The text of this article is available in Russian and English languages at: https://geors.ru/archive/article/825/

FEATURES OF COMPOSITION AND CEMENT TYPE OF THE LOWER TRIASSIC RESERVOIRS IN THE NORTH OF THE TIMAN-PECHORA OIL AND GAS PROVINCE

N.N. Timonina
Institute of Geology of the Komi Science Centre, Urals Branch of the Russian Academy of Sciences, Syktyvkar, Russia

Abstract. The work is devoted to the study of cement type and composition of the Lower Triassic deposits of the Timan-Pechora province, their influence on reservoir properties of rocks. The work was based on laboratory studies of core, generalization of published data. Morphological and genetic analysis of clay minerals was carried out using X-ray and electron-microscopic methods. As a result of the conducted studies it was established that the type, composition and distribution of the cement is influenced by the composition of demolition sources, sedimentation conditions, and post-sedimentation transformations. Kaolinite, chlorite, smectite and hydromica associations are distinguished according to the predominance of clay mineral in the sandstone cement. Kaolinite cement of sandstones is most typical for continental fluvial facies, especially channel beds. Smectite association is most characteristic of the floodplain, oxbow and lake facies of the zone. The revealed regularities will contribute to the improvement of accurate reconstruction of sedimentation conditions, construction of more adequate geological models of the reservoir, taking into account its reservoir heterogeneity both at the level of the reservoir and its constituent interlayers.

Keywords: oil and gas province, type of reservoirs, void, clay minerals, regeneration
DOI: http://doi.org/10.18599/grs.19.1.7

For citation: Timonina N.N. Features of Composition and Cement Type of the Lower Triassic Reservoirs in the North of the Timan-Pechora Oil and Gas Province. *Georesursy = Georesources*. 2017. V. 19. No. 1. Pp. 38-44. DOI: http://doi.org/10.18599/grs.19.1.7

Within the Timan-Pechora oil and gas province, Triassic sediments account for 30% of the total basin filling. The industrial oil and gas potential of this complex is proved by the discovery of a number of hydrocarbon fields within Shapkin-Yuryakhinsky swell, Laisky swell, Kolvinsky megaswell, Sorokin swell, and the water areas of the Pechora and Barents seas (Fig. 1). Lower Triassic sediments are characterized by considerable lateral and vertical heterogeneity, besides, they are often confined to deposits of heavy high-viscosity oil, which causes considerable difficulties in choosing the method of development. This causes the need to identify the structural features of the pore space of the Lower Triassic sediments and the finely dispersed component, which cause different productivity.

At present, rational development of fields is impossible without a detailed characterization of heterogeneity factors that control the features of the structure and potential oil-bearing capacity of productive horizons (Bruzhes et al., 2010). Minerals of cement are indicators of sedimentation environments and degree of sediment conversion. In addition, cement clastic rocks significantly affect the formation of their reservoir properties, with an important role played not only by the type of cement and the nature of its distribution, but also the composition. Studies of cement of terrigenous rocks and their influence on the accumulation and migration of hydrocarbons are enlightened in the works of such researchers as I.D. Zkhus (1966), D.D. Kotelnikov, A.I. Konyukhov (1961), R.S. Sakhibgareev (1989), A.V. Ezhova (2007), L.N. Bruzhes (2012), V.G. Izotov (2008, 2015), L.M. Sitdikova (2010, 2015), V.N. Morozov, (2013), V.A. Shmyrina (2013) and others.

Triassic oil and gas bearing complex has a regional distribution, in the east it is limited by the Urals, in the west by the Timan Ridge. The maximum capacity of the complex (2.8-3.6 km) is confined to the central parts of the Korotaikhinsky and Bolshesyninsky basins. Small layers (100-500 m) are confined to the Izhma-Pechora basin (Kalantar, Tanasova, 1988). The Lower Triassic deposits are represented by rhythmic interstratification of red-brown clays, greenish-gray siltstones and gray sandstones with layers of conglomerates of intra- and extraformational composition. The sandstones that make up the section are painted mainly in various shades of gray: from light gray to greenish gray. The granulometric composition is from fine to coarse grained. There are textures: massive, large unidirectional cross-bedded, horizontally layered, etc.

