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## LITHOGENESIS OF VEND-CAMBRIAN DEPOSITS OF SOUTHWEST SLOPE OF BAIKITSKAYA ANTECLASE (BASED ON THE STUDY OF THE SECTION OF THE IRINCHIMINSKAYA PARAMETRICAL WELL 155 IN EAST SIBERIA)

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The results of the study of sedimentation conditions and the subsequent diagenetic, catagenetic and imposed epigenetic rock transformations in the section have been examined. The display in the cut of epigenetic changes of rock and expansion of bitumoids point to the perspectivity of the territory and oil-and-gas-bearing capacity.

The study of lithogenetic features of sedimentary strata formation is necessary for evaluation of prospects of oil-and-gas-bearing capacity of the investigated territory. The Irinchiminskaya parametrical well has been drilled on the area of the Tokhomskaya subzone of the Tokhomo-Olenchiminskaya facies zone of southwest slope of Baikitskaya anteklase of Eastern Siberia and studied with application of a complex lithologic-petrographic, mineralogic-geochemical and luminescent-microscopic technology [1]. Researches were executed in the petrologic-geochemical laboratory of Institute of Geology and Gas of Tomsk Polytechnic University. The opened by the well deposits were investigated by the samples of core and slurry selected accordingly at 1...2 m and 5...10 m. The core is studied in intervals of opening of *usolskaya* ( $\epsilon_{is}$ ) – 2347...2385 m, *teterskaya* ( $V-\epsilon_{it}$ ) – 2479...2500 m, *sobinskaya* ( $V_{sb}$ ) – 2500...2530 m, *katangskaya* ( $V_{kg}$ ) – 2567...2597 m, *kolymovskaya* ( $V_{klm}$ ) – 2650...2672 m, *omorinskaya* ( $R_3-V_{om}$ ) – 2672...2809 m and *velminskaya* ( $R_3-V_{vl}$ ) – 2837...2849 m suites. Slurry is studied from depositions of *belskaya* (int. 1830...1902 m), *usolskaya* (1905...2460 m) and other suites from the intervals where selection of the core has not been carried out.

Rocks of the *velminskaya* suite (int. 2809...2869 m) are represented by red-brown finely-medium-grained layered sandstones. By the structure they are feldspar-quartz graywacke with congestions of micaceous minerals along the planes of stratification, with conformal structures of grain contacts with dolomitic, quartz and micaceous-hydromicaceous cements (Fig. 1). The sorting of terrigenous material is average. Quartz, microcline and kalispär-perthite, albite prevail in the structure of fragments. Fragments of quartzites, volcanites, micaeous slates can also be found.

Interlayers of brown, red-brown aleurolites, argillites and their transitive versions are marked among sandstones. An inclination of interlayers is 3...5°. Aleurolites and aleuroargillites prevail in the upper part of the suite.

Rocks of the suite were formed in the active enough shallow (close to the coastal line) well aerated environment. Fragmentary versions with fine, well sorted and rounded terrigenous material were accumulating.

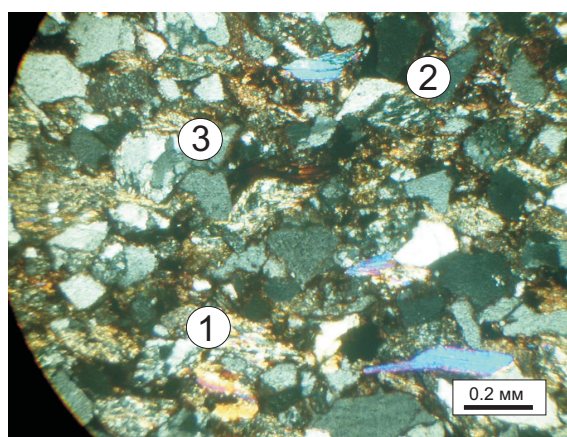


Fig. 1. Thin section. Nicol x. Sandstone (feldspar-quartz graywacke) hydromicacidized (1) with hematite (2). Conformal structures of grain contacts are visible (3.) Velminskaya suite. The well Irinchiminskaya 155P. The depth is 2847 m

Fragments are cemented by various authigenic minerals, among which hematite is often present (Fig. 1) which specifies to the development at lithification of sandstones and aleurolites of oxidizing conditions. However the thin eruption of an organic substance (OS), present in cementing units, apparently, promoted formation of glauconites and green chlorates, formed in regenerative conditions. These minerals quite often accompany red-brown hematitized breeds, forming in a number of cases greenish spots, thin *слойки* and lenses. In the upper parts of the suite section their number increases and they give a bright greenish shade to rocks.

