

Post – sedimentation influence on filtration capacity reservoir rock properties (Pur-Tazov oil\gas-bearing area)

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Abstract. The processes of the second mineral formation (kaolinite, carbonates and micas) were identified during the post-sedimentation transformation studies in oil\gas deposits. Besides, quartz regeneration, solid product destructive formation processes and hydrocarbon oxidation processes were -determined. Correlation analysis of the mineralogy and petrophysics data revealed the post-sedimentation influence factors on the reservoir properties of deposits. It should be noted that the second kaolinite composition increase results in water saturation and density decrease, porosity and, especially, permeability increase. Quartz regeneration and second mica formation deteriorate the reservoir properties or poorly influence them. The hydrocarbon decay and oxidation products, as well as secondary carbonate seal the void space, replace the soluble rock debris and sharply deteriorate the reservoir properties of oil and gas deposits.

1. Introduction

Nowadays, oil and gas-bearing forecast provides necessary knowledge on hydrocarbon accumulation mechanisms, concepts of sedimentary rocks formation and transformation, especially organic geochemistry, post-sedimentary reservoir and cap rocks alterations for enhanced oil recovery and deposit identification [1-4]. To understand the processes related to the formation of reservoir properties in hydrocarbon accumulation zones we should determine and specify the geophysical techniques data with the help of mineralogy-petrography and other analyses [5].

The mineralogy-petrographic research results were based on transparent, polished (thin) sections (302), laboratory data of open porosity, permeability, water saturation, rock density identification, as well as X-ray analysis. The research area includes Jurassic-Cretaceous sediments from 8 deep stripped wells (Vankor-11, North-Vankor-1, West-Lodochnaya-1, Ichemmink-1, Yachindinsk-1, North-Tukolandsk-1, Tukolando-Vadinsk-320) drilled in PurtaZov oil and gas-bearing area (N-E Western Siberia). The following suites were stripped: Tanamsk K₂tn, Salpadayakhinsk K₂sl, Nasonovsk K₂ns, Dorozhkovsk K₂dr, Dolgansk K₂dl, Yakovlevsk K₁jak, Malokhetsk K₁mch, Sukhodudinsk K₁sd, Nizhnekhetskaya K₁nch, Yanovstansk J₃-K₁ jan, Sigovsk J₃sg, Tochinsk J₂₋₃tch, Malyshevsk J₂ml, Leontyevsk J₂ln and Vymsk J₂vm.

The Jurassic-Cretaceous sediments are confined to the Northern part of the Western Siberia Platform being subjected to differentiated uplifting [6]. According to V.A. Krinin data the investigated



area is inclined towards the western border of Southern Hudoseysk rift zone, which is characterized as a linear tectonic structure via gravimetric and seismic data [7]. This indicates the fact of existing dislocation processes (permeable zones) within the investigated area and possible abyssal fluid penetration into Jurassic-Cretaceous sediments.

So, these sediments were subjected to the following alterations: diagenetic, katagenetic, metagenetic during sedimentation and evolution in the process of sedimentary basin subsidence (phased epigenesis), as well as dislocation-metasomatic [2] transformations associated to fluid migration and oil and gas-bearing formation processes during the areal inversion development. It is rather difficult to identify the mineral associations of phased and superposed epigenesis because of their property convergence [8].

During diagenesis and katagenesis the rocks were subjected to compaction, unstable feldspar debris disintegrated and underwent argillization. Similar, but more considerable sequence could have been observed during dislocation-metasomatic processes – intensive dissolving of terrigenous components and sandstone cement resulting in secondary void space formation. Besides, carbon dioxide metasomatism stimulates secondary minerals formation: mica, clayey and flinty carbonates and other minerals [2, 9]. As a result, diagenetic and katagenetic intergranular structure is destroyed; intergranular channels are formed in-situ complex contacts. Moreover, under favorable conditions the zones of secondary highly-porous rocks with integrated-void spaces are formed.

