ROLE OF DEEP FLUIDS IN PROCESS OF FORMATION OF HOLLOW SPACE OF COLLECTORS OF DEEP HORIZONS OF THE EAST OF RUSSIAN PLATE

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The deep fluids transform rocks of crystal basement of the East of Russian Plate. As a result, the void space holded by a complex of clay minerals is formed. The paper presents the results of the study of features of the formation of clay minerals microstructures. Exploration of the features of the processes of rocks reformation under the influence of deep fluids let control the path of fluid migration.
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The geological studies by seismic prospecting and deep drilling clearly indicate that the basement of ancient platforms is a mobile, ever-evolving system, in which various destruction processes form specific, near-horizontally bedded zones of destruction. Due to crushing, grinding and alteration by deep fluids these zones have high permeability and porosity [(Sitdikova, 1991; Sitdikova et al., 1997; Sitdikova & Izotov, 1999, 2003)].

The void space in destruction zones of the crystalline basement is formed by various mechanisms. The most characteristic ones for the region under study are:

1. Deformation processes with the formation of fracture systems;
2. Leaching (corrosion) of rock-forming minerals;
3. Recrystallisation with the formation of microaggregates shaping the voids.

Deformation-fluid processes result in the formation of fracture systems that are most characteristic of the compression stage of development of the destruction zones. This process creates conjugated fractures channelling gas-liquid fluids at high rates. The deformation fractures may occur both throughout the rock mass and in some rock-forming minerals. Fragile minerals, such as garnet, pyroxene and quartz, are highly affected by deformation. Process of fracturing in some minerals forms the primary structure of the void space.

The author's research indicates that the intensity of the action of deep fluids that migrate through fracture zones increases with depth, and these produce a stronger effect on the rock-forming minerals [(Sitdikova, 1997)]. The long-term effect of these fluids leads to corrosion and leaching of the rock-forming minerals and to the formation of a new type of the void space – corrosions voids. The most active corrosion and leaching processes take place in the decompression zones. These processes are accompanied by the formation of finely dispersed minerals including the argillaceous ones [(Sitdikova, 1991, 1997, 1999, 2003)]. Corrosion and leaching initially take place in fractured zones of minerals or on their facets, most commonly with the formation of clay mineral assemblages. The newly formed clay mineral assemblages may be subparallel or may form various tubular or acicular assemblages depending on crystallisation conditions.

Various particle models describe microstructural features of clay minerals' microassemblages. Most abundant are the microassemblages in which clay particles and ultramicroassemblages are coupled by basal planes, by basal planes and edges and by edges. These combinations form structural elements of various shapes. The existing models resulted from studying argillaceous rocks. The cellular or honeycomb microstructure was first proposed in 1925. Assemblages of clay particles in this model form closed cells. In 1932, a similar, flocculent-cellular model was described. The house-of-cards model was developed in 1926 and further studied in 1950. The natural existence of the house-of-cards model was proved in 1959. The term "cryptostructure" was proposed for compressed or deformed kaolinite. A clay coating around sand grains within clay rocks was found in 1968 and then in 1970 [(Sokolov, 1986)].

Most of the above-mentioned models were developed by visual observations or optical microscopy. However, they were confirmed experimentally only by raster electron microscopy [(Sokolov, 1986)].

To date, classifications of microstructures and textures of clay mineral assemblages have mainly been developed for sedimentary rocks. Argillisites (low-temperature metasomatic rocks that are mainly composed of clay minerals) of great depths remain virtually unstudied. The author has studied the structure and texture of clay assemblages of the destruction zones to characterise principal models of their distribution and to link these models to the compression and decompression stages of the basement development [(Sitdikova, 1997)]. In the process, both the author's morphological models of clay matter and those described by other researchers were used.

The characteristics of pores and voids in the destruction zones are largely governed by the mechanism of the formation of clay mineral microassemblages. The mutual arrangement of separate packets defines the type of the pore space. The mechanism of formation of microassemblages composed of nano-sized minerals was studied by raster electron microscopy using an XL-30 microscope.

The author has classified the microstructures of clay mineral assemblages, characteristic of the compression and decompression stages of development of the destruction zones, using conventional approaches to the analysis of clay mineral textures [(Sokolov, 1986)].

