Specific features of Bazhenov suite sediments in south-eastern Nurolsk sedimentary basin (Tomsk Oblast)

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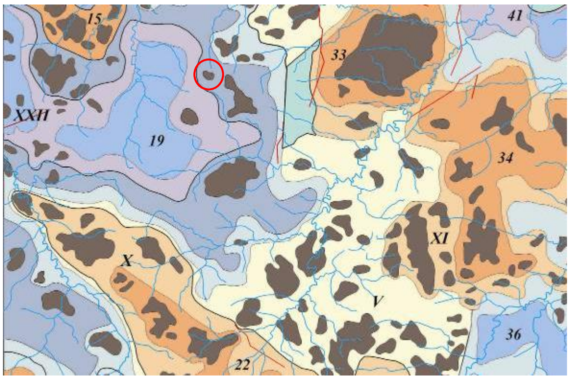
Abstract. The specific sediment features in Georgiev (J_3kmgr), Bazhenov (J_3vbg) and Kulomzin (K_1bkl) suites, exposed by drilling in the S-E Nurolsk depression (Tomsk Oblast), were defined and described via petrographic, X-ray diffraction and fluorescence-microscopy analysis methods. The classification of agrillites was identified, the structure-texture features, composition, voids and bitumen types and their distribution were determined. It was defined that Bazhenov suite argillites are characteristic of fine-dispersion, high biogenic silica content and scattered organic matter, enriched multi-composite syngenetic bitumen (from light to resin-asphaltine), as well as fractured surface where the migration of light bitumen occurs.

1. Introduction

Bazhenov suite bituminous sediments (Volgian-Early Berriasian) are today a relevant issue in terms of both the formation of source rocks [1, 3] and the potential production of shale gas and shale (light tight) oil [5] within it. The suite, embracing a complex of Domanic source rock formations [8, 9], is characteristic of high lithologic heterogeneity and consists of clay-carbonate-silica rocks, which, in its turn, are organic matter sources of plankton remains with silicic skeletons: radiolarian and diatoms [2]. According to the data [10], siliceous Bazhenov formation «black clay» is regarded as a source rock for more than 85 % of all oil reserves in the Western-Siberian basin. Effective core porosity for argillaceous-siliceous rocks in Bazhenov suite ranges from 3–8 % [4]. Bazhenov suite in studied area overlies Georgiev (Kimmeridgian) suite clays and is overlaid by Kulomzin (Berriasian) suite clays, involving gradation [6].

2. Target formation features and research methods

Investigated Georgiev, Bazhenov and Kulomzin suite sediments were taken from the core depth interval of 2822.3–2795.0 m. in Western-Kvenzersk well № 4 (figure 1), located in similar local elevation in S-E Nurol'sk megadepression within the Central Nurolsk megadepression (Western-Siberian petroleum province, Pudinsk oil-and-gas region, Tomsk Oblast). The cross-section included brownish dark-grey argillites, fine-platy, foliated areas, smooth flinty fracture and containing phosphated and calcitated macrofauna remains. Measured on core, the borders between suites have not been established. In this case, litho-petrographic, X-ray diffraction and fluorescence-microscopy analysis methods were used (18 samples). The thin sections were investigated as following: under the polarization microscope Polam-213 via transmitted-light (nH 1) and polarized light (nH 2); fluorescence-microscopy analysis – fluorescence microscopy Mik-Med II. The research methodology was previously proposed [6, 7].



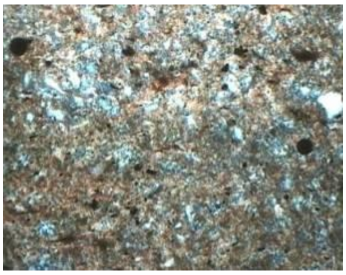
Legend
- Negative superorder structures
- Negative structures I order
- Positive structures II order
- Negative structures II order
- Intermediate structures II order
- Positive structures III order
- Negative structures III order
- Positive structures IV order
- Faulting
- Western-Kvenzersk area

