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Moving factors of regional geodynamics of the Caspian Sea

Les mécanismes en mouvment de la géodynamique régionale de la Mer Caspienne

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ABSTRACT
Methods for description of moving factors in geological environment reflecting natural evolution of geological deformation and moving. With reference to regional tectonics of the north-east section of the Caspian Sea, man-caused influence due to development of a large-scale oil field is shown in a diagram.

RESUME
Les méthodes de la description des mécanismes en mouvment du milieu géologique qui réflètent l'évolution naturelle de la déformation géologique et les mouvements sont décrites dans cet ouvrage. Aussi appliquant pour la téctonique régionale de la Nord-Est partie de la Mer Caspienne l'influence de l'exploitation de gisement pétrolier sur une grande echelle est schématiquement presenté.

1 INTRODUCTION

The Caspian Sea and surrounding area are of great economical interest for not only five countries located near the Caspian Sea (Russia, Kazakhstan, Azerbaijan, Iran, Turkmenistan) but for many other countries of the world. The reason for this interest is unique hydrocarbon resources in this region. This fact is proven by a special session G-20.06 "Geology of Caspian and Aral seas regions" organized during XXXII International Geology Congress IGC-32 on August 20-27, 2004 in Florence (Italy). Mainly, attention was focused on issued of oil and gas content. As to our subject, geodynamics of the region is of particular interest. Geodynamics itself is specific and big problem. Therefore, it can be expounded in some logical reports. Report I below is limited with targets set, approaches outlined for reaching such targets and summary of our own preliminary results.

2 TARGETS

Earth's crust structures are consequence of tectonic process evolution. So called subsurface tectonic maps are sections of geodynamic picture in a particular geologic period. They are developed as a results of interpretation of various geological information. Previous structures, reasons for their formation and modification, main cycles and periods of geodynamic evolution are reconstructed (recreated) on their basis.
The Caspian Sea extends in meridian direction and crosses some latitude-oriented structural elements. These structures appeared as a consequence of interaction among ancient East-Eurasian platform, young Skifsko-Turanskaya platform and Alpine-Himalayan contorted zone. Each of the above tectonic areas includes some subordinate elements (Khain et al. 2004). In particular, new International Tectonic Map of the Caspian Sea and its surroundings (2003) and Geodynamic Map of Caspian and Aral regions developed by Kazakh geologists shall be noted. However, the latter map has not been produced to wide circle of specialists.
In any case as to clearness of description of isodepth of sedimentary cover base and abyssal fractures of the Caspian Sea, we use a map (Fig. 1) included into our publications before (Aitaliev et al. 2002). Taking into account our purposeful interest, we will study the
Kazakh sector of North-East zone of the Caspian Sea separately and on increased scale and specify the largest oil and gas fields in offshore water, i.e. West and East Kashagan (Fig. 2). The main elements are geological fractures in the area studied.
From other sources the geological fractures pass closer to the above fields and in addition to the fields marked in Figure 2, there are fractures of sub-latitude orientation. The target is to forecast behaviour of the geological fractures caused by people's influence in process of oil production in the above fields.

3 METHODS FOR APPROACHING OF THE ABOVE TARGET

Oil withdrawal from a collector having impact on environment causes stress relief. Generally, such stress relief is abnormally high. To ascertain effect of oil withdrawal, we shall know stress status (to put it more precisely, pre-stress condition) in advance. Just stress status determination for geological environment is the main problem.
Z. Yerzhanov, academician, noted (1983) that existing ideas of nature and character of tectonic movements are ambiguous, they are kinematic as they have no moving factors being active forces. Ambiguity of the latter can be demonstrated using the following fact. In addition to idea of formation of present tectonic structure of the Caspian region under influence of East-Eurasian platform, young Skifsko-Turanskaya platform and Alpine-Himalayan contorted zone, there is an opinion that the third moving factor is Mediterranean moving zone. In its turn, these tectonic structures form Central Asian paleo-ocean (Uralsk and Turkestan segments); Kazakh paleo-continent; Gurievskiy, Mugodzharskiy, Ustyurtskiy, North Kazakhstan paleo-microcontinents, etc.

