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NUMERICAL RESEARCH STRESSED-DEFORMED STATE OF ROCKS IN THE SALT DOME AREAS OF CRUST

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ABSTRACT

The technique of an assessment of zones of possible oil and gas traps is developed. It is quantitatively confirmed that formation of salt diapirs leads to formation of oil and gas traps. Practically they are dated for the areas, adjacent salt diapirs. It is shown that hydrocarbonic tanks are connected with zones of the raised temperature gradients.

Key words: Diapir, oil, gas, traps, salt, dome, pressure, stress, deformation, rocks

1. INTRODUCTION

Search of hydrocarbons is one of complex and actual challenges of geology of oil and gas. Detection of new oil fields and gas in practice is, as a rule, reduced to searches of possible traps (collectors) of hydrocarbons. Still there are no techniques, the equipment and mechanisms which could find unmistakably underground tanks where there are oil or gas fields [1–4]. Geologic-geophysical methods include search structural and the stratigraphic conditions favorable for accumulation of hydrocarbons, and also gravimetric, magneto metric and seismic shooting. Then the allocated sites will be tested for availability of oil and gas by drilling of prospecting wells. It should be noted that the relation of wells which gave though any inflows of oil or gas, to the unsuccessful averages 10%. Besides, by the estimates [2–3], only one of seventy wells drilled for searches of new fields, corresponds to commercially favorable field.

Many world oil fields and gas settle down in areas of salt and dome tectonics [2–5]. Classical example is Caspian Depression which two thirds are located in the territory of Kazakhstan. Therefore in crust geologic-geophysical researches and natural supervision, laboratory and numerical modeling, the analytical researches which review is provided, for example, in [1, 4–9] are devoted to formation of salt and dome structures.

In works [10, 11] possibility of existence of small-scale thermal convection in the top horizons of crust is shown. It has essential impact on distribution and formation of salt diapirs in a sedimentary cover. In [12–14] the technique of an assessment of probable oil and gas traps which, as showed calculations, are dated for zones with raised to thermal gradients is developed. It was confirmed with space monitoring of hydrocarbonic fields of the territory of Kazakhstan [15].

In the real research results of works [10–14] are generalized. Data of numerical modeling stressed-deformed state of a sedimentary complex and a subsalt bed, formation of oil and gas traps are analyzed. For statement simplification authors were limited to two-dimensional model.

2. CALCULATION PROCEDURE

Process of formation of salt diapirs in crust is described by hydrodynamic system of the equations of Stokes of movement of viscous non-uniform incompressible liquid in the field of gravity in approach of Bussinesk. The differential initial and regional task corresponding initial differential is written down in a divergent a view with use of a method of splitting on physical processes and monotonous differential schemes [8, 12, 13]. Realizations, correctness of a differential initial and regional task are given in [8, 13].

Against the initial hydrostatic pressure to which action rocks are subject, process of formation of salt diapirs happens due to change in time stressed-deformed state on of layers of rocks and is accompanied by formation of the raised and lowered zones of concentration of stress and deformations. Stone salt (ship's biscuits) represents rather plastic material.

The sedimentary cover and subsalt bed are the fragile rocks which mechanism of destruction is the fragile cracking, being accompanied a dilatation. Thereof in zones of the increased concentration of stress there is destruction to formation of steam space, excess stress are removed.

Local zones of the lowered stress (oil and gas traps) where hydrocarbons migrate being in layers of rocks are as a result formed. For salt domes oil and gas traps are formed in areas of their wings (over wing and sub wing space), and also in the field of sub dome space of a subsalt bed that was revealed deep drilling.

At calculation on durability of rocks the criterion of durability based on size of a deviator of tangent stress, sufficient for practice [12, 13] was used. At first fields of pressure, speeds and temperature were defined by numerical modeling. Then on them there were fields of stress σ_{11}, σ_{22}, σ_{12} and τ. Zones of the increased concentration of a deviator of tangent tension were allocated and the most probable locations of oil and gas traps [12, 13] were defined.