Figure 1. Tectonic map- location of Western-Kvenzersk area, Tomsk Oblast: V – Chuziksk-Chizhapsko mesoanticline; X – Lavrovsk mesoridge; XI – Pudinsk mesoelevation; XXII – Central-Nurolsk mesodepression; 15 – Festival ridge; 19 – Tamratsk depression; 22 – Lavrovsk ridge; 33 – Luginestsk depression; 34 – Ubileinoe elevation; 36 –South-Pudinsk downfold; 41– South -Sobilin depression**.**

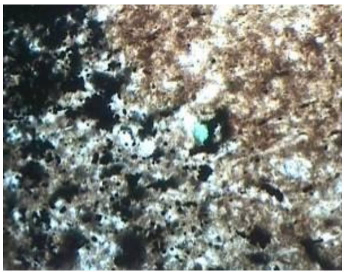
3. Classification of sediments and lithotype characteristics

According to structure features and composition, five lithotypes were identified.

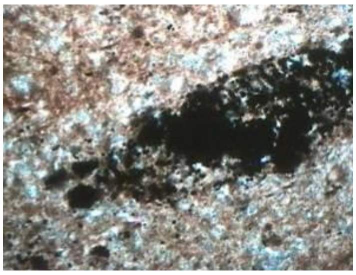
Lithotype 1 (L-1) – clayey aleurite pyritized agrillites (figure 2) – is abundant in the lower section of studied interval (2822.3–2816.2 m.). Rocks are brownish dark-grey, whereas the color intensifies up-section. The rocks are homogeneous with concealed lamination; contain concretions and pyrite fines, tubular and scallop shell remains, phosphatized onychite layers, as well as isolated poor fossil burrow traces.



Flaky matrix with aleuritic impurities; Thin section 1; nH 2; depth 2816.5 m.



Chlorite and accumulations of loam pyrite; Thin section 1; nH 1; depth 2816.5 m.



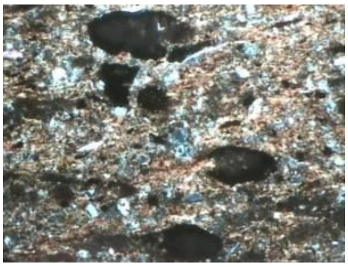
Pyritized burrows; Thin section 1; nH 2; depth 2816.5 m.

0 0,1 0,2 0,3 0,4 мм

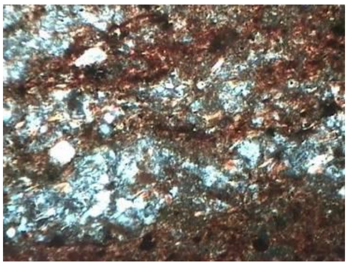
Figure 2. Characteristic features of clayey aleurite pyritized agrillites – lithotype 1.

Microscopically, pelitic and lepidoblastic textures were observed in argillites as a result of formed flaky-fibrous argillaceous hydromica (64 %) aggregates. The following was observed throughout the thin section: fine-aleuritic (up to 0.01–0.02 mm.) quartz and biogenic siliceous material (20 %), composing microclusters in the primary rock matrix, and radiolarian shell skeleton remains; irregular distributes loam pyrite (10 %); dispersed tiny (less than 0.01 mm.) rhombohedral and irregular dolomite grains (1 %); isolated chlorite grains. Pyrite being confined to burrows provides shells for radiolaria, belemnite and acline to the extent of complete pseudomorph formation.

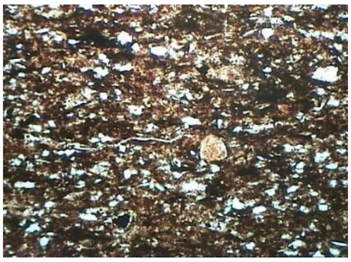
Lithotype 2 (L-2) – clayey-siliceous brownish-black bituminous argillites (figure 3) – extends to 2816.2–2814.1 m. These rocks are proportionally composed of pelitic and lepidoblastic clayey (43.2–49.3 %) and microcrystalline and biogenic siliceous (47.6–53.3 %) material which are normally and lenticular distributed and include algae, onychite and belemnite, radiolarian shell and sponge spicule remains. After secondary mineralization uneven occurrences of pyrite (2.1–5.4 %) and calcite trace impurities (2.8 %) are well-defined. Dispersed organic matter, evenly and layerwise distributed, can commonly be found in these rocks and, in this case, the rock matrix has a reddish brown tint, where, thin, relevant to bedding, open cracks are evident.