The color of siltstones varies from greenish-gray to bluish-gray. Widespread use of thin-layered textures and micro textures, predominantly horizontally layered and lenticular-layered, there are also rocks with disturbed stratification and textures of stirring. Clays and mudstones are widely represented in the section, painted in various shades of brown from reddish to dark chocolate. The main rock-forming minerals are minerals of smectite group, hydromica. Textures of mudstones are horizontally laminated, discontinuous, often broken, cloddy textures. These deposits are characterized by the presence of carbonate lenses and inclusions made with large-crystalline calcite. In the described sandstones, both carbonate and clay cements are widely represented. Quartz also occurs, but it has a subordinate value in comparison with carbonate and clay minerals. It is represented, as a rule, by small, well-faceted crystals that

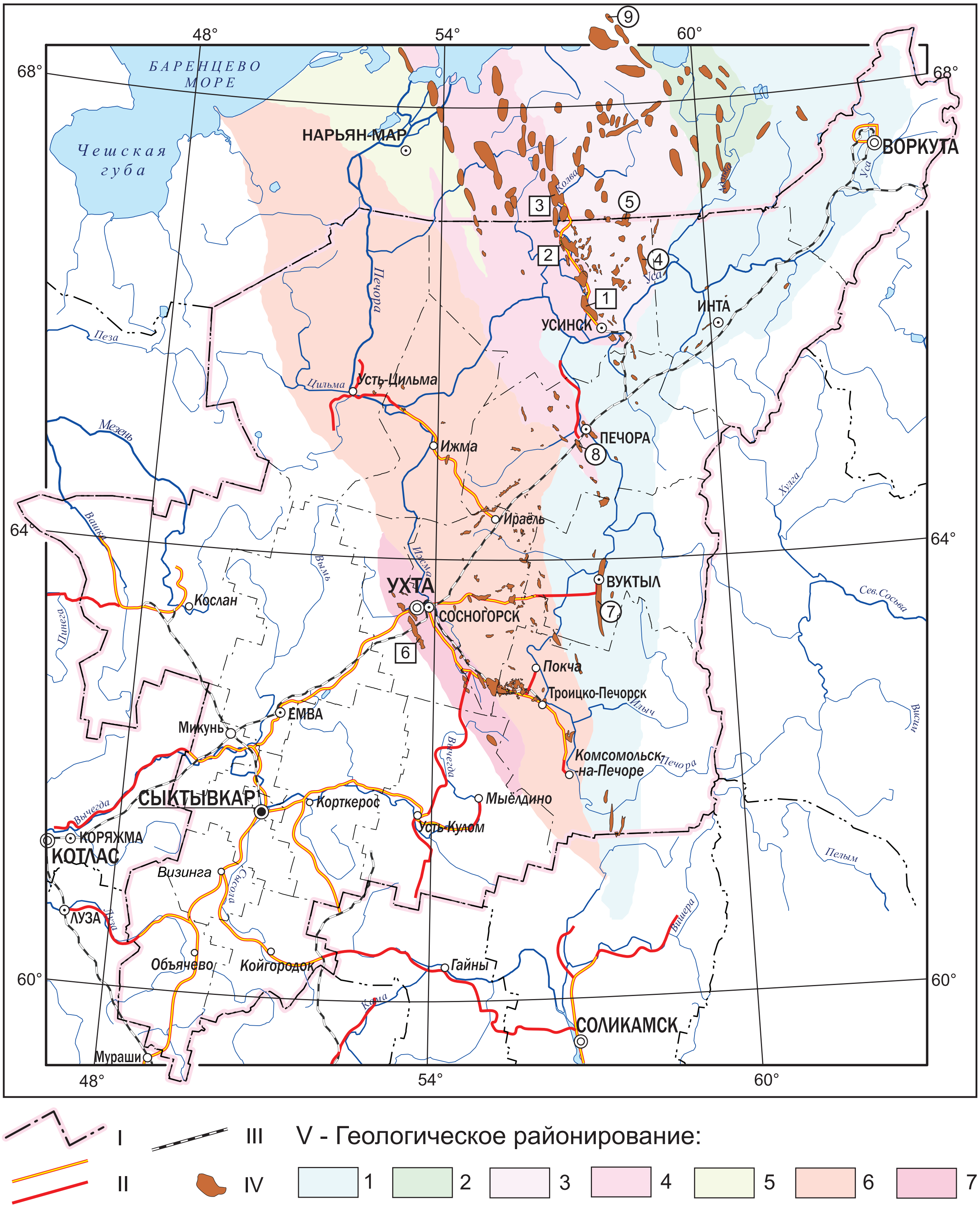

Fig. 1. Tectonic scheme of the Timano-Pechora oil and gas province. I – The border of the Republic of Kazakhstan; II – Highways; III – Railways; IV – Hydrocarbon deposits: 1 – Usinsky, 2 – Vozeysky, 3 – Kharyaginsky, 4 – Srednemakarikhinsky, 5 – Sandiveysky, 6 – Yaregsky, 7 – Vuktylsky, 8 – Kirtaleolsky, 9 – Varandeysky; V – Geological zoning: 1 – Pre-Ural marginal trough, 2 – Varandey-Adzvinsky structural zone, 3 – Khoreyversky depression, 4 – Pechora-Kolvinsky aulakogen, 5 – Malozemelsko-Kolguevsky monocline, 6 – Izhemsko-Pechorsky syneclise, 7 – Ukhta-Izhmsky swell.