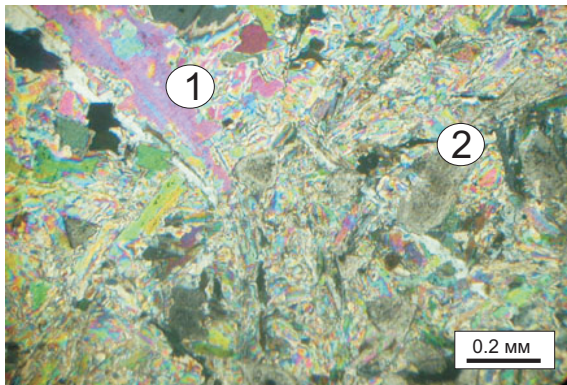
Rocks of the *omorinskaya* suite overlay the deposits of the *velminskaya* suite. They are represented by sandstones, fragmental-sulphatic-carbonaceous rocks, dolomite, micaceous aleurolites and argillites. Layers of solid grey-colored dolomites with capacity of 8...9 m, irregularly enriched by anhydrite and containing impurities of argillaceous, aleuritic and psammitic material are recorded in the roof and the base (Fig. 2)

In deposits of the suite aleurolites are irregularly argillaceous, sometimes sandy, dolomitic and anhydritic. Argillites also contain sandy, rarely anhydrite and dolomite impurity material. Interlayers of sandstones are

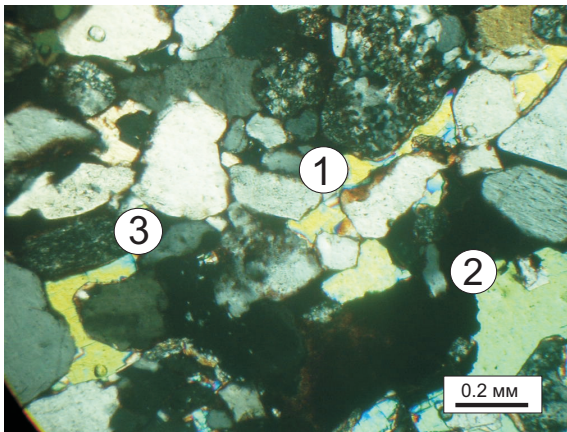
greenish-grey, pinkish-grey, and sometimes reddish-brown. They are irregularly enriched by (Fig. 3), dolomite and argillaceous substance. In composition sandstones are feldspar-quartz, sometimes solid homogeneous quartzitic. The capacity of interlayers varies from 0,5 up to 1,5...2 m.

Dynamic conditions, characteristic for areas of source area, remain at formation of the lower parts of suite.

Diagenetic transformations of rocks are accompanied by hematitization of cement, weak display of RC burial processes. Up the section oxidizing modes of deposit lithification are replaced by weak-regenerative and regenerative with accumulation of thin-dispersed sapropelic RC, glauconite and green chlorite.



**Fig. 2.** Thin section. Nicole x. Dolomite-anhydrite rock with spherocrystals of anhydrite (1) and rhombic crystals of dolomite of a zonal construction (2). Omorinskaya suite. The well Irinchiminskaya 155P. The depth is 2682,2 m



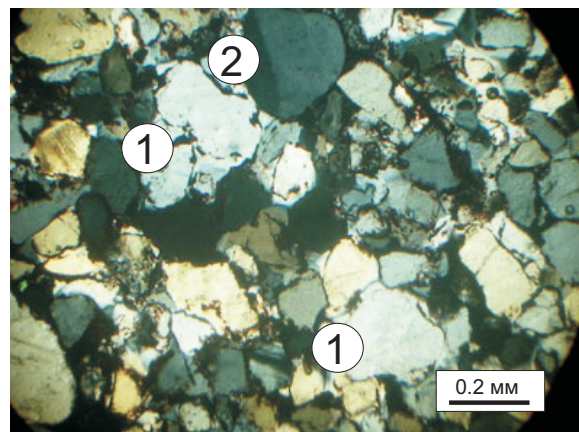
**Fig. 3.** Thin section. Nicole x. Sandstone oligomictic with hydrocarbons, hematitized (1) with anhydrite poikilitic (2) and quartz regeneration (3) cements. Conformal and incorporation structures of grain contacts are visible. Omorinskaya suite. The well Irinchiminskaya 155P. The depth is 2730 m

