Epigenetic (Postsedimentary) Transformations in Sedimentary Rocks of the Lower Cretaceous Malokhetskian Formation in the Krasnoyarsk Territory

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Abstract. In this paper we consider transformation of sedimentary rocks of the Lower Cretaceous Malokhetskian formation (Krasnoyarsk Territory), which is associated with the instability of various minerals in an increasingly changing thermodynamic conditions. We found that these changes may be due to interlaminar dissolution, replacement, plastic deformation, cataclase or regeneration. Typically unstable minerals experiencing interlaminar changes are subject to these processes. Such changes are considered on the example of quartz, mica, feldspar and mafic minerals. Epigenetic changes have left their mark in the direction of reducing the pore space and deteriorating pore connectivity that degrades reservoir properties. Identified regularities greatly simplify solutions of theoretical problems about the complex relationships in natural systems.

Keywords: Epigenesis, postsedimentary conversion, deposit, Malokhetskian formation, rock-forming minerals, secondary changes, pore space, regeneration, interlaminar dissolution

DOI: 10.18599/grs.18.1.5

For citation: Galinskiy K.A., Funikova E.N. Epigenetic (Postsedimentary) Transformations in Sedimentary Rocks of the Lower Cretaceous Malokhetskian Formation in the Krasnoyarsk Territory. *Georesursy* [Georesources]. 2016. V. 18. No. 1. Pp. 29-32. DOI: 10.18599/grs.18.1.5

Introduction

Mineralogical composition of Malokhetskian formation is advisable to explore within the same area. The study of the mineral composition of the formation and identification of epigenetic changes was performed within Tagulsky area. Tagulsky oilfield is geographically located in the north of the Krasnoyarsk Territory, out of Arctic Circle, at a distance of 1700 km from the city of Krasnoyarsk. The field is confined to Bolynekhetsky oil and gas regions of Pur-Tazovsky oil and gas area (Faibusovich, Braduchan, 2010).

Maloketskian formation (K_1mh) conformably lies at sukho-dudinskian suite. It is characterized mainly by sediments of underwater deltaic plain (shallow conditions), poorly lithified sandstones and siltstones from dark gray to nearly white, containing lenses and interlayers of limestone varieties, inclusions of carbonized plant remains and fragments of coal (Faibusovich, Braduchan, 2010) (Fig. 1).

Uneven regeneration and partial leaching characterize postsedimentary changes in such rocks. Porosity and permeability of malokhetskian sediments undoubtedly worsen. In the composition of clay and clay-carbonate cements kaolinization processes appear, knot cement can form.

Remains of micro- and macrofauna were not found in the formation sediments. Early- Hauterivian and Early-Aptian age of the formation is adopted on the basis of spore-pollen complex. Thickness reaches 146 m (Decision of the 6th Interdepartmental Stratigraphic Meeting on the consideration and adoption of revised stratigraphic schemes of Mesozoic deposits of Western Siberia, Novosibirsk, 2003).

In malokhetskian suites the flowing layers are allocated: Mkh-III, Mkh-II, Mkh-I (Fig. 1). Reflecting horizon I^B is confined to the bottom of Malokhetskian formation (Fig. 1). In respect of oil and gas the layer Mkh-III is of particular interest, which is penetrated at full thickness within Tagulsky area in 5 wells. The thickness of sandstones varies from 41.2 m to 71.0 m. The layer has uniform lithology, sand content of 0.789 (Regular variations of reservoir properties ..., 1986).

Layers of malokhetskian formation (K_1mh) are combined into malokhetskian productive level (K_1mh), which is mostly sandy. It is genetically associated with deposits of underwater delta plain (delta front sediments). The terrigenous material by channels (submarine continuation of delta channel) was imposed in the coastal part of the sea. As a result of the waves formed precipitates were subjected to partial erosion and redeposition and accumulated along the outer edge of the underwater plains.

Physical and lithological characteristics of the studied sediments

Main lithological and physical reservoir properties of the layer Mkh-III are shown in Table 1.

Layer Mkh-III is composed of medium-fine sandstone and silty sandstones of light gray to nearly white color. Rocks are poorly lithified up to sand; contain interlayers of strong calcareous sandstones to limestones. Gross sand of the layer is 0.568-0.916, average value of 0.79, the average number of permeable intervals – 8.