can often be observed in the pore space together with kaolinite. The formation of quartz seems to be due to the liberation of silica during kaolinization of feldspars in the early stages of post-sedimentation history. The content of quartz cement in sandstones does not exceed 1-2 (Fig. 2).

The abovementioned cements are characterized by a considerable variety in the number, nature of the distribution in the rock, the uniformity of filling the space, relationship with the debris and, finally, generation time. Carbonate cement in Lower Triassic sandstones, as shown by chemical and X-ray analysis, is represented by calcite containing minor admixtures of iron, manganese and magnesium. The content of calcite in the composition of cement varies and can reach 40% or more of the total weight of the rock. By the number and distribution in sandstones, the basal and porous types of cement are most common, although the meniscus (incomplete pore) is also recorded.

Basal cement is a large-crystalline variety of calcite, and, as shown by electron microscopic studies, is crystallized in the form of rhombohedra. Cement of this type is confined to the base of sand layers. This is due to the fact that the most coarse-grained deposits with free void space lie in this part of the section. The presence of large crystals of calcite indicates crystallization in fresh nonmagnesium media, i.e. formation of cement of this type could occur in the phreatic zone (Makhnach, 1989).

Cement of pore and bunch-pore type is represented by fine crystalline calcite and occurs in poorly sorted medium-grained sediments with a large amount of aleurite material that prevents the growth of large calcite crystals. This type of cement has found wide distribution in sandstones of various facies nature (Fig. 3). Finally, the meniscus type of cement occurs less frequently than the previous ones, it fills the corners of pores, inheriting the form of water films held between debris by surface tension forces. Often the central pore area is filled with authigenic clay minerals or calcite of later generation.

Cement of this type was formed in the vadose zone, where dissolution prevailed over carburization in the absence of a permanent body of groundwater. Calcite cement in the described sandstones is characterized by a wide variety of types in the uniformity of pore filling, which significantly affects the reservoir properties of the deposits. The size of calcite crystals varies from less than 0.005 to 1 mm. It has a diverse structure: from covert to large crystalline. The first type is confined to sandstones with a high content of clay minerals. This is explained by the fact that clay particles can serve as centers of crystallization, which allow the formation of a large number of crystals, however, they also limit the further development of these crystals. This type of cement could form at any stage of deposits formation – from sedimentation to metagenesis. Calcite of the spherulite structure occurs in the medium-grained sandstones of the first (basal) layer. Its presence can be explained by the fact that, due to the presence of clay particles, the pore space remains only partly free. Crystalline nuclei only get limited growth due to the selective sorption of colloidal particles at the corners, edges and facets of the crystal, which have the highest atomic density. This type of cement has become very limited in the described sediments: it is found only in the lowest pack of sandstones of the basal layer.

Perhaps this is the soil layer, and carbonate of the spherulite structure formed at the stage of hypergenesis. Large-crystalline poikilitite cement is typical for medium- and coarse-grained, well washed sandstone interlayers in which the most favorable conditions exist for free pore crystallization. They often have cement of a corrosive type. The degree of corrosion of detrital components is determined, mainly, by the intensity of solutions circulation, i.e. the total number of active waters passed through the pore space. When the fragments are replaced by calcite, grains acquire fancy, twisting contours, often they are divided into fragments or completely replaced. The biotite and plagioclase are most often replaced, relicts, fragments or contours ('shadows') of grains often remain from them. The time of calcite formation is early and late diagenetic, calcite of the first type was formed together with sediment; due to sedimentary calcite, some layers of sandstone retain their pink coloration. Formed in the early stages, it prevented penetration of solutions and reduction of ferrous iron. Perhaps the formation of carbonate cement occurred in