Microassemblages are the most characteristic structural and informative units of clay matter of the destruction zones penetrated by deep and superdeep Wells. Microassemblages are associations of clay particles and ultramicroassemblages that are not decomposed in water in the absence of physicochemical dispersants or mechanical action. These assemblages are detected in microfractures in the form of fine, partially oriented zones of clay particles or in hollows including pseudomorphoses in rock-forming minerals.

The formation of a specific complex of clay minerals and the assemblages that reflect their formation conditions under directed pressure take place in some abnormal pressure zones of the fractured basement [(Sitdikova & Izotov, 1999)]. This governs the development of microstructures with ordered structures and textures of clay assemblages. The most characteristic, laminar microstructures – directed parallel or subparallel to the maximum mechanical stress in rocks or along sliding planes – are associated with the formation of large packets of clay minerals [(Fig. 1, 2)].

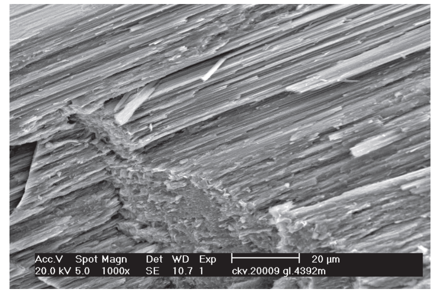

Fig. 1. Laminar microstructures represented by iron-magnesium chlorites. Compression stage. Borehole Novo-Elkhovo-20009, depth 4392.0 m.

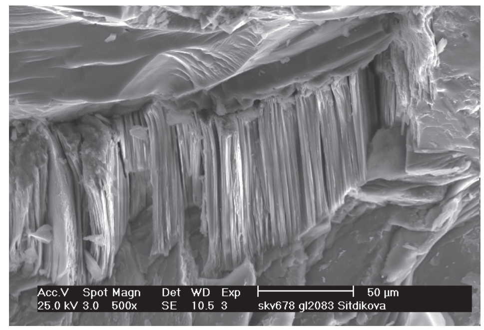

Fig. 2. Laminar microstructures, hydromica packets. Compression stage. Borehole Novo-Elkhovo-20009, depth 4392.0 m. Magnification: 1000.

Particles in such assemblages are arranged in a foliated manner and are coupled by basal planes.

The varying stress directions in rocks cause the formation of turbulent microstructures with curved packets of clay minerals that produce local turbulence and thus appear in the form of a petrified turbulent flow. The clay assemblages are coupled by basal planes or, rarely, by basal planes and edges at low angles with the mechanical bending of the clay packets and their partial twisting.

The mosaic distribution of unequal local stress and the growth of some clay minerals cause the formation of a "house-of-books/cards" structure [(Fig. 3)].

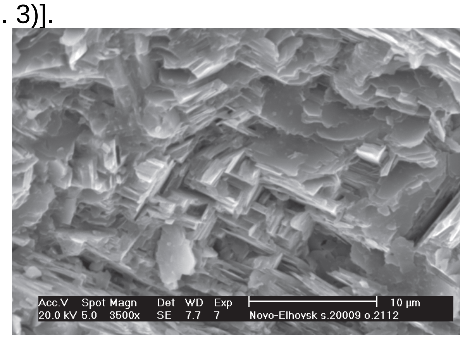

Fig. 3. House-of-books microstructures. Compression stage. Borehole Novo-Elkhovo-20009, depth 4392.0 m. Magnification: 1000.

The nonuniform mechanical alteration of the destruction zones creates porphyroblastic microstructures. The most typical microstructures of this kind are characteristic of kaolinite zones. Research data show that finely dispersed kaolinite with a turbulent texture may contain porphyritic formations of large kaolinite flakes. This type of microstructures is most characteristic of the rocks penetrated by Wells on the depth of 2200-2500 meters.

In the decompression zones, the pressure drop creates an excess of the void space and facilitates the circulation of deep fluids and free growth of minerals. This process is accompanied by the alteration of clay microstructures created in the compression stage. This stage is characterised by the following main structural models: the step-like/house-of-cards [(Fig. 4)] and "a deformed house-of-books/cards". Because of the changing stress tensor in rocks, clay particles are coupled by edges and by basal planes.