Accumulation rate of fragmental and argillaceous material in the section periodically decreases. An increase in salinity and alkalinity of waters takes place. A share of argillaceous-dolomitic and cleanly dolomitic varieties with prevalence of thinly laminated and parallel-laminated textures testifying to stabilization of dynamic conditions of sedimentation and change of their stag-

nant conditions of sedimentation environment increases among deposits. The latter promote the development of regenerative reactions, sulphate-reduction, and abyssal decomposition of an organic substance. In this connection, the quantity of carbonatic and sulphatic minerals increases, halogen postsedimentary diagenetic formations as well as globular and crystal pyrite appear.

Buried RC is collected in appreciable quantities, represented by lumps and spotty concretions in internal parts of a crystallizing dolomite, and by lenses and thin interlayers in rocks. Diffused forms of the buried RC quite often emphasize its primary organogenic biomorphic and algal nature.

Rocks of the *kolymovskaya* suite (int. 2597...2672,4 m) are mainly composed of red-color (due to hematitization – Fig. 4) sandstones, aleurolites, argillites and their transitive versions. Thin intercalations of grey-color irregularly anhydritized (up to dolomite-anhydrites), sometimes silicified argillaceous dolomites are occasionally marked. Psammitic material in them is present in the form of an impurity of feldspar-quartz composition (up to 5...15 %) with prevalence of quartz.

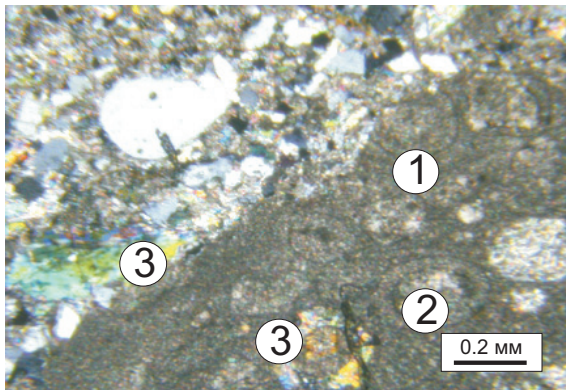


**Fig. 4.** Thin section. Nicole x. Sandstone inequigranular with quartz regenerating (1) and hematitic contour (2) cements. Kolymovskaya suite. The well Irinchiminskaya 155P. The depth is 2652,9 m

Jointing, sometimes with polish faults along the faces of fissure, is characteristic for aleuroliteous argillites and argillaceous aleurolites.

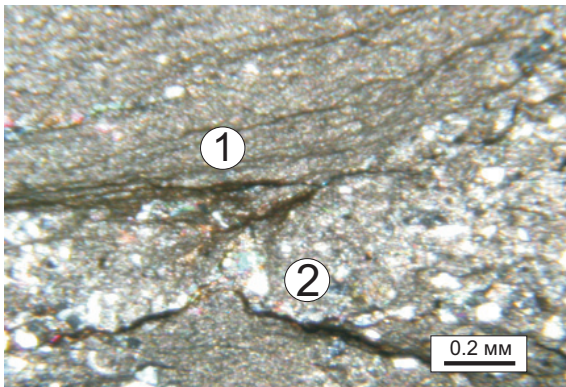
Rocks of the *katangskaya* suite (int. 2564...2597 m) intermittently overlie the deposits of the *kolymovskaya* suite. The section is represented by interstratifications of grey, dark grey, sometimes brownish dolomites and dark grey and black argillaceous dolomites. Spots of white sugary anhydrite, lenses of black-brown silicon, interlayers of red-brown and multicoloured marls are marked.

Thin parallel, gently rolling lamination of rocks is emphasized by interlayers of various colors. Undulated, obliquely-laminated, lenticularly-laminated textures prevail in deposits of the suite, which testifies to active dynamics of the environment during formation of deposits. Parallel thin-laminated textures specify to steadier conditions of accumulation and lithification of sediments.