Oreintation of hydromica and radiolarian shells;
Thin section 6; nH 2;
depth 2813.98 m.



Siliceous material lenses;
Thin section 3; nH 2;
depth 2815.62 m.

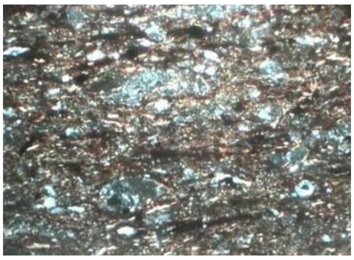


Matrix saturated with organic matter, layer-by-layer cracks;
Thin section 5, nH 1;
depth 2814.53 m.

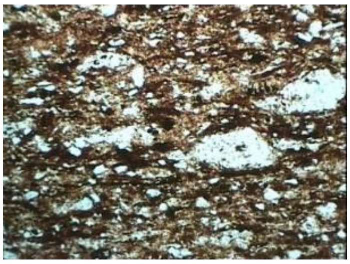
0 0,1 0,2 0,3 0,4 мм

Figure 3. Characteristic features of clayey-siliceous argillites – lithotype 2.

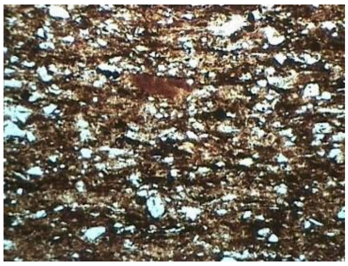
Lithotype 3 (L-3) – brownish-black bituminous argillites: clayey (37.1–37.7 %) - *siliceous* (49.2–51.5 %) *carbonated* (figure 4) –overlies vertically at the depth interval of 2814.1–2813.2m., having non-uniform horizontal lenticular and gently dipping foliated bedding and lepidoblastic texture.



Siliceous material and hydromica;
Thin section 8; nH 2;
depth 2813.26 m.



Poorly preserved radiolarian;
Thin section 8; nH 1;
depth 2813.26 m.



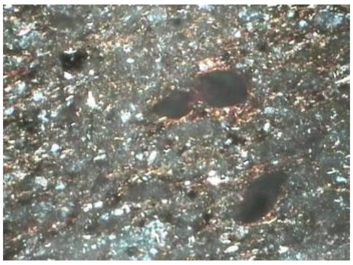
Uniformly and lumpy distribution of organic matter;
Thin section 7, nH 1;
depth 2813.77 m.

0 0,1 0,2 0,3 0,4 мм

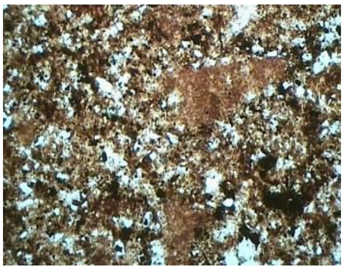
Figure 4. Characteristic features of clayey-siliceous argillites – lithotype 3**.**

Rocks are carbonized (ankerite – up to 0.5 %, calcite – 7.7–10.8 %) weakly pyritized and contain dissolved and recrystallized organogenic remains, often pyrite-calcite replaced: belemnites, onychites, scallop shells, radiolaria, poorly preserved sponge spicules. The organic matter is thin, evenly and layerwise dispersed in the rock matrix, tinting it reddish-brown; and this organic matter is often concentrated as lumps and inclusions. Subvertical and inclined cracks are fractured into large blocks in the top rock, where white calcite can be observed on the sheeting planes. Throughout the layer the characteristic crude oil can be perceived.

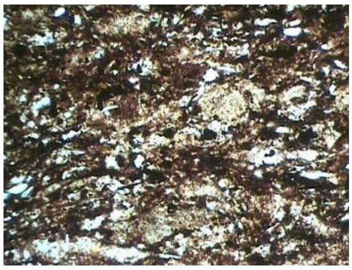
Lithotype 4 (L-4) – brownish-black bituminous argillites: clayey (25.1–35.6 %) - *finely-washed high silica* (49.9–64.6 %) (figure 5) – is within the depth interval of 2813.2–2801.9 m. The rocks are composed of weakly dyscrystalline siliceous material and flaky (rarely, fibrous) hydromica aggregates, including thin (up to 0.02 mm.) siliceous bands, concretions and pyrite fines (4.7–10.3 %) and calcite (0–9.6 %).