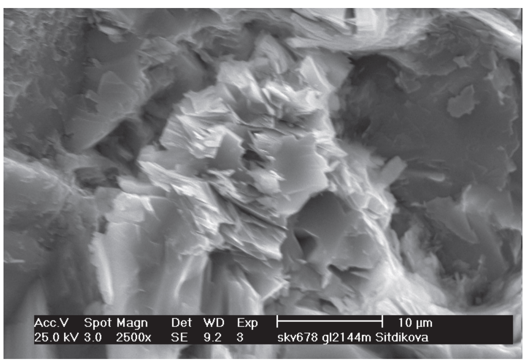

Fig. 4. Step-like/house-of-cards microstructure represented by hydromica packets. Decompression stage. Borehole Tlyanchi-Tamak-678, depth 2144.0 m. Magnification: 2500.

Deeper horizons contain flower-bud/conchoidal microstructures created by decompression, nonuniform deformation and shrinkage of clay packets [(Fig. 5)].

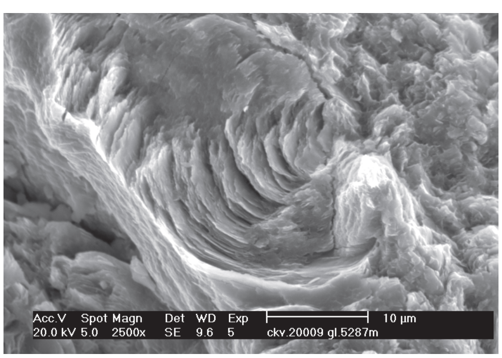

Fig. 5. Flower-bud/conchoidal microstructure of mixed-layer minerals of the mica-smectite type. Decompression stage. Borehole Novo-Elkhovo-20009, depth 5287.0 m. Magnification: 2500.

The clay mineral assemblages are coupled by basal planes. Further unloading of rocks causes the curved packets to straighten, to concentrate around centres of residual stress, to create edge-edge, plane-plane and plane-edge links and to form radial-fibrous, petal microstructures.

It should be noted that the described microstructures are closely associated with the clay mineral composition of the destruction zones. For instance, chlorites are morphologically are less prone to bending deformations and are characterised by large, subparallel flakes. In many cases, kaolinites form domain-like microassemblages, composed of axially directed particles and ultramicroassemblages, or cryptostructures [(Fig. 6)].

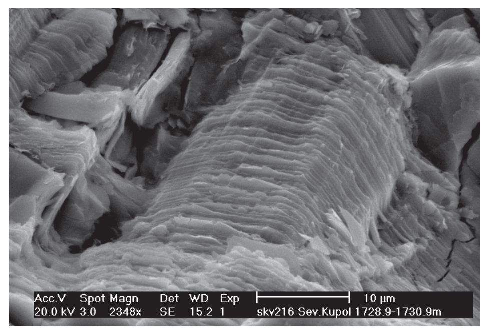

Fig. 6. Cryptostructure – subparallel kaolinite packets in pores and voids in rocks of the decompression stage. Borehole Severnyi Kupol 216, 1728.9-1730.9 m. Magnification: 2348.

Microassemblages of montmorillonite and mixed-layer minerals are thin and lamellar. The microassemblages have vague boundaries between them and are intergrown. Hydromicas in many cases form globular microassemblages with a diameter of several to tens of micrometres.

The obtained data indicate that voids of deep reservoirs in the basement, i.e. destruction zones, are characterised by their specific features and formation mechanism. These data are of practical importance for identifying and characterising the development features of unconventional reservoirs in the crystalline basement of the East of Russian Plate.

Fluids of deep crustal horizons are responsible for the formation of voids in overlying horizons by leaching, corrosion unstable mineral phases of rocks. Deep fluids are non-equilibrium systems with respect to the formed species, they can form specific types of voids on the migration routes. Exploring the features of the processes of reformation of rocks under the influence of deep fluids we can control the path of fluid migration and hydrocarbon accumulation zone of possible systems.

The formation of pores and voids in the destruction zones of the Tatarstan Arch's crystalline basement is associated with various deformation-fluid processes that produce complex fracture systems both in certain minerals and in the whole rock mass. Another important process is the leaching (corrosion) of rock-forming minerals followed by the crystallisation of microassemblages that shape pores and voids in a specific way. The structural features of microassemblages were described using the existing, classic models of the relations between clay mineral particles. The author has also classified the microstructures of clay mineral assemblages, characteristic of the compression and decompression stages of development of the destruction zones. This study has covered the conditions of the formation of microstructures and their role in the formation of pores and voids in unconventional reservoirs at great depths within the destruction zones of the East of Russian Plate.

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