3. RESULTS OF NUMERICAL MODELLING

In the calculations of density of a sedimentary cover given below and a subsalt bed relied the equal: $\rho_1 = \rho_3 = 2.6$ g/cm^3; ship's biscuit – $\rho_2 = 2.2$ g/cm^3.

In fig. 1 profiles of a salt dome at two various moments of dimensionless time for three-layer model without taking note of temperature with dynamic viscosity of layers are presented: $\mu_1 = 10^{18}$ П, $\mu_2 = 10^{17}$ П, $\mu_3 = 10^{19}$ П. Here isolines of deviator of tangent stress are put. On all borders of settlement area the sticking condition was set.

Rising up, the salt dome rips up overlying oil layers of a sedimentary cover, forming in it zones of the raised deviator of tangent stress in over wing space (fig. 1a). When deviator of tangent stress reach critical value, in these zones there is a fragile destruction and dumping of stress. Dynamic pressure goes down that promotes migration of hydrocarbons, i.e. formation of oil and gas traps.

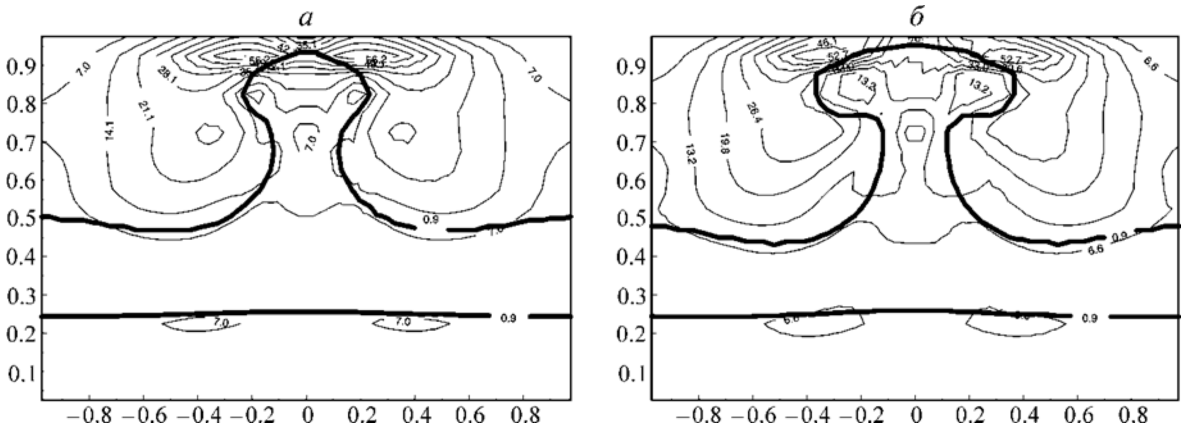

Fig. 1. *Formation of a salt dome in time (three-layer model: a – for t = 0.4; b – for t = 0.6) and distribution of isolines of a deviator of tangent stress*

Over time increase intensity of introduction in overlying layers of a sedimentary cover and the sizes of a dome (fig. 1b). It leads to radial movement of oil and gas traps in areas of over wing space and additional migration of hydrocarbons in them. At the same time in zones of sub wing space intensity of a deviator of tangent stress (see fig. 1a, b) increases that creates conditions for formation of new oil and gas traps. Thus, formation and development of a dome is accompanied by emergence and increase in volume of oil and gas traps in the at dome areas.

In fig. 1a, b the weak curvature of border of a subsalt bed owing to its low intensive current would be visible. In work [8] it is established that nature of movement a ship's biscuit in the three-layer environment strongly differs from two-layer as the sole is linked to the deformed basis which in the course of gravitational instability is involved in movement up on the same channels, as ship's biscuits though density of a subsalt layer is higher than density a ship's biscuit.

