**SOUTH CASPIAN BASIN - EXCITEMENT AND MOVEMENT OF SEDIMENTARY MASSES : MECHANISM AND GEOLOGIC CONSEQUENCES.**

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Mud volcanism and diapirism presents one of the interesting and unusual phenomena with periodical eruptions of great amounts of mud, gases (hydrocarbonaceous mainly) and water. Eruption products accumulate near the mouth and create volcano cone. The size of volcano cone depends from the eruptions frequency and the character of hard material as well. The frequent eruptions and big cones of the mud volcanoes are observed in places where the thick plastic rocks are. Together with it the relative height, slope forms and other morphological features of the volcano are determined by the consistency of the erupted breccia.

Morphological peculiarities of the mud volcanoes are clearly observed on the aero-and satellite images. (Fig.1)

The value of the latter ones is especially important for observing the dynamics of the mud volcanoes development. Volumes of hard gaseous products from the depths as well as the sizes of the mud volcanic bodies show the scale of the mud volcanic process. The calculations had shown that the total volume of the mud volcanic breccia flowed from the 220 volcanoes of the SCB western flank is about 100-110 billion.km$^3$. As a result of repeated eruptions the fresh flow of breccia overlap the previous flows and growth the total thickness. The thickness of breccia flows varies from 40 to 100 m. The length of breccia flows having fan- or finger-shaped forms reaches 2-3 km, the width - 200-500m. Hard products form the mud volcanic body. Bigger volcanoes have the body with height 300-400m and base diameter 3-3.5 km.

The mud volcanic eruption is usually accompanied with great column of flame reaching 200-300 m in height and 50 m on the base. The burning flame is usually observed on the distance of 100-150km.

The amount of gases ejected into the atmosphere during the eruption is 2xl07-5xl08 m$^3$. During the quiet period their emanation is 2-3 times lesser. The formation of the mud volcanic constructions takes place not only in the periods of their intensive activity. An intensive flow of mud breccia out the crater is observed even in periods of their long quietness.

The dynamics of development and grandiosity of mud volcanic process in scale of geologic time can be produced by determination of total number of eruptions of separate mud volcanoes. The latter is determined from the correlation of the mud breccia total volume of some mud volcanoes with the volume of the mud breccia ejected during separate eruptions. Thus, for formation of the biggest volcanoes Turagai and Great Kyanizadag it required over 6000 and 7000 eruptions accordingly. The development of lesser volcanoes was accompanied by 550-1200 multiple eruption.

The eruption gases, water and unconsolidated masses are the high potential energy and are distinguished by increased mobility under favorable conditions. It was proposed to call them "excited sedimentary sequences" bearing in mind their geologically and geophysically "aggressive" character with respect to underlying rocks. The most vivid examples of excited geological bodies are mud volcanoes, clayey and sandy diapirs, diatremes, gas hydrates, and so on. The study of these geological bodies as independent objects of dynamic geology is at the early stage. Their role in the formation of the structure of petroleum basins and mineral deposits remains to be unravelled.

**Model of spontaneous excitation - unconsolidated sedimentary systems**
During the phase transitions in the sedimentation basins (liquid - gas, solid body - gas types) dramatic changes occur in the thermodynamic environment, physical properties of rocks and fluids accompanied by strong dynamic effects. We proposed to call this type unstable series "excited systems" (Guliev, 1999). Relatively low-amplitude occurrences

(formation of faults of different genetic origin, effects of local and strong remote earthquakes, impulses of negative pressure etc.) may be triggers to excite the system. They result in considerable change of physical and geochemical properties of the rocks and fluids.

Within the sedimentary complexes one can observe phase transitions of different types. The widest spread is the transition of "liquid-gas" type, which occurs throughout the section of the sedimentary cover. Figure 2 illustrates the different stages on this type process on experimental models.

Another variety of the phase transition of "solid body-gas" type occurs during the decomposition of gas hydrates. Low geothermal gradient in the SCB together with high pressures allow to suppose, that they lower boundary of gas hydrate spread may subside that the relatively deep. Phase transitions of "solid body-liquid" type may occur during the transition of minerals from one modification into another. Accumulation of HC (proceeding from the above) should be considered as consequence of series processes including convective transfer of the matter, emersion of decompacted clayey bodies, phase transitions and linked with the generation, migration and accumulation of HC.

