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GEOLOGY

Endogenic Clastites and Their Role in the Formation of Petroleum Pools in the Southern Siberian Craton

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Regularities in the distribution of oil- and gas-controlling platform structures, especially marginal systems and relevant lithostructural associations, attract the attention of many researchers. The specific role in the formation of oil and gas (hereafter, petroleum) pools is attributed to overthrust and thrust dislocations. In the opinion of Pushcharovsky [1], "… platforms did not loose any significance for tectonics, geodynamics, or applied geology. It is sufficient to mention the high petroleum potential of ancient complexes in the Siberian Craton, including rocks located below Siberian traps."

Recent studies [2–5] show the existence of a specific class of rocks in nature that do not belong to the classic triad—sedimentary, igneous, and metamorphic rocks. These apparently sedimentary formations actually represent tectonometasomatic rocks (endogenic clastites). They are pseudosedimentary mechanochemical clastogenic rocks, which externally resemble sedimentary rocks. In fact, they originate from the endogenic tectonometasomatic transformation of any substrate by deep fluids [6]. The original results of recent studies of both theoretical and practical significance indicate that this phenomenon can be registered as an important discovery.

The world practice in exploration and development of petroliferous basins demonstrates that almost monomineral quartz sandstones serve as the major collectors of oil and bitumen, for example, in the Atabaska (Canada), Orinoco bitumen belt (Venezuela), and others. The commonly accepted lithological concept, according to which quartz sands and sandstones are only sedimentary rocks, is undoubtedly incorrect and needs to be revised [7]. The pressing issue of secondary destructive collectors (in particular, quartz sandstones) defined as oil and bitumen collectors has been discussed in petroleum geology for a long time. Lithostructural associations with secondary fractured–porous collectors, which represent favorable traps for oil and gas, form in both allochthonous and autochthonous overthrust–thrust structures. Such fractured collectors are widespread in terrigenous and calcareous–dolomitic rocks, as well as silicified or carbonate shales, e.g., depression facies of the Ural foredeep, Domanik facies of the Volga–Urals region, the Bazhenovo Formation of West Siberia, lenticular bodies of quartz and quartz–feldspar sandstones (Nepa Formation) in the lower part of the Vendian terrigenous section of the Markovo–Verkhnii Chon group of deposits in the Nepa–Botuoba petroliferous province of the southern Siberian Craton, fractured siliceous rocks and black shales of the Arkansas Novaculite Sequence in the Appalachian thrust belt, and others. They occur also within the crystalline basement. For example, permeable aquifers confined to fractured thrust zones among Archean gneisses of the crystalline basement were discovered in the Kola superdeep borehole. Therefore, the study of rocks with properties of secondary enhanced collectors (secondary porosity, fissuring, cavernosity, and so on) and fluid-confining beds has a high theoretical and practical significance.

We studied endogenic clastites in the course of documentation of deep oil- and gas-prospecting boreholes during tunneling in the Baikal, Kodar, Northern Muya areas and in basal members of the sedimentary cover of the Siberian Craton. In these areas, clastic rocks resemble, at first sight, usual terrigenous sedimentary rocks, but they have undoubtedly different genesis. Their origin is related to complex mechanochemical transformations due to fracturing, grinding, rolling, and recrystallization of separate minerals in primary rocks with subsequent intense circulation of aggressive waters and deep fluids along tectonically weakened zones. One of the most characteristic sections of these rocks is observed in the Northern Muya tunnel. Here, one can see an alternation of massive granites, fractured granites (with intense development of tectonic clay along

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fractures), and disintegrated granites. The latter granites are transformed into sand (40–50%), rubble (5–10%), grus (25–30%), and clay (5–10%) fractions. The section also includes a zone of intense disintegration and chemical decomposition with the formation of subplastic clayey material (up to 10–90%) and clayey mass with admixture of sand and grus. In other sections, where clays are intensely developed and feldspars are entirely hydrolyzed, members of monomineral quartz sands appear in some places. Such sections show a rhythmic pseudobedding due to the frequent alternation of clays and sands.