**Fig. 5.** Thin section. Nicole x. Aleurite-sandy lens in dolomite (1). Oolitic formations of dolomite (2) and fragments of anhydrite (3) are visible. Katangskaya suite. The well Irinchiminskaya 155P. The depth is 2586,7 m

Features of composition and lamination of rocks along the section specify to deficiency of fragmental material during sedimentation, to intermittent accumulation of deposits, displays of consedimentational deformations (Fig. 6).



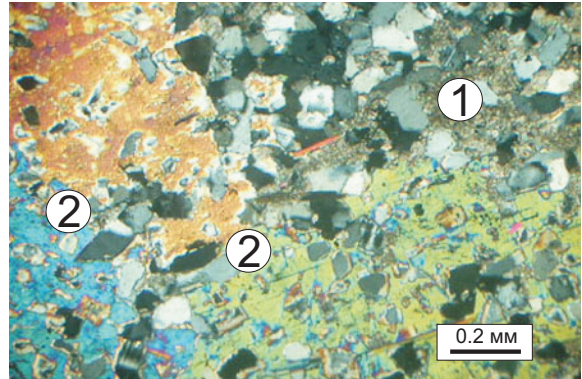
**Fig. 6.** Thin section. Nicole x. Dolomite argillaceous (1) with an impurity of aleuro-psammitic material (2) and attributes of consedimentational deformation. Joints are executed by hydrocarbons and hydromicas. Katangskaya suite. The well Irinchiminskaya 155P. The depth is 2586,7 m

Diagenetic transformations of rocks changed – the oxidizing sour environment promoted deposition of hematite in fragmental rocks, and its change by alkaline, regenerative, was accompanied by formation of argillaceous-dolomitic, siliceous-dolomitic and anhydritic cements (Fig. 7).

Dolomites, enriched by diffused carbonaceous substance, are often recorded among rocks of the suite. Features of substance distribution allow assuming its primary algal nature in the form of stromatolitic, less often oncolitic detritus. Rocks quite often contain pyrite, testifying about occurrence of regenerative conditions of diagenesis of deposits. Bitumoids, dated to zones of catclase, are marked in rocks of the suite.

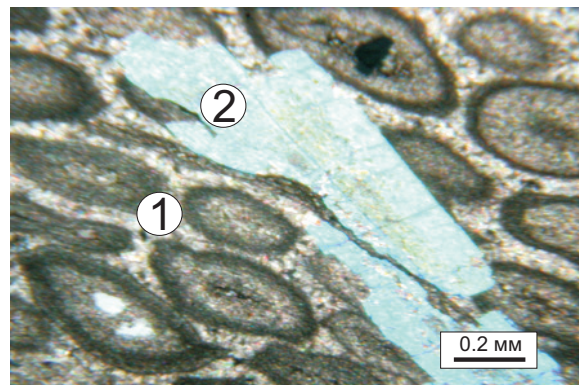
Deposits of the *sobinskaya* suite (int. 2500...2564 m) overlie on deposits of the *katangskaya* suite. The section is represented by grey, dark grey fine-crystalline dolomites, as well as by greenish-grey and light grey, their po-

rous versions. Numerous interlayers, spots and lenses of grey fine-grained anhydrites, interlayers of aleurosandstones, fine-grained feldspar-quartz and quartz sandstones on porous anhydritic and dolomitic cement are marked. The Capacity of interlayers of the main versions of rocks varies from 0,2 up to 2...3 m. Fractured sandstones with inclusions of bitumoids are recorded in the interval of 2504...2528 m.



**Fig. 7.** Thin section. Nicole x. Sandstone oligomictic average-fine-grained with dolomitic porous crystal-grained (1) and poikilitic basal anhydritic (2) cements. Anhydrite forms glomeroblastic accretions. Katangskaya suite. The well Irinchiminskaya 155P. The depth is 2583,2 m