Based on the above theme can make a conclusion that in the SCB, thermal decomposition of the OM will be, most probably, a regional-mosaic nature, i.e. processes of thermal decomposition of the OM will be most intensive near zones of the discharge of HC (close to channels of active mud volcanoes or, so called subvertical zones of heightened instable zones), formed in massive clayey series. In accordance with the above-mentioned, migration and accumulation of HC in reservoirs will be also unbalanced in space and time i.e. the traps, to which extended the channels of HC discharge (so called, subvertical zones of the impulse discharge of matter.

### Model of gravitation instability

One of the possible models of mud, gases and water migration within Paleogene-Miocene rocks of the South Caspian regions can be the Rayleigh-Bonard-type gravitational instability [Guliyev, Kadirov, 1999]. Let us consider the three-layer model describing the deep structure of Alpine rocks in the region. This sequence consists of the following layers (from the bottom to top): the lower layer is composed of terrigenous-carbonate rocks; the middle layer is composed of clayey sediments; and the upper layer consists of sandy-clayey sediments.

An important feature of the middle layer is the high content of dispersed organic matter (OM) that serves as a starting material for the HC generation. Due to the high HC content, clayey rocks remain weakly consolidated and highly plastic even at great depths (5-10 km). In the process of subsidence, these rocks are additionally enriched in HC supplied along fractures from underlying rocks. The existence of unconsolidated and highly plastic zones is confirmed by the universal manifestations of mud volcanism and diapirism. The formation of Paleogene-Miocene rocks in the South Caspian Basin regions can serve as an example of the lower molasse section. The thickness of this section is, on the average, 4-5 km, but it attains 7-8 km in some places. The maximal values are registered in the zones of intense mud-volcanic activity. Based on prospecting drilling data, clays and clayey rocks in central sectors of the South Caspian Basin regions range from 50 to 95%. The viscosity of such layers is evaluated is based on the growth of time value for shale diapirs. Depending on the diapir development period, the viscosity varies from $10^6$ to $10^{12}$ Pa·s. The viscosity of overlying and underlying rocks is higher by 5-6 orders of magnitude. The density of sedimentary layers varies from 2.3-2.6 g $cm^{-3}$ for clays, to 2.5-2.6 g $cm^{-3}$ for sandstones, and 2.6-2.9 g $cm^{-3}$ for limestones. In regional unconsolidation zones, the clayey rock has a lower density (up to 0.2 g $cm^{-3}$). The results of geothermal observations in Azerbaijan indicate that the heat flow varies from 40 to 90 mW m-2 in Alpine rock zones with oil-and gas-bearing basins. The less viscous Paleogene-Miocene sedimentary rocks have the following parameters: the temperature coefficients of volume expansion $\alpha$ = 3 x $10^{-3}$ $K^{-1}$, the temperature conductivity coefficient $\chi$ = 5 x 10-7 $m^2$ $s^{-1}$, and the thermal conductivity coefficient k = 2 W $m^{-1}$ $K^{-1}$.

The thermal conductivity coefficients for sandstones and limestones are equal to 5.17 and 4.40 W $m^{-1}$ $K^{-1}$, respectively. Therefore, the Paleogene-Miocene rocks are thermal insulators and undoubtedly play an important role in the thermal field formation within the overlying layers. The influence of convective motion within the intermediate layer

on the temperature distribution in sedimentary layers of the region South Caspian Basin was determined using the formula []:

$$Ra = \alpha g q d^4 \rho / \chi k \eta$$

where $\rho$ is the density of the intermediate(weakly consolidated) and highly plastic layer. According to the linear theory of stability, if the Rayleigh number exceeds the critical value Rac, the convective motion appears. The critical Rayleigh number for a horizontal layer with the "adherent" boundaries is $Ra_c$ = 1295 . The Rayleigh number evaluations for the Paleogene-Miocene layer with the thickness d = 5 km show that $Ra=10^4$. Since $Ra_c = 10^3$ for the Paleogene-Miocene layer is one order of magnitude less than the characteristic Rayleigh number, the convective motion in the form of two-dimensional rollers must occur in this layer.

