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Influence of Fracture Zones on the Deformation of the Astrakhan Carbonate massif and on Formation of the Giant Hydrocarbon Deposit

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The authors consider in this work a specific fluid regime forced by collision of the Karpinsky Ridge that resulted in formation of the giant hydrocarbon deposit in the Astrakhan carbonate massif. We propose a new model of giant deposits formation owing to the self-oscillation of fluid migration in the fault-overthrust zone.

Geomechanical models of the fluid dynamics with both one-phase and two-phase fluids in overthrusts and faults, more than 7 km deep, are proposed. Based on the models, we studied conditions and mechanisms of giant gas and gas condensate deposits formation in structures like the Astrakhan Arch carbonate massif. The Astrakhan carbonate massif is characterized by an increase in reservoir capacity of carbonate rocks owing to generation of jointly cavities during faulting.

Self-oscillation processes are developing in faults owing to shifts of fault boundaries. These oscillations squeeze fluids out from faults into overthrusted rocks in which they migrate along weakness zones. Migration of a two-phase fluid in the porous medium takes place between reverse self-oscillations resulting from the gas accumulation in fractured cavities.

Any fluid migration is initially induced by lateral stresses in the crust and lithosphere which result from global geodynamic processes related to the mantle convection. The global processes are further transformed into regional movements in weakness zones.

According to geophysical data, structure of the Astrakhan Arch is characterized by numerous faults. Crustal blocks within the Karpinsky Ridge region are affected by tectonic forces which lead to displacements along the faults and to seismic events. Fluids appearing in the focal zone may cause the so-called trigger effect.

Most filtration models for faults are based on the assumption about hydrocarbons and water filtration through an elastic (or elastic-fragile) skeleton, i.e. on the elastic consolidation model. These phenomena are described by parabolic equation of piezoconductivity. Observed characteristics of the cyclic process (which fail to correspond with this category of models known as the dilatancy-diffusion concept), and analysis of the mathematical model of similar cyclic processes, allow us to suggest that a variation cycle of seismotectonic regime in this region consists of rapid and slow phases. The fluidization phase in a fault is a slow phase of viscous consolidation during which fluids are pressed out from main fissures into smaller ones. The reverse process of fluid pumping into faults is described by the rapid dilatancy phase.

During loading of the fault, there appears a dilatancy effect related to opening of fissures. At this moment, the pore pressure in faults falls, and fluids rush down along the fault strike. Calculations show that a displacement in the dilatancy regime results in such negative pressures within the fault, which create a powerful effect of fluid pumping into the fault both from above and from below. When the pressure in the fault relaxes, fissures become closed (at least partially), and the compaction phase commences. The compaction phase is longer and corresponds to a decrease in porosity. The pore pressure increases up to the level of geostatic pressure during this phase. Fluids rush partially upward through the fault and through feather joints, and partially, penetrate into the nappe body through feather faults at that time. Fissures open under this pressure in fractured weakness zones. Because of this, the fluid outflow is unevenly distributed within the volume taking place only in the weakness zones.