Layer	Well No.	Coring interval, sea level, m	Lithology	To porosity, %		Water saturation, %	Carbonate content, %
				effective	total		
Mkh-III	Tgl-4	2060-2083,5 1977,3-2000,8	sandstone	18,7	19,1	31,4	13
	Tgl-13	2086-2100 2010,7-2024,7	sandstone	13,1*	13,6*	25,2*	19,7*

*Table 1. Information on lithological and physical properties of productive layer Mkh-III of Tagulsky area. * – After extraction.*

Open porosity by core is defined in the well Tgl-4 and ranges within 6.5-25.8%, permeability – 0.06-365.5x10^3 micron^2, residual water saturation – 18.5-56.6 %. Porosity ranges within 14.6-28.0%, with an average of 20.5% according to logging data.

Overlying siltstone and aleuropelite deposits of marsh type serve as cap rocks.

Sedimentogenesis of Malokhetskian formation (Mkh-III layer) and lithological-petrographic characterization of rocks

Layers of maloketskian formation are composed of medium-fine sandstones and silty sandstones of light gray to nearly white color. Rocks are poorly lithified up to sand;

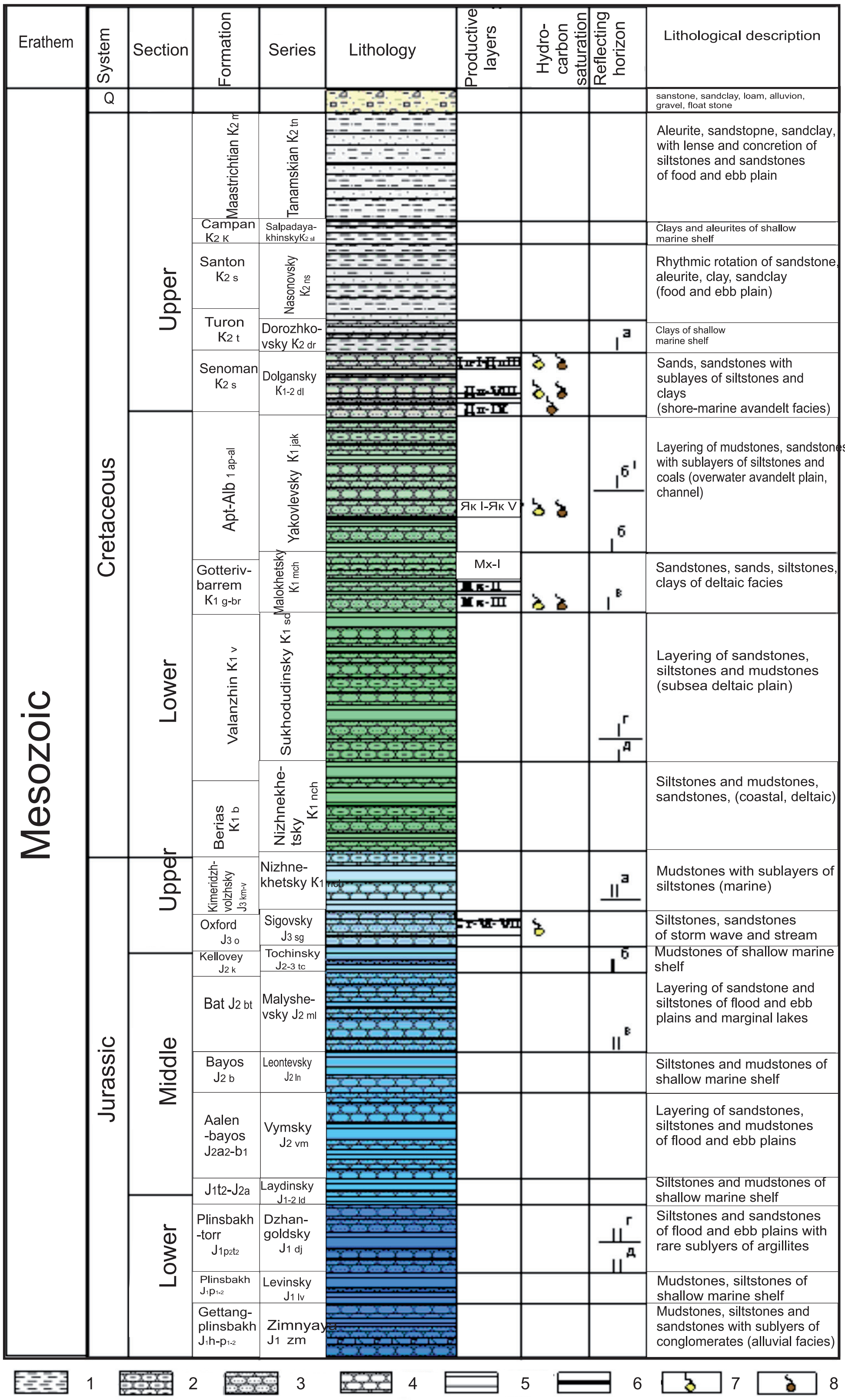

Fig. 1. Generalized section (lithological column) of the Jurassic and Cretaceous sediments of Tagulsky field (Saks, Ronkina, 1957). 1 – clay, 2 – clay siltstone, 3 – sandstone, 4 – siltstone, 5 – mudstone, 6 – coal, 7 – gas, 8 – oil.

contain interlayers of strong calcareous sandstones to limestones. Texture is oriented layered, with weak stratified accessories. There is quartz with rare air droplet inclusions of pelitic dimension, with traces of uneven recovery; feldspar – plagioclase and potassium differences; heavily leached differences are quite common (Fig. 2).

When considering sedimentation of malokhetskian formation we can draw the following conclusions.

- In terms of petrographic characteristics the studied intervals are presented by two types – siltstone and sandstone, in varying degree converted.

- In terms of mineralogical composition the studied rocks are feldspar-quartz.

- The majority of samples are characterized by a combination of several types of cement. However, their quantitative ratios are variable, usually dominated by clay or silica cement.

Epigenesis of malokhetskian formation (postsedimentary conversion of rocks)

It is known that along with lithological features rock epigenetic transformations largely determine the nature of reservoir rocks and indirectly influence the formation of lithological traps (Frolov, 1992). Therefore, in addition to studying petrographic composition of the rocks, we reviewed secondary processes of the studied objects.

Changes in the rock-forming minerals