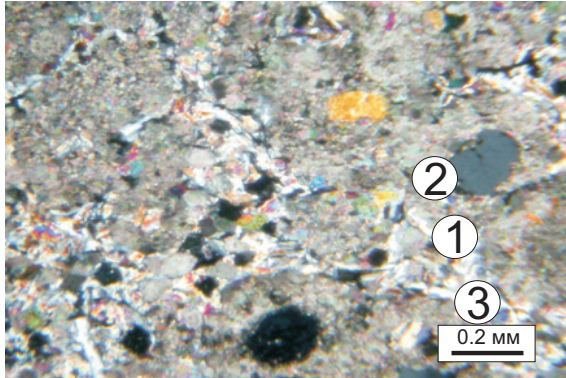
Deposits of the suite were formed mainly at very weak addition of aluminosilicate material in conditions of underbalance of a caving pool by sediments. Periodic updatings of the pool by terrigenous material have caused formation of the structures reminding turbiditic, as well as microtextures of rolling-laminated, lenticular-laminated with attributes of consedimentational deformations (Fig. 8).



**Fig. 8.** Thin section. Nicole x. Dolomite oolitic (1), aleuro-psammitic with crystalloblasts of anhydrite (2). Sobinskaya suite. The well Irinchiminskaya 155P. the depth is 2520,3 m

The presence in rocks of lumpy spherical dark pelitomorphous formations with carbonaceous substance (Fig. 8, 9) specifies to existence in deposits of a significant amount of microfauna and flora, and also testifies to fluctuations of the Eh mode in the deposit and about change of the oxidizing environment of diagenesis of deposits on poorly regenerative. Attributes of stabilization of sedimentational conditions are marked in the upper

parts of the suite section: fissured subparallel textures emphasized by argillaceous and carbonaceous substance appear. Conditions of formation of the suite deposits are connected with reduction of dynamic activity in moving of terrigenous material, climate aridization, an increase of the chemogenic component in mineral units. The pelitic material of rocks contains carbonaceous substance, as well as numerous lumps, clots (1...2 mm) and spherical remains of organisms and their colonies having zonal constitution. Deposits of the sobinskaya suite are gradually replaced by deposits of the teterskaya suite.



**Fig. 9.** Thin section. Nicole x. Dolomite pseudo-oolitic (1), sandy (2), with anhydrite (3). Sobinskaya suite. The well Irinchiminskaya 155P. The depth is 2530,0 m

Rocks of the *teterskaya* suite (int. 2461...2500 m) are represented by intersratified grey, dark grey, greenish-grey average-fine-grained dolomites with lenticular inclusions of bluish color anhydrite (Fig. 10). Interlayers of argillaceous dolomite, sandstones, aleurosandstones, feldspar-quartz and quartz on porous anhydritic, sometimes dolomitic, cement are found in the section. The thickness of interlayers ranges from 2...3 m up to 16 m.

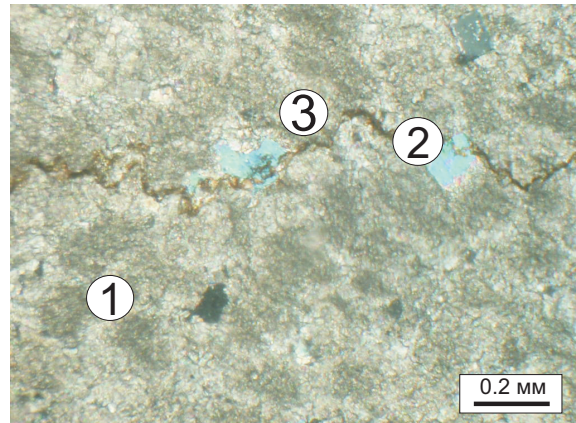
Argillaceous dolomites and dolomitic marls are dark grey, grey and greenish-grey in color, indistinctly-laminated and thin-parallel-laminated, less often lenticular and undulated-laminated textures. They are represented by interlayers from 0,4 up to 1,5...2 m thick.

Sandstones are mainly grey and light grey color, fine- and medium-grained, massive and layered. Thickness of their interlayers ranges from 0,2 up to 1,5 m.

Anhydrites are grey, light-grey bluish, smoky, finely-medium-grained with the size of grains from 0,1 up to 0,3 mm. Partially they have cavernous-porous textures. The thickness of interlayers varies from 0,1 up to 0,6 m.

Preservation of average contents of argillaceous minerals in rocks of the *teterskaya* suite at a level of contents of the *sobinskaya* suite testifies to continuation of influence of addition sources on processes of sedimentogenesis, at preservation of the tendency of climate aridization.