The formation of such clastites is related to destructive tectonic movements, on the one hand, and tectonometasomatic transformations of primary substrate, on the other. The grain size of sand material depends directly on the crystallinity and fracturing degree of primary granites. The lithological and grain-size composition, as well as inherited properties of primary material, characterize the fine clastic and dispersed endogenic clastites as in situ products of the destruction and reworking of granitoids. This is evident from poor sorting and angular appearance of rock fragments. The detrital material could be insignificantly transported in the suspended state by water flows during a low-amplitude uplift or subsidence of a part of the region. The material could be significantly transported during the water breakthrough to the surface, for example, in riftogenic depressions. Such mechanochemical transformations of rocks at the sedimentary cover/crystalline basement boundary are established in several boreholes of the Verkhnii Chon field. The systemic interval-by-interval sampling of core material with the subsequent study of thin sections and petrophysical properties of all transitional rock types ranging from their unaltered varieties to typical endogenic clastites is the main method used for the study of secondary rock transformations.

The knowledge of lithological alterations in different rock associations, including granitoids in deep crustal zones of tectonic fractures, is far from being sufficient. Tectonoseismic transformations of granitoids under influence of deep fluids in tectonically weakened zones produce endogenic clastites that are different from weathering crusts and mistaken for sedimentary rocks. The proposed model of the endogenic clastite formation allows us to revise the genesis of Cenozoic loose fine clastic and dispersed rocks in uplifts of the Baikal riftogenic system. We can outline the following evolutionary succession in tectonometasomatic transformations of high-Na granitoids:

(1) destruction of mineral and structural properties of rocks (formation of fractured granites);

(2) disintegration with preservation of cataclastic and structural properties (formation of saprolites);

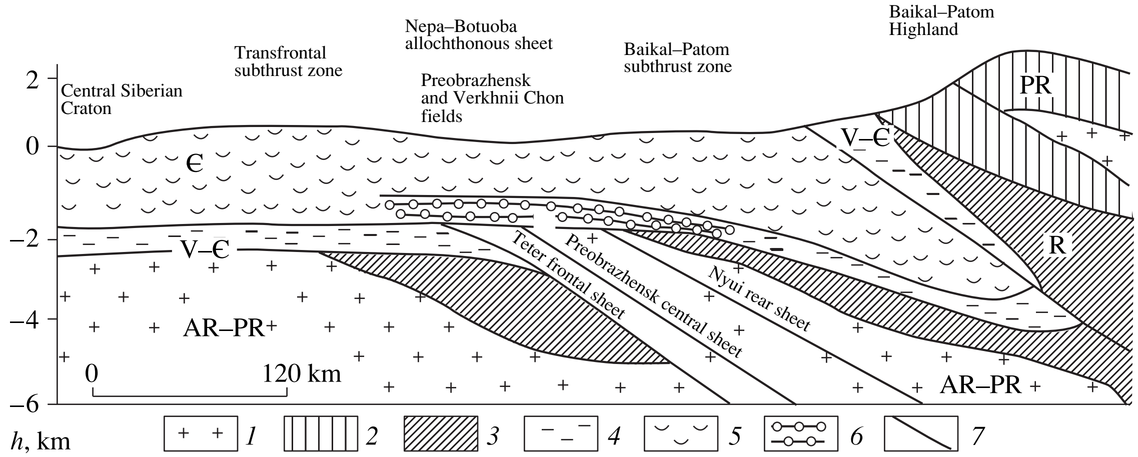
(3) hydration (formation of argillized saprolites); and

(4) hydrolyzation (formation of argillisites).

Thus, products of intense tectonometasomatic transformation of granitoids in activated zones of the Baikal rift system were a principal source of fine-clastic material, which constitutes thick sandy sequences in river valleys and depressions. This interpretation represents the novelty of the genetic model proposed for sandy sequences in the Baikal region and their relation with endogenic clastites. This model differs substantially from the previous models and shows that lithostructural transformations of granitoid rocks in deep crustal zones of tectonic dislocations should be scrutinized up to endogenic clastites.

It is known that arch areas of the Nepa–Botuoba anticline are most promising in the southern Siberian Craton with respect to commercial petroleum deposits. For example, the Preobrazhensk, Verkhnii Chon, Dulis'ma, Danilovka, and other areas incorporate numerous petroleum shows in basal layers of the Vendian subsalt terrigenous complex represented by the Markovo, Yarakta, Verkhnii Chon, and other horizons (Fig. 1). Most of them are composed of cataclastic quartz or quartz–feldspar sands with a content of clayey material admixture progressively increasing upward the section. Sandy deposits form lenticular discontinuous bodies that often pinch out along the strike. Such patterns led to contradicting views on the genesis of sandy bodies, their stratigraphic correlation in different borehole fields, and identification of numerous pseudostratigraphic analogues of the Nepa Formation and associated productive horizons. In the Markovo–Verkhnii Chon group of deposits, cataclastic collectors constitute a basal (almost continuous) horizon resting upon the crystalline basement. Its thickness varies from a few centimeters to 25–30 m with maximal values in boreholes 25, 39, 62, and 93.