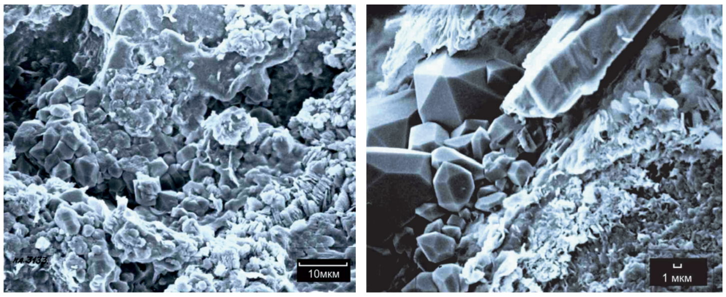

Fig. 2. Quartz crystals in the pore space of the Lower Triassic sandstone

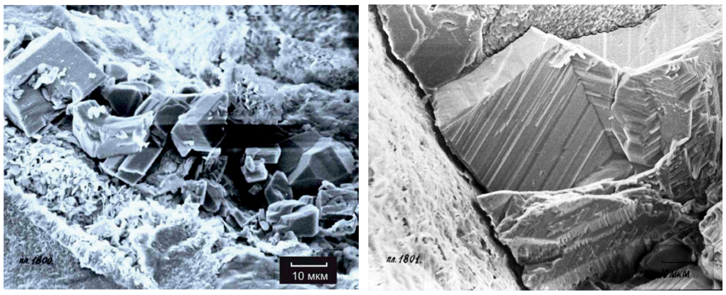

Fig. 3. Calcite crystals in the pore space of the Lower Triassic sandstone

the early stages of sedimentation, this was facilitated by various processes. In conditions of arid climate, an increase in groundwater

The increase in concentration led to the precipitation of carbonates and the formation of calcite cement. The most favorable conditions for the growth of calcite crystals existed in well-washed coarse-grained sediments (Fig. 4). The presence of such clay minerals as smectite prevented wide penetration of dissolved carbonates into pore space. In such layers, porous and basal-porous cement was formed, represented by fine- and medium-crystalline calcite. Cement of a later generation is recorded in sandstones with a hydrothermal chlorite cement and porous kaolinite cement. Clay minerals fill the peripheral parts of pores, and calcite – the central parts of pore space.

Clay minerals of sandstone cement are represented by kaolinite, chlorite, hydromica and minerals of the smectite group. In Triassic sediments, distribution of kaolinite is uneven both in section and in area. A decrease in its content is noted from the bottom upwards in the section: in the deposits of the Kharyaginsky area its quantity is reduced from 80-90% in sandstones of the basal layer to 10% in the upper part of the section. In the transition from coarse-grained to fine-grained sediments, a decrease in the content of kaolinite is noted. As shown by the conducted studies, sandstones formed in the conditions of the river basin are enriched with kaolinite.

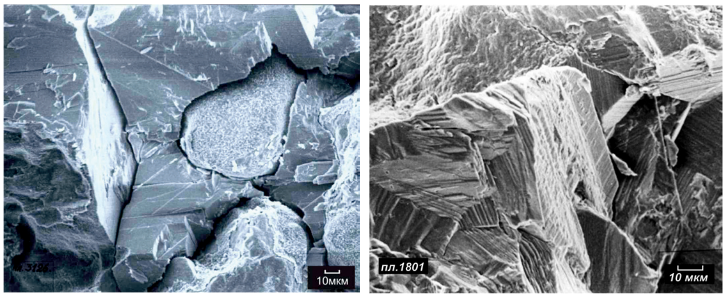

Fig. 4. Large-crystalline calcite in the intergranular space of the Lower Triassic sandstone

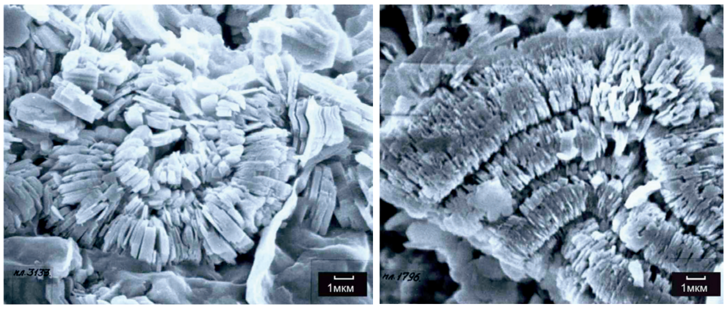

Fig. 5. Vermiculite-like aggregates of kaolinite

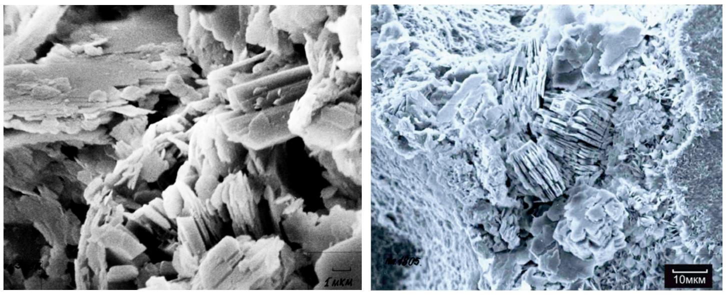

Fig. 6. Allotigenic kaolinite in the intergranular space of the Lower Triassic sandstone

