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Oil and gas extraction and elastic potential of the Earth's bowels

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Despite the significant volumes of dissolved gases in underground waters there is rapid depletion of them due to the oil- and gas development. It results in significant decrease in the proportion of flowing wells caused by reduction of elastic potential of formations and can refer to significant unaccounted artificial degassing. Man-made change in thermal and pressure conditions in the bowels can involve dangerous geo-ecological consequences and therefore requires further study of the physico-chemical properties of geological materials under high PT conditions in order to predict the possible events and protect the geological environment.

Key words: elastic potential of the bowels, natural gas production, the elastic-and-plastic properties, fluid system, the geological environment, geo-ecological state of the bowels

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According to estimation of a number of authors (L. M. Zorkin, V. N. Kortsenstein, B. V. Stadnik and other) the volume of dissolved in stratal waters gases in oil and gas basins of the former USSR make up $4.2 \cdot 10^{15}$ m^3. Relevant data are given in the Table 1.

Table 1. Volumes of dissolved gases in stratal waters of oil and gas structures in the territory of the former USSR [*Zorkin*, 1989]

Geological structure	Volume of dissolved gases, trillions m^3
West European platform	1474.3
Siberian platform	745
East Siberian plate	1000
Scythian and Turanian plates	439
Turanian plate	151
Modern geosynclines and Cenozoic troughs	375.2
Total	4184.5

If to comparison these data with contemporary level of natural gas production (2009) in the CIS these recourses should be sufficient for the given territory for 5 thousand years [*Sokolin*, 2010]. The curves of oil and gas output in RF are similar to the curves of total output in the USSR (CIS) and are illustrated by Fig. 1.

Fig.1. Oil and gas output in Russian Federation.

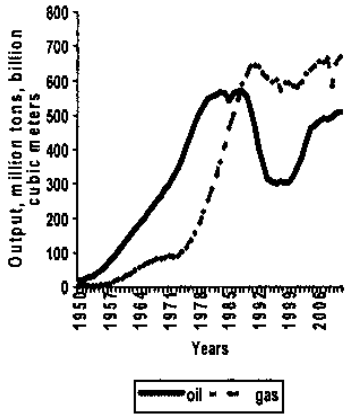
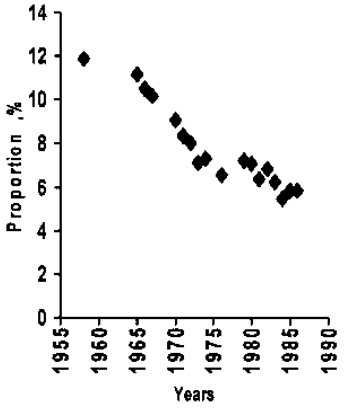


Fig.2. Proportion of flowing wells in the oil industry of the U.S.



There are some correlations between reduction in the elastic potential of the Earth's bowels and the level of oil and gas raw materials extraction. As an indicator showing the compressibility properties of the bowels it is convenient to use the data on change in the share of flowing wells when developing the fields. The data for oil and gas industry of USA are given in the Fig.2.

The global volume of dissolved gases for stratal waters of oil and gas basins of the world according to data of the most authors are varied within the limits of 10^{16}–10^{17}m^3. [*Zorkin*, 1989; *Valyaev, 2011a; b*]. I.e. for modern level of gas output its reserves dissolved in underground waters should be sufficient for approximately 15 thousand years.

However, nevertheless such enormous reserves the elastic potential of bowels in the territory of RF is already exhausted. The essential reduction of the quote of flowing wells, decreasing their flow rates and increasing of oil watering with the time testifies to it. So, for the past half-century the share of flowing wells in RF is reduced almost by an order, similar decrease have occurred in the countries of CIS as well, it means that compressibility potential has lost significantly in these territories, which occupies 15% of the land. Information about these negative changes there is in the works [*Maghidov*, *2011 a, b*]. In the work [*Maghidov*, *2011b*] the data are given that in the USA, one the largest regions of the world, the quote of flowing wells fell below the threshold of 10% back in the 60s of last century, as evidenced by Fig.2. Russia achieved this only in the beginning of the 90s [*Maghidov*, *2011b*].