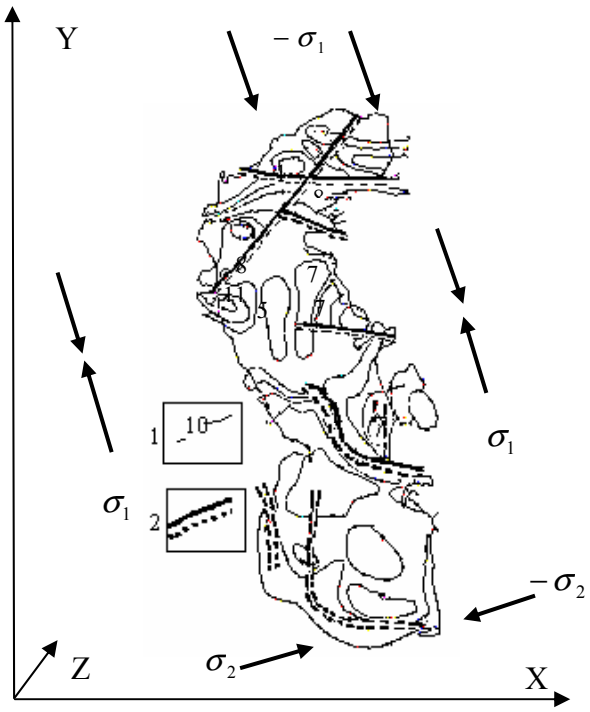

Figure 1. Scheme of Isodepth of Sedimentary Cover Base (Lebedev L.I., 1987)
1–isohypses of sedimentary cover base, km.;
2–abvssal fracture

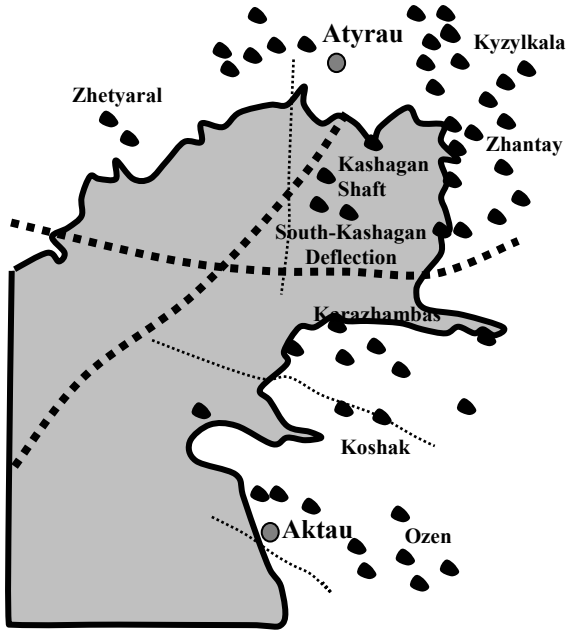

Figure 2. Scheme of location of oil and gas structures of the Kazakh sector of the Caspian Sea and its surroundings.
1– oil, oil and gas, gas and oil fields;
2 – local fractures; 3 – main fracture

Due to indistinct and missing information many plausible ideas can be adduced, there can be attempts to prove their retro-reality pseudologically. The only scientific approach is to substantiate on physical and mechanical basis mechanical models proposed. Taking into account the present development of calculus mathematics, it is not difficult to provide efficiency of their use. At first, it is expedient to develop direct methods, namely, to select such system of effective forces providing the most suitable picture of deformation and geological movements for existing geomorphology by way of approaching quazistatic aims of geodynamics and excluding inertia effects.