The characteristic time of the temperature setting for the liquid layer can be determined by the formula:

$$\tau = d^2 / N \chi$$

where N is the Nusselt number that characterizes the efficiency of convective heat transfer and shows how many times the total heat flow passing through the layer during convection exceeds the conductive heat flow. One may assume that N = 0.263Ra1/ 4, and $\tau$=6,38x$10^5$ years.

For the intermediate (viscous) layer, the time of convection setting is much less than the age of the Paleogene-Miocene sequence. Hence, convection in this layer is stationary. After the setting of convection, the temperature at the boundaries of the Paleogene-Miocene layer also becomes stabilized. The disturbance wavelength characterizing the distance between two close ascending flows at fixed temperatures at the Paleogene-Miocene layer boundary is determined by the formula $\tau$ = 2.016d. If the horizontal dimensions exceed the thickness severalfold, a few convective cells are formed. If the stresses generated by the flow exceed the ultimate strength of overlying rocks severalfold, uplifts can be formed above the ascending flows. The transposition of HC-rich clays will facilitate their migration and accumulation in upper sections of the same sequence. In any case, the transposition of clays due to thermal convection can directly affect the intrastratal HC migration. Probably, the intrastratal HC migration caused by thermal convection was one of the factors governing the formation and activation of mud volcanoes.

Figure 3a illustrates the scheme of the activation of mud volcanoes in the three-layer model of the sedimentary sequence. In the framework of this model, it is presumed that the HC-bearing clay rises from the Paleogene-Miocene layer depth during thermal convection. As the clay ascends, the lithostatic pressure on the rising masses diminishes, and HC is released. If the intrastratal migration leads to the accumulation of sufficient quantities of HC, its activation in the fracture zone of mud volcanoes becomes possible.

A characteristic feature of mud volcanoes consists in their linear distribution and spacing. This fact can be explained by the intrastratal migration model. The dependence of disturbance of wavelength, which characterizes the distance between two close ascending flows on the middle layer thickness, makes it possible to correlate changes in distances between volcanoes to changes in convective layer thickness. The convective cell dimension depends on changes in the middle layer thickness and distances between ascending flows (mud volcanoes). The relationship between the wave-lengths specified in the models is as follws $\lambda_1 > \lambda_2 > \lambda_3$ . (Fig 3b).

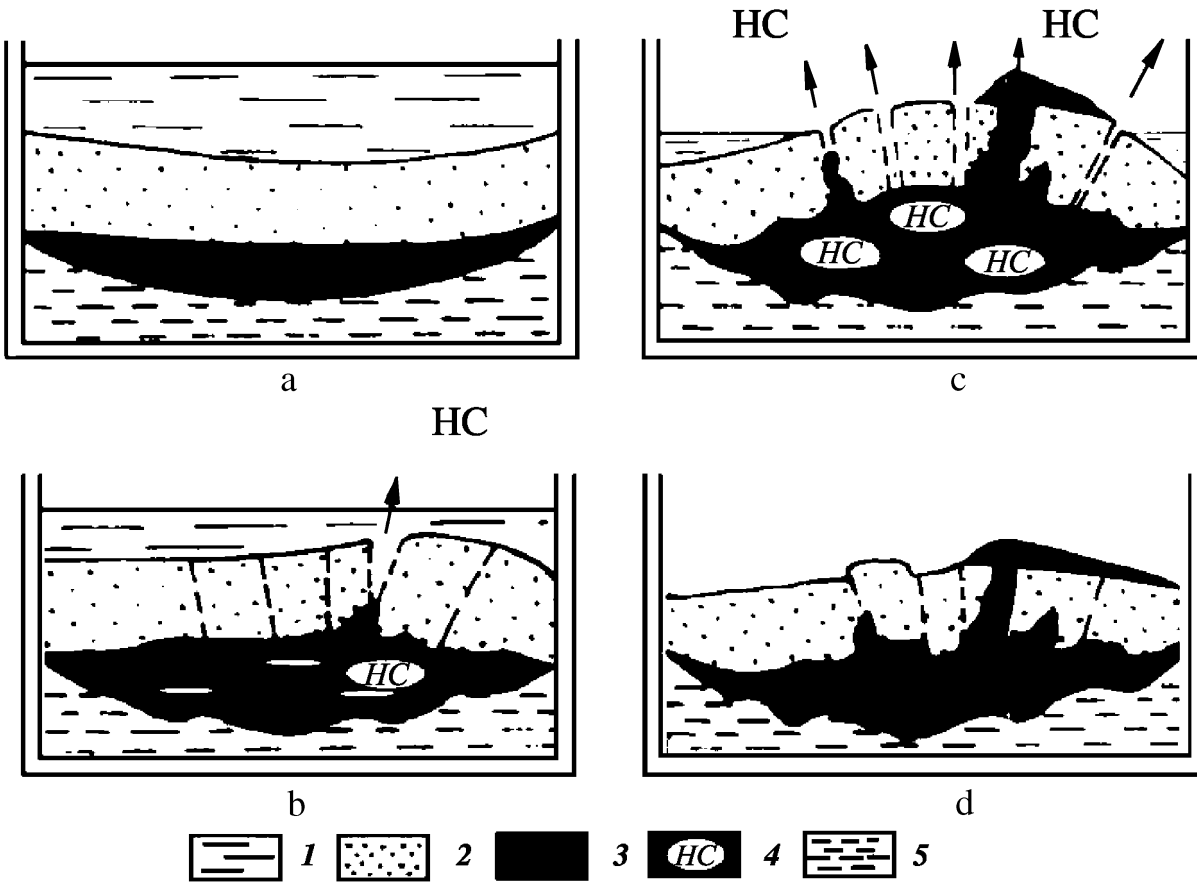**Fig 1** Mud flows on mud volcano Galmaz and Gushchu