Salt dome, moving up, forces out a heavy overlying layer down owing to what under a dome the area of the lowered pressure where the part of an underlying layer flows is formed. It should be noted that when viscosity of a subsalt bed and a sedimentary cover is about 1.5-2.0 orders more than viscosity a ship's biscuit; development of instability will happen as well as in two-layer model, i.e. the subsalt bed isn't deformed. At reduction of a rupture of viscosity of layers the subsalt bed is deformed more considerably, creating prerequisites for formation of collectors of oil and gas of larger, than at dome.

In fig. 2 formation of the main salt diapir and secondary diapirs at various moments of dimensionless time for two-layer model taking into account temperature influence with dynamic viscosity of layers is shown: $\mu_1 = 10^{18}$ П; $\mu_2 = 5 \cdot 10^{17}$ П. Initial distribution of temperature on space was set by linear function of vertical coordinate. On the upper bound zero temperature, on bottom – 250 °C was maintained. In two points of a settlement grid modeling a local source of heat, temperature was set 50 °C above. Initial limit of the section of layers – a straight line. Besides, in fig. 2a, b isotherms, and in fig. 2*в*, *г* – isolines of a deviator of tangent stress are represented.

Calculations showed that value of components of stress for the developed phase is about 2.0-2.5 times more, than for less developed phase. In the top part of over dome space and the dome the stretching horizontal and squeezing vertical stress works. In the lower part of a dome the squeezing stress is formed. The lower central part of a dome is characterized approximately by identical intensity of vertical stress, and the greatest distinction in intensity is characteristic for its peripheral part. The size of tangent stress changes at 1.0-1.5 time that is connected with formation of a vortex zone. It should be noted that distribution of stress in time will be coordinated with the mechanism of formation of a salt dome. The similar picture is observed and in the field of formation of peripheral domes.