2. Results and discussion

To identify the carbon dioxide metasomatism influence on the oil and gas-bearing deposits, the relationships between mineralogical-petrographical and petrophysical parameters have been studied. Based on statistical analysis results in the most common influence relationships of the secondary mineralogenesis and hydrocarbon oxidation product formation on reservoir properties were determined (table 1).

Table 1. Open porosity and permeability mean values (during post-sedimentation).

Secondary processes	Porosity, %	Permeability, $n \cdot 10^{-3}$ MKM^2
Kaolinite formation		
Weak or absent	12.47	9.58
Moderate	15.19	7.96
Intensive	17.83	65.44
Carbonate formation		
Weak or absent	14.58	21.71
Moderate	15.44	17.97
Intensive	16.66	10.92
Quartz regeneration		
Weak or absent	15.74	16.06
Moderate	14.40	20.57
Mica formation		
Weak or absent	15.30	14.89
Moderate	14.88	23.52
Intensive	13.16	–

As a result of the carbon dioxide influence on the rocks, petrogenetic components were evacuated and pores in debris and cement were formed and cement to the extent of complete cement dissolution. Such rocks are considered to be more permeable. These evacuated components redeposit and form compacted cementation zones.

Muscovite and feldspar replacement of kaolinite occur with little evacuation. During stage processes, three-layer clay minerals are formed; high zone of secondary kaolinite is developed close to

carbon dioxide deposits [2]. Either cations or significant silica (which is redeposited in the form of regenerated quartz rims) portions are evacuated during this process.

Statistic data identified that during secondary kaolinite formation porosity and, especially, rock permeability improve (table 1). Usually, cement microporosity is formed (figure 1).

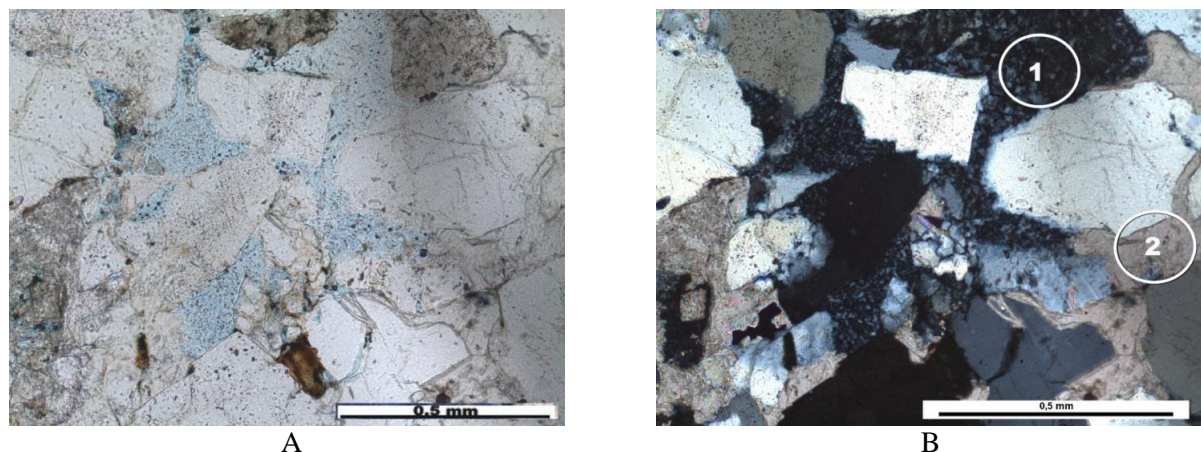


Figure 1. Microporosity in kaolinite cement (1). Secondary carbonate formation (2). North-Tukolandskaya well -1, depth 2525. A – nicols \parallel , B – nicols \times . Lens magnification 10.

Besides, kaolinite is a hydrophobic mineral and has the lowest absorption capacity, i.e., the mineral does not absorb oil in the productive layers, but enhances recovery. During formation testing these kaolinite properties decrease due to the influence of alkaline -based clayey drill mud, which, in its turn results in hydrophobic filming of crystals, sealing of cracks and rock cavities and further recovery constraints; and, eventually, mud filtrate with an oil film. To eliminate this problem relevant drilling technology should be applied, for example, CO₂ injection [1, 10-12].