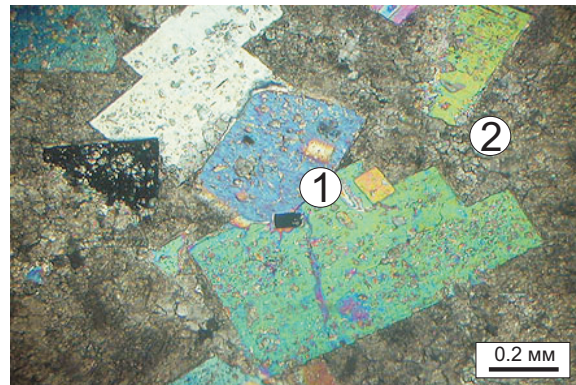
Deposits of the *teterskaya* suite with gradual transition are overlapped by rocks of the *usolskaya* suite (int. 1902...2461 m). In lithologic composition the *usolskaya* suite is dismembered on halogen-carbonaceous *podosinskaya* pack, non-saline *osinskiy* permeable horizon and powerful *nadosinskaya* halogen-carbonaceous strata.



**Fig. 10.** Thin section. Nicole x. Dolomite crystal-grained lumpy, spotty (1), with crystalloblasts of anhydrite (2) and stilolitic suture with hydrocarbons (3). Teterskaya suite. The well Irinchiminskaya 155P. The depth is 2499,4 m

The *podosinskaya* pack (int. 2400...2461 m) is mainly composed of grey, dark grey dolomites and inequigranular anhydraceous dolomites with interlayers and lenses of salts, as well as thin layers (first few mm) of argillaceous substance and dotted inclusions of sulphides. Textures of rocks are thin- and indistinctly-laminated, lenticularly-laminated линзовиднослоистые, massive, impregnated.

The *osinskiy* horizon (int. 2340...2400 m) is composed of dark grey and black dolomites and dolomitic limestones, thin-medium-grained, anhydritic, cavernous and fractured with interlayers and layers of salts (Fig. 11, 12). Textures of rocks are lenticular-laminated, rarely stilolitic fractured and cavernous, structures are organogenic. Rare fractures are executed by bitumoids.

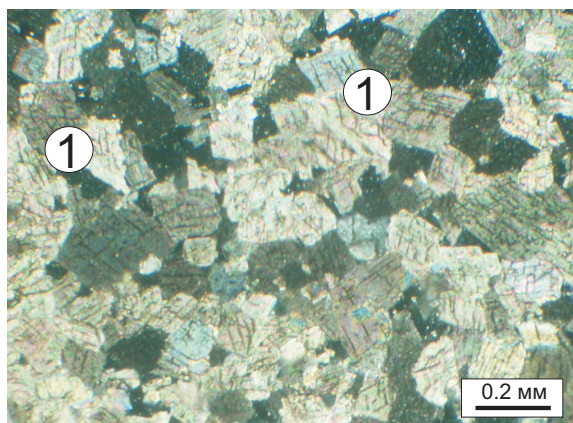


**Fig. 11.** Thin section. Nicole x. Porphyroblasts of anhydrite (1) in crystal-grained dolomite (2). Usolskaya suite. The well Irinchiminskaya 155P. The depth is 2360,3 m

The *nadosinskiy* horizon is represented by dolomites, argillaceous dolomites, dolomites with anhydrite and salts, various in structural-textural properties. They were formed in conditions of the arid type of lithogenesis in conditions of suburbs of large brined reservoirs. Significant capacity of deposits, variety of rocks and their petrographic features specify steady filling of the pool with brines, pelitic and biogenic substances, as well as periodic evaporation of moisture, deposition of salts and burial of the dispersed organic substance.

Diagenetic transformations of rocks were carried out in highly regenerative conditions with increased alkalinity at slow abyssal decomposition of the buried RC and its transformation into a very thin sapropelic suspension. Introduced into the pool material possessed high content of carbonaceous substance, especially in places of wide development of argillaceous deposits.

The *Belskaya* suite was studied only by the slurry. Its rocks are mainly represented by limy dolomites and dolomites with textural-structural features characteristic for the *usolskaya* suite. They were formed in conditions of the low-active environment of the salty periodically evaporated pool.