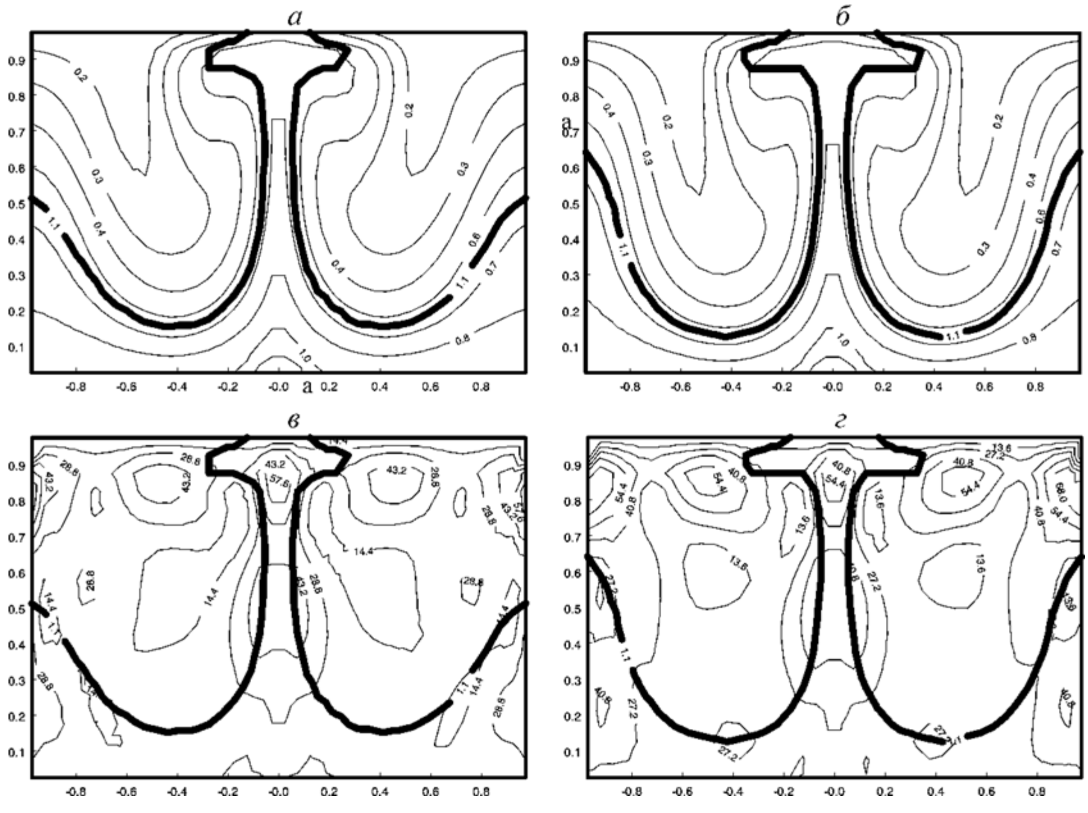

Fig. 2. *Formation of diapirs in time (two-layer model) and distribution of isotherms (a – for t = 0.8; b – for t = 1.0) and isolines of a deviator of tangent stress (в, г)*

By calculations it is established that the developed phase of a salt dome diapir (fig. 2b, d) is characterized by more considerable sizes of a deviator of tangent stress, than less developed. The greatest deviator in size of tangent stress in the developed phase are observed in over wing, sub wing and bottom central parts of a dome. Therefore, probable oil and gas traps can be formed in adjoining wings of domes areas. The assessment of the areas of these areas taking into account porosity of a sedimentary cover gives possible volumes of stocks of hydrocarbons.

Apparently from fig. 2a, isotherms of high temperatures are bent more strongly, than low. This fact can indicate concentration of movement of the environment in areas with an increased temperature. Isotherms from 0.3 to 0.5 fill the area adjacent to wings of a salt dome. Therefore in these areas temperature is increased on 30–90 °C of rather next areas of a sedimentary cover. It is well known that the size of a geothermal gradient is one of the main parameters and signs of generation of minerals [15]. Temperature increase increases the speed of chemical reaction by 10 °C twice in the environments favorable for allocation of hydrocarbonic connections, including oil. In work [15] cards of distributions of a geothermal gradient and a thermal stream in the top part of crust of Kazakhstan are constructed. The analysis of these cards showed that fields of the Western Kazakhstan and the water area of the Aral Sea are located in zones with the raised level of a geothermal gradient. Distribution of isotherms to fig. *2a,b* and distribution of zones of the raised deviator of tangent stress to fig. 2*в,г* quantitatively confirm that hydrocarbonic stocks are attached to areas with the raised temperature gradients.

Calculations showed that local sources of heat have essential impact on formation of diapirs [10, 11]. At the zero reference temperature in a sedimentary cover of an isotherm are bent in the course of formation of diapirs, but remain in a body of domes. It means that process of gravitational instability prevails over thermal effects. Convection simply doesn't manage to develop.

In fig. 3 evolution of formation of a salt diapir in deeply lying sedimentary complexes (at depths of 6-15 km) in case of three-layer model with dynamic viscosity of layers is presented: $\mu_1 = 2.6 \cdot 10^{19}$ П, $\mu_2 = 2.2 \cdot 10^{18}$ П, $\mu_3 = 2.6 \cdot 10^{20}$ П.

Initial distribution of temperature is set by linear function of vertical coordinate. On the upper bound zero temperature, on the bottom –380 °C was maintained.

In three points of a settlement grid modeling a local source of heat, temperature was set 70 °C above than the initial. Fig. 3*a, b* would give an idea about distribution of isotherms, fig. 3*в*, *г* – of distribution of isolines of deviator of tangent stress both in a sedimentary cover, and in a body of a dome and a subsalt bed.

Apparently from fig. 1-3, thermal gradients have essential impact on formation of a subsalt bed, strongly deforming sub dome space (areas of limits of the section of ship's biscuits – sub dome sedimentary breeds).