The middle part of the subsalt complex (Tirsk Formation and its analogues) comprises the Parfenov, Botuoba, Tirsk, Kharystan, and other productive horizons. In some of them, quartz is supplemented with anhydrite, halogens, and clayey aggregates. The secondary porosity of quartz sandstones in the Parfenov Horizon of the Kovykta deposit is related to dissolution of quartz under pressure and its subsequent migration in the alkali medium. According to [8, p. 57], "…we should expect intensified quartz redistribution in sandstones under increasing geostatic and decreasing formation pressure, all other factors being equal." The upper part of the subsalt complex is composed of substantially carbonate and halogenic rocks (Danilovka Formation and its analogues). The associated clayey–carbonate and sulfate–carbonate (Preobrazhensk, Ust'-Kut, and Yuryakh) halogenic horizons are frequently brecciated, fissured, and leached in detachment and fold zones. Secondary collector properties of carbonate rocks in the Preobrazhensk Horizon are related to the granular, cavernous–granular, and, to a lesser extent, fissuring porosity. Filtration–capacity properties of carbonate rocks vary along the lateral and vertical directions due to different contents of clay and salt. The



Geological cross section of the southern Siberian Craton. (*1*) Crystalline basement; (*2*) folded complex of the Baikal–Patom Highland; (*3–5*) formations of the platformal sedimentary cover: (*3*) Riphean, (*4*) Vendian–Cambrian, (*5*) Cambrian; (*6*) endogenic clastites with properties of secondary collectors and fluid-confining beds; (*7*) thrusts.

hydrocarbon deposits in them are confined to zones of enhanced collector properties rather than anticlinal structures [9, p. 49]. In the Cambrian sedimentary cover developed in the frontal detachment zone of the halogenic sequence, regional petroleum shows are confined to the Osa productive horizon composed of porous–cavernous brecciated dolomites. Low-angle detachment zones developed mostly within the carbonate sequence are also recorded above the Osa Horizon. Fractures are governed by the Balykhta, Khristoforovka, and Bil'chir productive horizons.

Thus, intense mechanochemical transformations of rocks in basal layers of the sedimentary cover and at the top of the crystalline basement are established in several deep boreholes drilled in the southern Siberian Craton. Numerous petroleum shows have been revealed in cataclastic collectors (endogenic clastites with enhanced properties of secondary reservoirs and fluid-confining beds) confined to basal layers of the Vendian subsalt terrigenous complex of the Preobrazhensk, Verkhnii Chon, Dulis'ma, Danilovka, and other prospective fields. Rocks of the middle and upper parts of the subsalt complex, which are less altered by mechanochemical processes, host a smaller number of petroleum shows.

The Riphean rock field at the southern margin of the Siberian Craton is characterized by more favorable structural–tectonic settings for the formation of endogenic clastites. The recent discovery of the unique Yurubchen–Tokhom petroleum field in the Riphean rocks at the western margin of the Siberian Craton [10] suggests that large petroleum pools can occur in the Riphean sequences, particularly beneath the Riphean thrust zones at the southeastern margin of the Siberian Craton. New large and unique petroleum fields can be discovered at the southern margin of the Siberian Craton on the basis of the model of nappe-and-thrust structure of this region and origin of the Baikal oil beneath the thrust zones. Recognition of this hypothesis will foster detailed geological–geophysical studies and deep drilling in the Baikal–Patom subthrust zone. This will make it possible to penetrate the thick allochthonous crystalline cover and recover Riphean petroleum pools beneath the thrust zones. Such fields have been discovered in Appalachia, Cordilleras, Carpathians, and other regions [11, 12]. Thus, we are on the eve of discoveries of new nontraditional hydrocarbon deposits confined to endogenic clastites beneath thrust zones at the southern margin of the Siberian Craton. This conclusion emphasizes the practical importance and theoretical significance of the problem under consideration.

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