Conversion of debris in Malokhetskian rocks is related to the instability of various minerals in increasingly changing thermodynamic conditions. Changes are caused by interlaminar dissolution, replacement, plastic deformation, cataclase, regeneration, soldering and dissolution under pressure. Unstable minerals experiencing interlaminar change include quartz, mica, feldspar, and dark-colored minerals.

Quartz

Quartz is one of the most common minerals in sedimentary rocks, although so far it is not used to assess epigenetic changes.

Schematically the fate of detrital quartz in sedimentary process is as follows. In weathering crusts and soils quartz undergoes corrosion and regeneration. During metagenesis its size and surface changes. Regeneration of quartz is through process during epigenesis, which can be implemented at any stage of conversion (diagenesis, katagenesis et al.) and accompanied by the formation of eventually dipyramid-prismatic grains (Frolov, 1995).

Quartz of sand rocks is a sensitive indicator of the transition from katagenesis to metagenesis and from the latter to metamorphism. Initial blastesis of detrital quartz indicates the beginning of metagenesis and appearance of fully blastic structures - the transition to the initial regional metamorphism.

The dynamics of the quartz changes with the increasing intensity of epigenetic changes reflect several consistent phenomena, followed by the formation up to four – five petrographic and genetic types of quartz. Following the advent of locally reclaimed quartz there is the development of multispectral autologous quartz borders, often reaching one third of the original clastic grains, due to the mass development, renewable several times. Emerging growths have microstructure (Fig. 3).

Increased degree of conversion is accompanied by the development of directed corrosion (Fig. 3). Subsequent transformations of quartz, commonly associated with the further increased deformation stress, contribute to the development of granulation and recrystallization, capturing porphyroblasts first from a periphery, and then the whole.

Feldspars

New feldspars of different composition are known: orthoclase, microcline, albite and oligoclase.

Feldspars are transformed predominantly into kaolinite. The initial stages of feldspars change occur in sandstones with carbonate cement. Initially, fragments are divided into rectangular blocks. In the second step oval spots appear, made of kaolinite. Later, the integrity of the feldspar fragment gets broken and kaolinite appears in the pores. The development of the process increases, fragments disappear, and kaolinite begins to occupy a significant portion of the pores. Chlorite and leucoxene are developed along fragments of effusives.