**Fig. 12.** Thin section. Nicole x. Dolomite crystal-grained with the well expressed disseminated buried RC, accomplished by cleavage, highly-porous (1). *Usolskaya* suite. The well *Irinchinskaya 155P*. The depth is 2350 m

Thus, formation of deposits of the studied section occurred in periodically shallow water pools in conditions of weak aeration of the environment and gradual aridization of the climate. It favored to salinization of waters, formation of evaporitic deposits, dying off, burial and accumulation of remains of animal and vegetative origin [2].

Diagenesis of fragmental-argillaceous and evaporitic deposits sated by organic substance and microorganisms (spherulitic, lumpy structures) took place in dynamically quiet environments in conditions of change of pH modes – from normal to alkaline and Eh – from oxidizing (*velminskaya* and *omorinskaya* suites) to transitive protoxicidic (*sobinskaya* suite) and then to highly regenerative (*teterskaya*, *usolskaya*, and *belskaya*). Stagnant conditions, decrease of Eh and increase of pH promoted abyssal de-

composition, polymerization and burial of RC [3–5]. Periodic display of highly regenerative conditions promoted an increase in the share of petrogenating kerogene of the II type among other forms of buried RC and to increase of petroparent potential of rocks and displays of sin-bitumoids (*usolskaya* suite, int. 2295...2360 m).

Katagenetic changes of rocks of the studied section were expressed in their condensation, crystallinity of a thin-dispersed material, partial oxidation of sin-bitumoids, reduction of the primary sedimentational hollow space, which sometimes promoted formation of local impermeable seams in dolomites of *usolskaya* (int. 2393...2405 m) and *sobinskaya* (int. 2505...2508,3 m) suites.

Epigenetic changes of rocks, which proceeded in conditions of dislocational transformations of plicative and cataclastic character and accompanying them fluid-migration, were showed in redistribution and migration of the most mobile components, recrystallization, integration or partial dissolution of separate grains of minerals, occurrence of zonality in their structure, as well as in formation of porous and cavernous spaces. Formed fractures, stilolitic suture and pores were filled by migratory bitumoids of mainly oily-resinous composition.

The study of lithogenesis of Riphean-Vendian-Cambrian deposits of southwestern slope of *Baikitskaya* antecline has shown that their sedimentation in conditions of gradual climate aridization, favorable conditions of accumulation of organic substance and its transformation in regenerative geochemical facies of diagenesis up to petrogenating kerogene of the II type and displays singenetic bitumoids, and epigenetic processes accompanied by transparent migration of epibitumoids, specify their perspectivity and assumes necessity of their continuation of drilling and survey.

## Conclusions

The detailed study of Riphean-Vendian-Cambrian deposits of southwest slope of *Baikitskaya* antecline has allowed characterizing facies features of sedimentation. It is established that formation of deposits was accompanied by diagenetic, catagenetic transformations of rocks and their subsequent changes as a result of the development of processes of the imposed epigenesis and migrations of hydrocarbonic fluids. The presence in the section of petroparent and epigenetically transformed rocks, transparent display of bitumoids, testify to perspectivity of the research area on oil-and gas content.

## REFERENCES

1. Stolbova N.F., Kiselev Yu.V., Betkher O.V., Stolbov Yu.M. Litho-geochemical features of the section of eastern board of *Bolshekhetskaya* depression (by results of the survey of the *Tukolando-Vadinskaya* parametrical well 320) // *Bulletin of the Tomsk Polytechnic University*. – 2004. – V. 307. – № 5. – P. 43–47.
2. Strakhov N.M. Types of lithogenesis and their evolution in history of the Earth. – Moscow: State scientific-technical publishing of literature on geology and bowl protection, 1963. – 535 p.
3. Teodorovich G.I. The doctrine on sedimentary rocks – Leningrad: Gosgeoltekhizdat, 1958. – 572 p.
4. Teodorovich G.I. On mineralogic-geochemical features of primary petroliferous and dispersed-bituminous suites // In the book: *Mineralogy and facies of bituminous suites of a number of areas of the USSR* / Edited by N.M. Strakhova. – Moscow: Publishing house of the Academy of Sciences of the USSR, 1962. – P. 61–77.
5. Yapaskurt O.V. Problems of the doctrine on lithogenesis // *Problems of lithology, geochemistry and sedimentary ore-genesis*. – Moscow: MAIK «Nauka/Interperiodika», 2001. – P. 9–26.

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