On the basis of detailed X-ray structural studies, four structural-morphological types of kaolinites were identified. The first type includes authigenic kaolinite, represented by large, well-crystallized aggregates, often having a columnar or vermiculite-like form. This type of kaolinite is confined to coarser grained sandstones (Figure 5). Genetically, kaolinites of the first type can be classified as formed under conditions of an open system with prolonged crystal growth in a free-pore medium (Malysheva et al., 1993). In the section, they tend, mainly, to the continental fluvial facies.

Kaolinites of the second type are represented by small-crystal aggregates that completely fill the pores of sandstones, develop along clastic components or allocated as nests in clay rocks. Kaolinites of this type are considered as transformational-authigenic. Their formation probably occurred in the peripheral parts of open systems in free pores or on a substrate. The third and fourth types combine kaolinites with a pseudomonoclinic cell and a low degree of order. Kaolinites, classified as the third type, are characterized by an asymmetric form of the 001 reflex with a distinct shoulder toward small angles. They are observed in sediments, diagnosed as fossil soils and, probably, have allotigenic-transformational origin. Kaolinites of the fourth type have symmetrical but broad basal reflections. These kaolinites are present in fine-grained sandstones, mudstones and clays and are considered as allotigenic. In the described deposits, kaolinite has a transformational-authigenic and authigenic origin. Transformational-authigenic kaolinite is characterized by a less perfect structure. A large number of large-sized kaolinite particles with a small thickness with uneven, as it were cut, edges were established in the electron microscope study (Fig. 6). It is confined, as a rule, to fine-grained and medium-grained sandstones formed on the riverine shallows. It fills almost all the pore space.

The clastic mineralization of clay minerals is determined by the degree of their stability in weathering crusts, during transport and in sediments. Kaolinite is the final product of the transformation of silicates in the hydromica-kaolinite weathering profile, it is stable both in the aquatic environment and in soils. According to a number of researchers, kaolinite is one of the most resistant to mechanical destruction of clay minerals and could be transported in suspension by water currents (Drits, Kossovskaya, 1991). The source of clastic kaolinite could be the weathering crust of Permian sandstones. The process of sandstones weathering was associated with the destruction of chlorites, feldspars and hydration of muscovite, while removal of silicic acid, iron and aluminum from the weathering crust took place. These elements, carried in a colloidal state, became sources for the formation of authigenic kaolinite.

In the formation of kaolinite of all types, the weathering crust participates to a greater or lesser extent as one source. This may serve as an explanation for the fact that the lower part of the section is enriched with kaolinite, in particular, the basal layer. Minerals of the smectite group became widespread in the Triassic deposits (Fig. 7). Microscopically, it is a poorly shaped finely dispersed mass, which has a homogeneous exchange. In clayey rocks, smectite is associated with glandular chlorite and ferrous well-crystallized hydromica (Fayer, 1986). For the deposits studied, the predominantly mixed composition of the absorbed complex is characteristic, although pure sodium and calcium are found. Sodium smectite contains one molecular layer of water in the interlayer space, whereas calcium contains two such layers.

Due to the peculiarities of its structure, smectite has the greatest absorption capacity, which explains its ability to cation exchange. If calcium smectite enters brackish water conditions, sodium cations can partially or completely replace calcium ions. If sodium smectite enters the alkaline medium, rich in calcium, the latter completely replaces sodium cations. Depending on the concentration of calcium and sodium cations, disordered alternations of smectite packages containing both sodium and calcium can form in the exchange complex. Lower Triassic sandstones formed in channel conditions are characterized by the calcium composition of the exchange complex, which is associated with the chemical features of river water. In the Triassic sediments, smectite occurs with sodium cations in the exchange complex; these deposits could form on the surface of floodplain, during the period of subaerial development.