Table 2 shows the results of statistical data manipulation (coefficient permeability (Kper), water saturation (Sw), rock density and kaolinite content) calculated for Ichemminsk well -1. The following relationships have been identified: amount of secondary kaolinite is directly proportional to rock permeability and, inversely, proportional to water saturation and density of deposits (table 2).

Table 2. Petrophysical properties of clastic sedimentary rocks and newly-formed kaolinite ratio (Ichemminsk well -1).

№	Suites	Rock	Reservoir class	Kper, n 10 ⁻³ mkm ²	Volume density, g/cm ³	Sw, %	Kaolinite, %
1	Yakovlevsk	Sandstone	2	737.1	1.99	13.3	84
2	Yakovlevsk	Sandstone	3	299.6	1.98	19.8	87
3	Yakovlevsk	Sandstones	3	236.07	1.99	20.9	80
4	Yakovlevsk	Sandstones	4	58.71	2.04	26.8	72
5	Yakovlevsk	Sandstones	5	1.78	2.16	41.7	66
6	Nizhnekhetsk	Sandstones	1	1310.8	2.13	14.7	31.5
7	Nizhnekhetsk	Sandstones	2	702.42	2.12	16.1	27.7
8	Nizhnekhetsk	Sandstones	3	228.78	2.14	20.4	33.3
9	Nizhnekhetsk	Sandstones	4	59.45	2.21	25.9	35.7
10	Nizhnekhetsk	Sandstones	3	188.22	2.13	19.5	42
11	Nizhnekhetsk	Sandstones	4	39	2.18	34.4	26.7
12	Nizhnekhetsk	Sandstones	5	3.44	2.2	47.1	38
13	Nizhnekhetsk	Sandstones	No	0.13	2.53	89.7	33

Secondary carbonate (one of the end products of carbon dioxide metasomatism) formation influences clastic rocks, the occurrence of which depends on the pressure gradient decrease and environment pH increase up to slightly alkaline (~8 and higher) conditions. Compacted zones of secondary carbonate might be formed in terrigenous rocks under conditions of repeated reactions. In broader terms, carbonate formation sharply decrease reservoir properties, rock permeability, in particular (table 1).

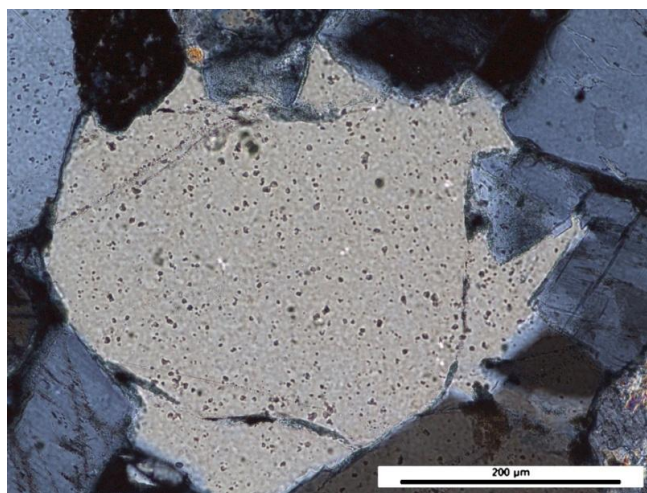


Figure 2. Quartz regeneration. West-Lodochnaya-1 well. Depth 3350. Nicols \times . Lens magnification 20.

Besides the two above-mentioned evacuation zone (kaolinite formation) and substance deposit zones (carbonate formation), there is an intermediate zone of quartz regeneration, as well as insignificant secondary kaolinite formation, excluding carbonates.

Quartz is the most stable to disintegration and mineral dissolution of all sedimentary rocks. Experimentally, quartz regeneration is related to structure dissolution under pressure. Thus, at pH=9.88 (according to Kashik data, 1965) [13]) silica becomes mobile. If there are aggressive compounds (K_2CO_3 and Na_2CO_3), and in the case of pressure increase, quartz can be dissolved even in conditions with lower pH (close to 8-9).