At the same time over the past half-century the operating well stock has increased in RF more than by factor 8; the average depth of wells has been increased during this period significantly [*Maghidov*, *2011a*]. The quantitative data on growth of the operating oil and gas well stock are shown in Fig. 3.

It should be noted that the total number of wells several times overpasses the operating well stock in RF therefore the summary density of wells is accordingly higher. In the given work only the density of development wells are taking into account.

Similar situation exists in other countries. As the number of wells the density of wells increases in the territory of individual countries and the world as a whole. Summary qualitative data on wells and their density in RF and in the world were given in [*Maghidov*, 2009] as of 1995. Dynamic of the average density change for oil and gas wells in RF is shown in Fig.4.

Fig.3. Operating oil and gas well stock in Russian Federation.

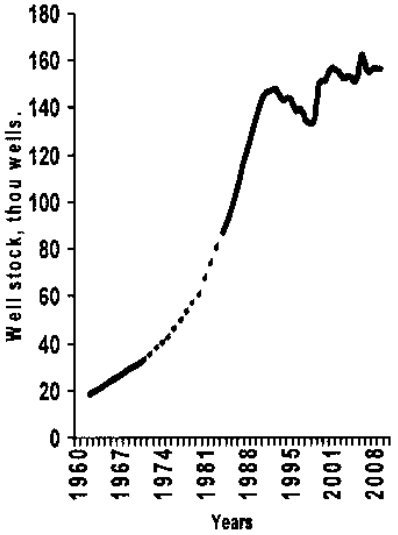
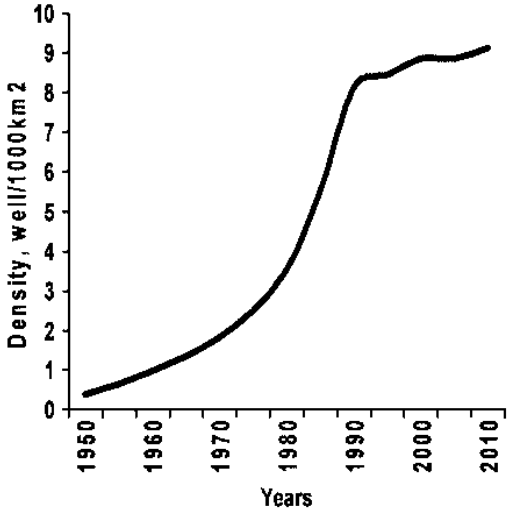


Fig.4. Dynamic of the average density change for oil and gas wells in RF (operating well stock).



Dashed lines – the calculated values

Data on changes in the density of wells represented in Fig.4 indicate significant slowing the rates of the density of wells growth last time in the territory of RF. Accordingly the drop in the proportion of flowing wells decreased in oil and gas industry of RF that illustrated by diagrams in the work [*Maghidov*, *2011b*]. As a whole one can speak about existence of inversely proportional relationship between the density of wells and the share of flowing wells. It means that further increasing the number of wells will contribute in even greater defluidization and thus a more rapid depletion of the compressibility potential. Increasing in the well density and their interference are shown schematically in Fig. 5.

