dynamic model identified by the authors.

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