**Fig 2** The experimental model of the spontaneous excitation – unconsolidated sedimentary rocks.
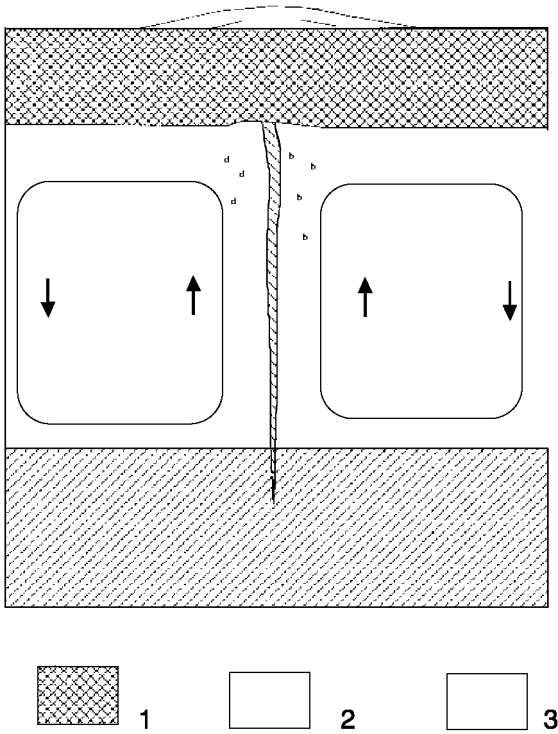1- water , 2- sand carbide , cavity filled with hydrocarbon gases , 5- clay

**Fig 3** a Model of mud volcano activation , (1) Sandy-clayey rocks , (2) plastic clayey rocks , (3) terrigenous-carbonate rocks .
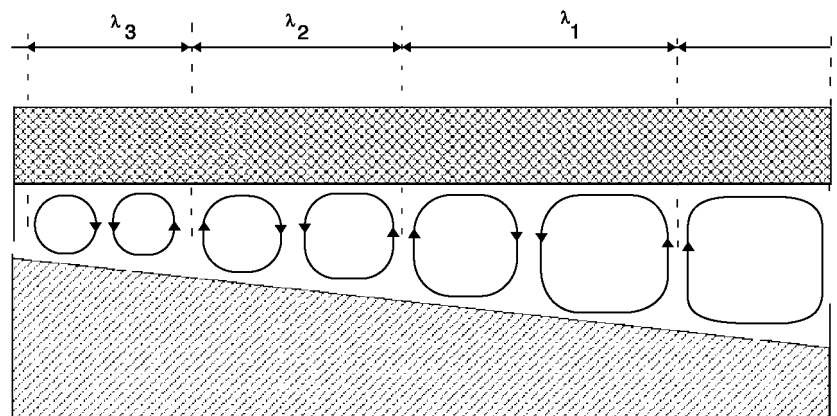


**Fig 3b** Distance between ascending flows vs . convective layer thickness