During dissolution and corrosion, wavy debris rims could be observed in quartz. As a result, there is a considerable amount of silica acid in the migrating solution, redepositing as regenerated growth rims on quartz debris (figure2). Due to granulometric properties increase of quartz grains, void space intake occurs, i.e. reservoir properties deteriorate.

Observed rims often reflect debris defects and differ from those of initial quartz grains in purity. As a result of epigenetic rock alterations, a band- zone was identified between the growth rim and quartz debris nucleus as microscopic foreign inclusions of ore-forming environment.

Intensive silica dissolution and its migration into adjacent layers could result in the formation of flinty interlayers and lenses which, in its turn, decrease reservoir properties (table1).

Intensive muscovite and biotite mica (from hydromica) formation could be observed in samples with increased shaliness. According to statistic data, reservoir rock properties are insignificantly decreased during these processes (table 1).

In the studied oil and gas-bearing deposits solid products of oxidation and degradation in hydrocarbons could be found in cracks, intergranular spaces and along argillized feldspars, the amount of which is almost 15-20% in terrigenous deposits.

Statistical data manipulation identified that hydrocarbon oxidized products formed in the systems defined by B.A. Lebedev classification “H-H”, “R-H” (rock hydrocarbon), “W-H” (water

hydrocarbon) [2] deteriorate the reservoir properties filling the pore space and preventing further migration.

Besides rock chemical alterations, dislocation processes are observed. It is rather difficult to evaluate their ambiguous influence on secondary void space formation. Gaseous-interstitial fluids via brittle deformations as migration channels could either provide secondary integrated void space or seal permeable zones by hydrocarbon solid products of oxidation (bitumen) and newly-formed minerals (carbonates, quartz, mica, etc.), resulting in decreasing reservoir volume.

Dislocation processes can particularly be observed on the feldspar and quartz clastics. Brittle and plastic deformations are identified among tectonic deformations. Destruction (shearing) of clastics is characteristic for brittle deformations, resulting in cataclasis of separate fragments, weak fracture zones, interfragmental stripping and induced porosity are determined. Plastic deformation is followed by displacement of quartz clastic extinction, its granulation, regeneration and recrystallization. Under conditions of intensive plastic deformation, oriented element destruction and distinctive cataclastic structures are formed. Sometimes, thin cracks of stripping are filled with hydrocarbon products, rarely – with newly-formed minerals.

Induced porosity with integrated void space, caverns and microporosity are formed under positive dislocation-metasomatic processes. At the same time, reservoir properties improve.

Based on the investigation of Jurassic-Cretaceous sediments Lower Cretaceous Nizhnekhetk and Yakovlevsk suites are characterized by highly intensive dislocation-metasomatic activity and, consequently, probable improved reservoirs. Sukhodudinsk, Malokhetk and Dolgansk suites are characterized by moderate and intensive rock transformation. These zones are characterized by cataclasis, rock fracturing, increased porosity and permeability and significant secondary mineral formations.

3. Conclusion

Obtained data showed that Jurassic-Cretaceous terrigenous deposits in N-E Western Siberia were subjected to both stage and dislocation-metasomatic processes, which resulted, in one case, in the formation zones of secondary high porosity rocks with integrated void space, or in the second case, the decrease of reservoir volume.

It was identified that as a result of carbon dioxide fluid influence, rock dissolution and secondary kaolinite formation occurred, which, in its turn, is hydrophobic mineral forming cement microporosity. These processes improve the reservoir properties, especially rock permeability. Secondary mineral formations (quartz regeneration, carbonates and mica formation) and solid bitumen formation either insignificantly influence or deteriorate reservoir properties.

Thus, forecasting effective reservoir zones forecast is related to the zones of intensive carbon dioxide metasomatism developing in the “Water-Rock” system and resulting in integrated void space formation. It is necessary to consider the following: the more active carbon dioxide metasomatism in the sedimentary basin is, the more pores, heterogeneous cavities in newly-formed void space are. In this case, it becomes more difficult to identify and detect effective and non-effective reservoirs.

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