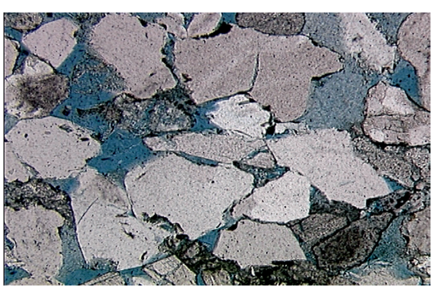

Fig. 2. Photos of the section No. 15485-08. View with crossed nicols, increase of 100X, sampling interval 2050.0-2060.0 m, sampling point 1.87m. Malokhetskian Formation, layer Mkh-III, well Tgl-4.

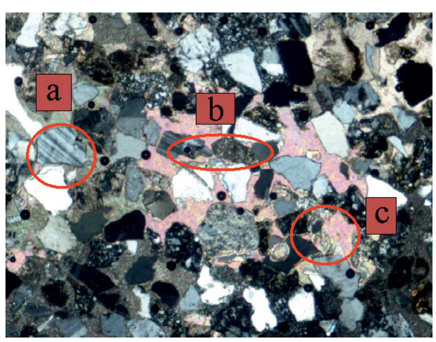

Fig. 3. Sandstone fine, arkose with uniform basal-pore carbonate cement. View – under crossed nicols, increase of 100X, sample 15551-08, interval 2073-2080 m, sampling point 0.29 m. Malokhetskian Formation, layer Mkh-III, well Tgl-4. a – regeneration of quartz grains, b – corrosion and regeneration of quartz, c – dissolution and corrosion of feldspar.

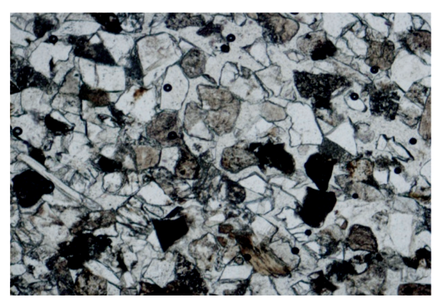

Fig. 4. Sandstone fine, arkose with uniform pore basal carbonate cement. View – under crossed nicols, increase of 100X, sample 15620-08, interval 2073-2080 m, sampling point 1.58 m. Malokhetskian Formation, layer Mkh-III, well Tgl-4. biotite in the stage of early amorphization.

In rocks with primary clay cement leaching of quartz is marked, sometimes contacting grains of quartz are fused. In the rocks with secondary cement there is a slight substitution of feldspar and muscovite with chlorite, and quartz and chlorite with kaolinite.

Mica (biotite, muscovite)

The detrital clastic rocks of the primary biotite are markedly transformed from early katagenesis. Rocks of this stage tend to have biotite of different degree of conversion from unaltered to completely converted (Fig. 4).

The other line of biotite conversion is its chloritization, capturing peripheral parts of its grains, or developing on colloform clots. Newly formed chlorite originally has brownish coloration, then it is recrystallized in a pale green chlorite.

Increased degree of postsedimentary conversion is accompanied by muscovitization and formation of alternating packages of chlorite and muscovite. In the later stages of the conversion (after diagenesis) biotite swells, splits into fibers and is converted into a variety of clay minerals; often between packages or fibers clusters of leucoxene iron oxides, carbonates and rarer opal are concentrated. Muscovite is hydrated, at the ends of plates is split and sometimes goes into kaolinite. The most intensely mica is altered in sandstones and less in siltstones.

Conclusions

The above changes result in the filling of pore space with secondary minerals or grains convergence. As seen from the above, detrital minerals disintegration leads to the formation of a number of growths. Thus, due to the feldspars and mica, kaolinite, hydromica, chlorite, montmorillonite are formed. Thus excess Na, K, Ca, Fe, Ti, Si are leached. Dissolution under the pressure also leads to the removal of Si and Na.

Features of epigenetic changes have left their mark in the direction of reducing the pore space and deterioration of pores communicability.

All this undoubtedly worsens the reservoir properties.

Thus, the established regularities largely simplify the solution of theoretical problems of the complex relationships in natural systems.

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Received November 11, 2015