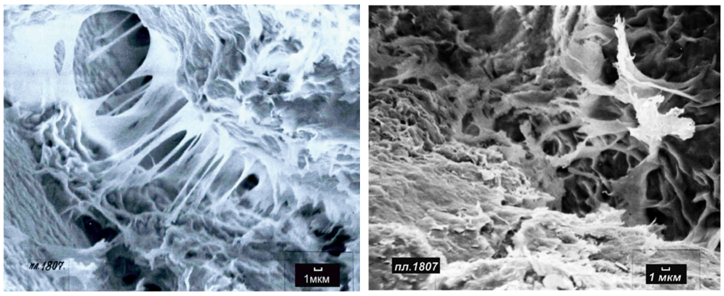

Fig. 7. Chlorite-smectite formations in the intergranular space of the Lower Triassic sandstone

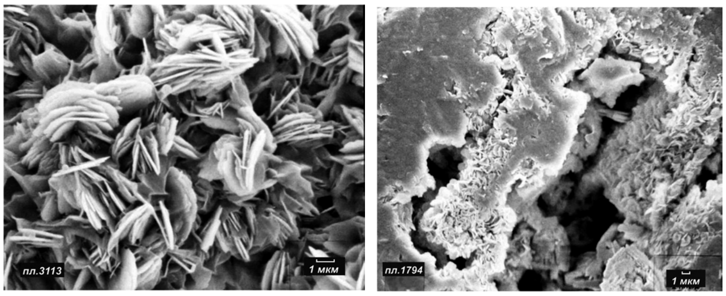

Fig. 8. Chlorite flakes fill the walls of porous space of sandstone

In fine-grained sandstones of the basal layer, its content does not exceed 50-60%, whereas in the upper part of the section its amount increases to 80-90%. Since the most favorable conditions for the formation of smectite exist in an alkaline environment under arid climate, an increase in its content may indicate an increase in the arid climate. Smectite is the most abundant in fine-grained sandstones, where it almost completely fills the pore space, making it virtually impenetrable. Due to the high absorptivity, smectite can swell considerably when saturated with water or organic filler. In these cases sandstone interlayers become almost impenetrable.

Microscopic and X-ray characteristics, chemical composition of the clay fraction allowed distinguishing several mineral varieties of the chlorite group. In the thin sections, chlorite minerals are present in the form of crochet margins on grains, fibrous and spherolite-like highly-refractory precipitates in pores and completely chloritized fragments (Fig. 8). The allocation of each of these varieties in pure form without the impurities of other clay minerals is difficult, therefore the x-ray characteristic and chemical composition is given by the samples in which one or another kind of chlorite predominates.

Microscopically, the fermentation chlorite is represented by a pale green border on detrital grains and has a thickness of 3-12 μm. A study with an electron microscope showed that these edges consist of small pseudohexagonal scales randomly located at different angles to the surface of clastic grains. Large-lamellar, fibrous-lamellar and spherulitic-like chlorite in the pore space is usually associated with an abundance of chloritized fragments. Authigenic, allotigenic and transformation chlorites can be identified by morphological features, chemical composition and structural characteristics. The authigenic formations include, first of all, crustification films composed of chlorite scales and, in chemical composition, belonging to the group of magnesian-ferruginous chlorites.

Chloritized rock fragments that fill pore space are considered as allotigenic formations, since chloritization is an inherited change. According to their chemical composition, they can be classified as a group of iron-magnesian chlorites. Transformational chlorites constitute the largest group and are represented by highly-refracting coarse-lamellar, fibrous-lamellar aggregates and are the result of metasomatic replacement of detrital rock components such as biotite, amphiboles, pyroxenes, tuffs, chloritized metamorphic rocks. The high content of chlorite is recorded in the sediments formed in floodplain conditions due to the increased content of chloritized clastic components.

In the Triassic sediments, hydromica has a subordinate significance with respect to other minerals. Microscopically, it is represented by small elongated scales that are in a mixture with other clay minerals, and is predominantly allotigenic in origin. In the early Triassic time metamorphic rocks were destroyed, the fragments of which were transferred by water currents. In the process of transport and accumulation in reservoirs, hydromicas underwent changes. At the stage of hypergenesis, gradual leaching of potassium ions and a change in the chemical composition occurred. With the removal of potassium ions into the inter-pack spaces, cations of sodium and calcium entered, changing the composition of the exchange complex. In the process of transfer by river water, mechanical disintegration of hydromica particles, further removal of potassium and enrichment of the exchange complex with calcium cations are also taking place. The increased content of hydromica is noted in siltstones and clays. In siltstones, its content can reach 20-30%, in clays – 30-40%. In sandstones, as a rule, the content of hydromica does not exceed 10%, in more fine-grained differences can reach 20%. In the Lower Triassic sandstones, polymineral cement is most often encountered, in the content of which all the above minerals are present in greater or lesser amounts (Fig. 9).