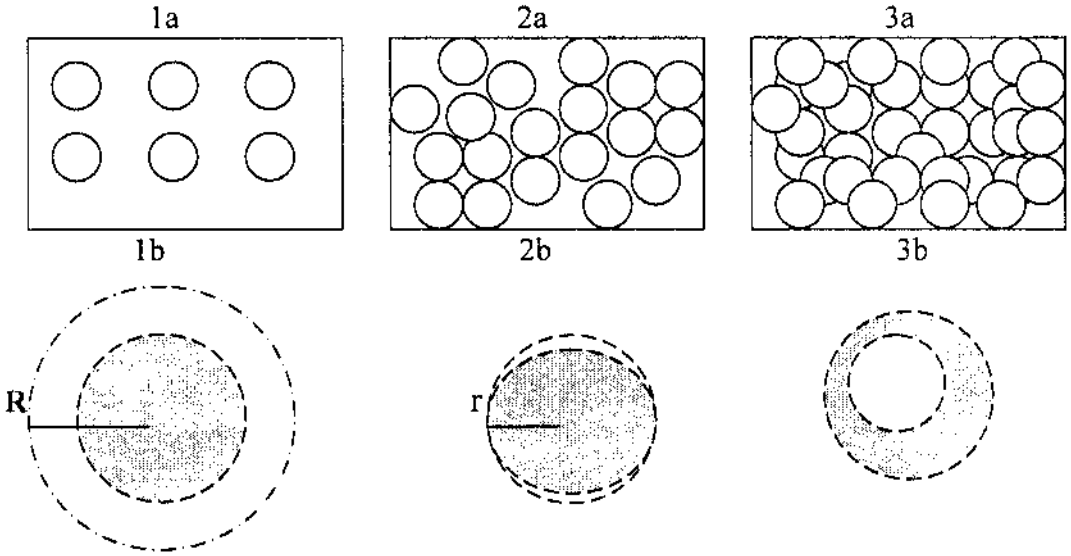


Fig. 5. Schematics of the density of wells spacing in the territory of the region
1. R>r (low density). 2. R=r (critical density). 3. R<r (supercritical density)
R is the average radius corresponding to one well (light area), r – radius of well influence (dark area); **a** is the density of well spacing on the territory; **b** is the zone of influence of an individual well (dark area)

Now we are probably in a situation when the density of wells approaches to position 2 (Fig.5) – the critical area where the average radius corresponding to one well became equal to the average radius of wells influence. The basic difficulty is to determine this average radius of influence. Strictly speaking some influence of an individual well or the system of wells to pay horizon can spread for 10 and more kilometers, the data given in the work [*Maghidov*, 2010] indicates to it.

The given above estimations of reserves of dissolved in stratal waters gases probably have been executed for all Earth's crust; the mentioned discrepancy then can be explained to some extent. Nevertheless, such rapid changes of the elastic potential of fluidal system can speak about significant unrecorded anthropogenic degassing, and inspire great concern over ecolological condition of the subsurface.

Changes caused by violation of the thermobaric field over large areas can impact to the very course of geodynamic processes. Violation of the natural hydrodynamic and hydrochemical regime as a result of oil and gas production entails not only the occurrence of local man-made anomalies, but forms global anomalies in such large regions as RF and USA. It may indicate that the density of wells is close to the critical point (Fig.5) and the very scales of artificial degassing took invalid dimensions.

Half a century ago academician A. P. Vinogradov noted the leading role of processes of the Earth's degassing in forming not only atmosphere and hydrosphere but geological objects in the bowels of the Earth [*Vinogradov*, 1964]. On opinion of some scientists, the degassing scales not only control the biosphere, but also determine the possibility of continuation of life on the Earth.

Today even registered artificial degassing connected with natural gas production already exceeded by an order the natural level of hydrocarbon degassing. According to the data of the author of [*Valyaev, 2011a*] the global scales of underground hydrocarbon degassing are $2 \cdot 10^{14}$ g/year that are significantly below of annually production of natural gas.

Under these conditions the investigations become vital, allowing to make reasonable predictions of behavior of the global geohydrodynamic system when growing rate of anthropogenic impact to natural fluid systems. It relates, first of all, to study of underground compressibility potential depletion. Studies of influence of changes in the thermobaric conditions to geochemical and geodynamical processes are equally important. In broad terms this requires investigation of theoretical and practical aspects of artificial defluidization of the bowels. Much can be calculated, but the targeted wide-scale studies are needed of geological environment behavior under impact of anthropogenic activity. As a reference one it is necessary to carry out experiments to study in situ the patterns of processes of natural changes in geological environment to have possibility to estimate further the consequences of man-made impact.

The above requires in additional wide complex of investigations of physico-chemical properties of geological materials at high *PT*-conditions as well change of elastic and plastic properties of argillaceous formations, especially pellite fraction when interacting with geofluids.

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