In a subsalt bed extensive areas in which big deviator on an absolute value of tangent stress work are observed. In the lower central part of a dome at the expense of the dynamic pressure and the increased temperature the considerable suction of a subsalt bed is carried out.

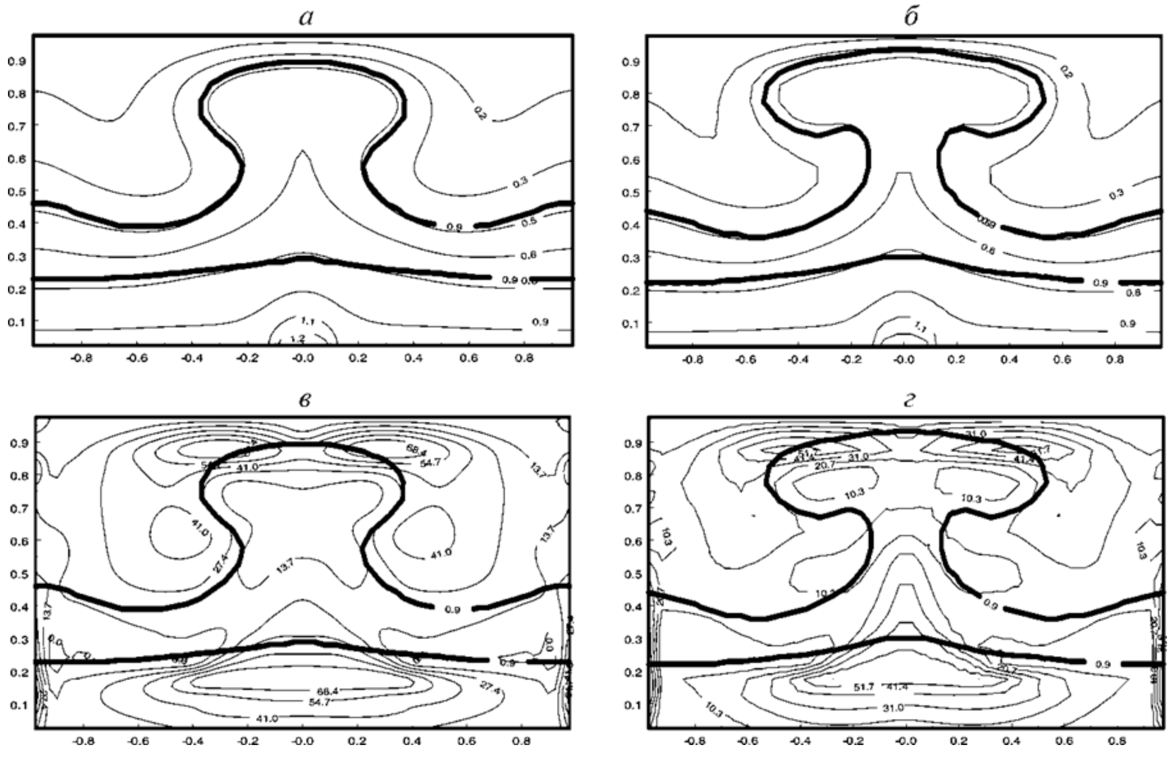

Fig. 3. *Formation of a salt dome in time (three-layer model) and distribution of isotherms and isolines of a deviator of tangent stress*

Therefore if at a subsalt bed there are large reserves of hydrocarbons, owing to a dilatation they will migrate in the central part of sub dome space. The quantitative assessment of these volumes allows defining probable stocks of hydrocarbons.

4. CONCLUSION

Formation of salt diapirs can lead to formation of oil and gas traps in adjacent to salt diapirs areas. Temperature is an important factor of formation of concentration of hydrocarbons both in the at dome and in subdome areas of salt diapirs. Bedding conditions have essential impact on formation of oil and gas traps a ship's biscuit and physical parameters of containing breeds.

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