As a result of the conducted studies, it was established that the type, composition and character of the cement distribution is influenced not only by the composition of the removal sources, but also by the conditions of sedimentation, and by post-sedimentation transformations of the deposits. According to the predominance of this or that clay mineral, kaolinite, chlorite, smectite and hydromica associations are distinguished in the cement of sandstones. Kaolinite cement of sandstones is most typical for continental fluvial facies, especially channel beds. The smectite association is most characteristic of the floodplain, old and lake facies of the semiarid zone. In addition to the structural and texture features serving as diagnostic features of channel sediments, mineralogical and petrographic features also exist, such as surface structure of grains, mineral associations and associated geochemical criteria.

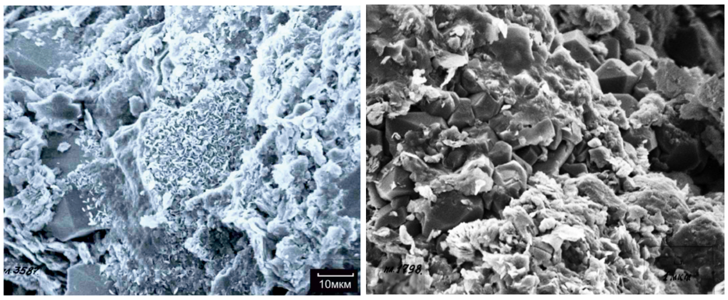

Fig. 9. Inter-grain space of Lower Triassic sandstones

The surface of grains that make up channel deposits, usually smooth, without cracks and scratches, the channel pebble is usually isometric or elongated. Channel sediments are enriched, as a rule, with quartz (in comparison with the floodplain deposits) from accessory minerals – ilmenite, zircon, and garnet. Differentiation of debris occurred due to different dynamic conditions in the channel and floodplain and is related both to the particle size, shape, specific gravity, and the varying force of the flow. Clay minerals, perhaps, are the most sensitive indicators of sedimentation environment. Thus, for channel sediments, the high content of kaolinite in cement of sandstones is most characteristic in comparison with other clay minerals.

Additional diagnostic features of depositions of the flood plain facies are enrichment with ilmenite, rutile, pyroxene. Sediemnts of the false rivers are enriched with hornblende, mica, tourmaline. Floodplain deposits are characterized by an increased content of clay minerals of the montmorillonite group in comparison with channel sediments. Additional criteria for facial diagnostics are geochemical indicators characterizing alluvial deposits as a whole, and allowing to isolate channel and floodplain deposits. In the process of hypergenic mineral formation, alluvial lithogenesis was accompanied by the concentration of Si, Fe, Mn, Ca, Mg, K, and Na. The most mobile forms of elements (included in readily soluble salts, absorbed complex, etc.) reflect the conditions of sedimentation.

Channel macrofacies are characteristic with maximum concentrations of Si and minimal Al, Ca, Mg, K, Na. Amorphous forms of Fe, Al and Si are concentrated in floodplain conditions. The processes of syneresis of colloidal compounds of Fe, Al, Si and other elements are accompanied by the formation of hypergenic oxides and hydroxides of Fe, clay minerals, etc. Dependences of the concentrations of amorphous compounds Fe, Al and Si on facies media can be used as geochemical indicators in the reconstruction of sedimentation environments of buried river sediments (Kuznetsov, 1973). The conditions of sedimentation determined the granulometric composition and roundness of the debris, the degree of their sorting, respectively, the configuration and sizes of the primary intergranular pores. Post-sedimentation transformations led to a change in the primary void space.

The processes of compaction, carburization, regeneration contributed to its reduction, and dissolution – to the increase due to the expansion of intergranular, the formation of intragranular micropores of recrystallized clay cement. A well-defined dependence of the reservoir properties from granulometric composition, sorting of detrital material and the cement content was revealed. Neoplasms of chlorite, film hydromica, kaolinite, as well as compaction reduce the volume of pore space and reduce the reservoir properties of sandy rocks. As a result of the conducted studies it was possible to establish that the high variability of the composition and structure of the cement minerals in the reservoir rocks is associated with local facial-paleogeographic conditions of sedimentation in river system conditions. Differentiation of the composition and type of cement requires an individual approach, a careful flexible selection of technologies in determining the development strategy of deposits and careful selection of a set of methods for increasing oil recovery for different sections of the fields in order to achieve the maximum oil recovery factor.

Acknowledgements

The author acknowledges support by the Programme of Fundamental Research of Urals Branch of the Russian Academy of Sciences (Grant No. 15-18-5-21).

References

Bruzhes L.N., Izotov V.G., Sitdikova L.M. Lithofacies Conditions of J1 Horizon Formation Within the Tevlinsko-Russkinskoe Deposit (Western Siberia). *Georesursy = Georesources*. 2010. No. 2(34). Pp. 6-9. (In Russ.)