4 EXISTING RESULTS

Kazakh geomechanics school started studying of earth folding, conditions for formation of linear, quaquaversal and system folding in seventies last century (Yerzhanov et al. 1972, 1975). Fundamental studies are applied well by the example of Prikaspiyskaya Basin in a field of biaxial tectonic forces, formation of salt domes including properties of region area are demonstrated (Z. Yerzhanov et al. 1996). Conditions for formation of salt-dome structures are studied based on computational modeling and their comparison with geological data (Martynov & Tanirbergenov, 2004).
Computational mathematical modeling was used to study lithosphere mode of deformation in Central Asia (Abidov et al. 2004). Three geodynamic mode were studied: pre-platform, platform and orogenic modes. The studies were made based on flat arrangement with reference to uniform lithospheric plate using a method of boundary integral equations. Using trial-and-error method, optimum compliance of external force and internal stress parameters reflecting the above geodynamic modes. Absolute values of internal stress allow to determine the dislocation extent of geo-structural elements, Level 2. Selection criteria was match of stress tangent density isolines with a half value of tens. str. at the boundary of orogenic and platform areas.
The authors of this Report make two-way investigations (Aitaliev et al. 2003a, b & c), (Aitaliev et al. 2004; Amanniyazov & Aitaliev, 2004). The first direction is more accurate definition of shakability of the Caspian region in view of existing seismic centers on the basis of refined methods including block structure and seismogenity of blocking fractures. Finite element discretization of the area provides passing of element borders through fractures where coupling conditions of fracture banks and seismogenity, if required, are specified. The second direction is to forecast influence of large-scale and intensive oil selection on geological mode of deformation and then on environment of the region. Thus, intensive oil production in Tengiz and Kashagan (zone 53^0 E, $46{,}1^0$ N) decreases horizontal stresses σ_{xx} and σ_{yy} to a value of $\Delta\sigma_r$ significantly. New stress values are $\sigma'_{xx} = \sigma_{xx} - \Delta\sigma_r$, $\sigma'_{yy} = \sigma_{yy} - \Delta\sigma_r$. Here y and x axes go along and across the direction of fractures. The latters mean north and east branches of a cross-shaped fracture in the North-East section of the Caspian Sea (refer to Fig. 2).

Conditions for demonstration of three main geodynamic modes have the following parameters:

Shear mode:

$$\sigma_{zz} < \sigma_{xx} < \sigma_{yy}, \quad 1 < \lambda_x < \lambda_y; \tag{1}$$

Thrust fault mode:

$$\sigma_{xx} < \sigma_{yy} < \sigma_{zz}, \quad \lambda_x < \lambda_y < 1; \tag{2}$$

Relief mode:

$$\sigma_{xx} < \sigma_{zz} < \sigma_{yy}, \quad \lambda_x < 1 << \lambda_y; \tag{3}$$

Variant I

$$\sigma_{xx} < 0, \quad \lambda_x < \lambda_y < 1, \quad \lambda_x < 0; \tag{4}$$

Variant II

$$\sigma_{xx} > 0, \quad \varepsilon_{xx} < 1, \quad \varepsilon_{yy} > 0,$$
$$\lambda_x - \gamma\lambda_y < \nu, \quad \lambda_y - \gamma\lambda_x > \nu; \tag{5}$$
$$(0 < \nu < 0{,}5)$$

where $\lambda_x, \lambda_y -$ coefficient of lateral pressure; ε_{xx}, $\varepsilon_{yy} -$ deformation; $\nu -$ Poisson's ratio.

If new stresses σ'_{xx} and σ'_{yy}, decreased to $\Delta\sigma_r$ are applied and if both stress value become less than σ_{zz}, formulae (2) is used and the shear mode is replaced with the thrust fault mode. If σ'_{xx} is less than σ_{zz}, but σ'_{yy} is more than σ_{zz}, the shear mode is replaced with the relief mode. If $\sigma'_{xx} < 0$ Variant I is applied and if $\sigma'_{xx} > 0$ Variant 2 shall be used.

5 CONCLUSION

The Caspian Sea is the largest oil and gas field at the southern boundary of Eurasia. Active and large-scale development of new fields can break the stable geodynamic conditions. To estimate these processes, mechanical and mathematical base shall be developed to determine the mode of geological deformation for the whole natural evolution period to the present time and in future under people's influence.

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