Drits V.A., Kossovskaya A.G. Glinistye Mineraly: Slyuda, Khlority [Clay Minerals: Mica, Chlorites]. Moscow: Nauka. 1991. 176 p. (In Russ.)

Ezhova A.V. The Structure and Genesis of the Void Space in the Reservoirs of the Oil And Gas Bearing Strata of the Southeast of the West Siberian Plate (Tomsk Region). *Litosfera = Lithosphere*. 2007. No. 4. Pp. 115-122. (In Russ.)

Faier M.M., Mamontova T.P. Dependence of Post-Sedimentation Changes in Clay Minerals of the Paleozoic and Mesozoic Deposits of the Timan-Pechora Syneclise from the Facies Conditions of their Formation. Clay Minerals in Lithogenesis. Moscow: Nauka. 1986. Pp. 51-62. (In Russ.)

Izotov V.G. Technological Mineralogy Of Oil Reservoir. *Sb. Materialov Rmo: Sovremennye Metody Mineralogo-Geokhimicheskikh Issledovanii* [Modern Methods of Mineralogical and Geochemical Research: Collected papers]. St. Petersburg. 2006. Pp. 140-142. (In Russ.)

Izotov V.G., Sitdikova L.M., Bruzhes L.N., Talipov I.F. Structure Features of Hollow Space of Hydrocarbon Collectors of the Jurassic Oil-Bearing System of the Tevlinsko-Russkinskoye Field in Connection with a Problem of Its Exploration. *Georesursy = Georesources*. 2012. No. 1(43). Pp. 6-10. (In Russ.)

Kalantar I.Z., Tanasova S.D. Facies Criteria for Stratification of Continental Deposits of the Triassic. Stratigraphy and Lithology of Oil and Gas Bearing Deposits of the Timan-Pechora Province. Leningrad: Nedra. 1988. Pp. 127-134. (In Russ.)

Kossovskaya A.G., Tuchkova M.I. To the Problem of Mineralogical and Petrochemical Classification and Genesis of Sandy Rocks. *Litologiya i poleznye iskopaemye = Lithology and Mineral Resources*. 1988. No 2. Pp. 8-24. (In Russ.)

Kotel'nikov D.D., Konyukhov A.I. Glinistye Mineraly Osadochnykh Porod [Clay Minerals of Sedimentary Rocks]. Moscow: Nedra. 1986. 247 p. (In Russ.)

Kuznetsov V.A. Geokhimiya Allyuvial'nogo Litogeneza [Geochemistry of Alluvial Lithogenesis]. Minsk. 1973. 280 p. (In Russ.)

Makhnach A.A. Katagenez i Podzemnye Vody [Catagenesis and Groundwater]. Minsk: Nauka i tekhnika. 1989. 335 p. (In Russ.)

Malysheva E.O., Larionova Z.V., Ryabinkina N.N., Timonina N.N. Prirodnye Rezervuary v Terrigennykh Formatsiyakh Pechorskogo Neftegazonosnogo Basseina [Natural Reservoirs in the Terrigenous Formations of the Pechora Oil and Gas Bearing Basin]. Syktyvkar. 1993. 154 p. (In Russ.)

Morozov V.P., Shmyrina V.A. Effects of Secondary Alterations of Reservoir Rocks on the Porosity and Permeability of Productive Formations Bs111 and Us11 at the Cluster Deposit. *Uchenye Zapiski Kazanskogo Universiteta. Seriya Estestvennye Nauki*. 2013. V. 155. No. 1. Pp. 95-98 (In Russ.)

Sakhibgareev R.S. Vtorichnye Izmeneniya Kollektorov v Protsesse Formirovaniya i Razrusheniya Neftyanykh Zalezhei [Secondary Changes in Reservoirs During the Formation and Destruction of Oil Deposits]. Leningrad: Nedra. 1989. 260 p. (In Russ.)

Zkhus I.D. Glinistye Mineraly i Ikh Paleogeograficheskoe Znachenie [Clay Minerals and their Palaeogeographic Significance]. Moscow: USSR Academy of Sciences. 1966. 235 p. (In Russ.)

About the Author

Natalia N. Timonina – PhD in Gelogy and Mineralogy, Chief of the Laboratory of Geology of Oil and Gas Bearing Basins

Institute of Geology of the Komi Science Centre, Urals Branch of the Russian Academy of Sciences

Russia, 167982, Syktyvkar, GSP-2, Pervomaiskaya St., 54
Phone: +7 (8212) 24-14-50

Manuscript received 12 Ocotober 2016;
Accepted 25 January 2017;
Published 30 March 2017