Siliceous material, hydromica flakes, calcite fines; Thin section 10; nH 2; depth 2810.8 m.



Organic matter in radiolarian shells; Thin section 13; nH 1; depth 2804.87 m.



Layerwise organic matter concentration, pyrite fines; Thin section 16; nH 1; depth 2801.96 m.

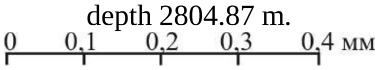
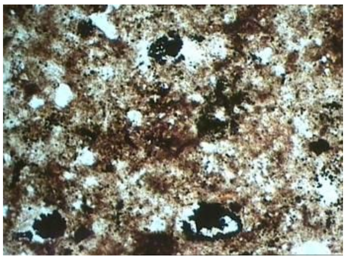


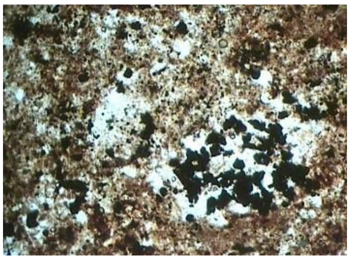
Figure 5. Characteristic features of clayey-siliceous argillites – lithotype 4.

Macrofauna includes fragments of variform onychite belemites, conical tubular shells, extending to 4 mm. and valva fragments; while microfauna includes desma, dissolved and/or intensely recrystallized siliceous radiolarian skeletons, their pyritized fragments with cellular texture. The rocks are organically saturated, whereas, this organic matter is correlated to either clay substance or siliceous rock constituent. The cavities in radiolarian shells are filled with this organic matter, which, in its turn, could be both dispersed and concentrated forming lumps, often, of bedding orientation. The dense rocks exhibit greasy surface and strong crude oil odor. The cores from above-described wells are split-off layered sections.

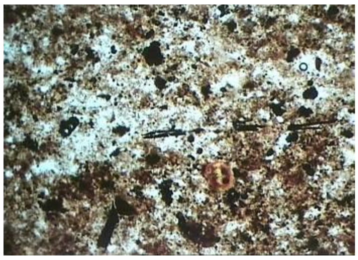
Lithotype 5 (L-5) – dark-grey siliceous argillites (38.1–44.9 %) - *clay* (41.6–50.7 %), *homogenous with pelitic texture* (figure 6), poorly – preserves onychites, radiolaria and plant tissue fragments within the depth interval of 2801.9–2795 m.



Pyritized radiolaria; Thin section 17; nH 1; depth 2800.4 m.



Pyrite and siliceous material; Thin section 18; nH 1; depth 2797.4 m.



Fine plant detritus, spicula; Thin section; nH 1; depth 2797.4 m.

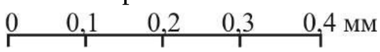


Figure 6. Characteristic features of clayey-siliceous argillites – lithotype 5.

The pyritizied (8.9–9.1 %) and weakly carbonized (2.3–4.4 %) rocks are composed of non-uniform decrystallized siliceous and clayey pelitic material, containing reddish brown dispersed organic matter, terrigenous quartz (1 %), and remains of fragmented macrofauna , sliced-abraded plant organic detritus. In decrystallization areas of siliceous material to fine-grained chalcedony quartz aggregates, an increasing pyrite content, as thin fines and small irregular grain concentrations, as well as layerwise pyritization have been observed. Comparable to lithotypes 2–4, the organic material content in rocks of lithotype 5 decrease.

4. Lithotypes in cross-section

Clayey-siliceous bituminous argillites (lithotypes 2, 3, and 4) distinguished in the mid-section of the total thickness 14.3 m., comparable to underlying (lithotype 1) and overlying (lithotype 2) agrillites, exhibit more homogeneous micro-texture, smaller component particle size, enriched siliceous material (quantitatively, verging to approximate or exceeding the clay constituent content itself), sometimes enriched calcite and pyrite (figure 7). According to the above-described specific texture and composition, Bazhenov suite is characterized by these argillites. Rocks of lithotype 1 are related to Georgiev suite, while clayey-siliceous argillites (lithotype 5) contribute to the lower section of Kulomzin suite.

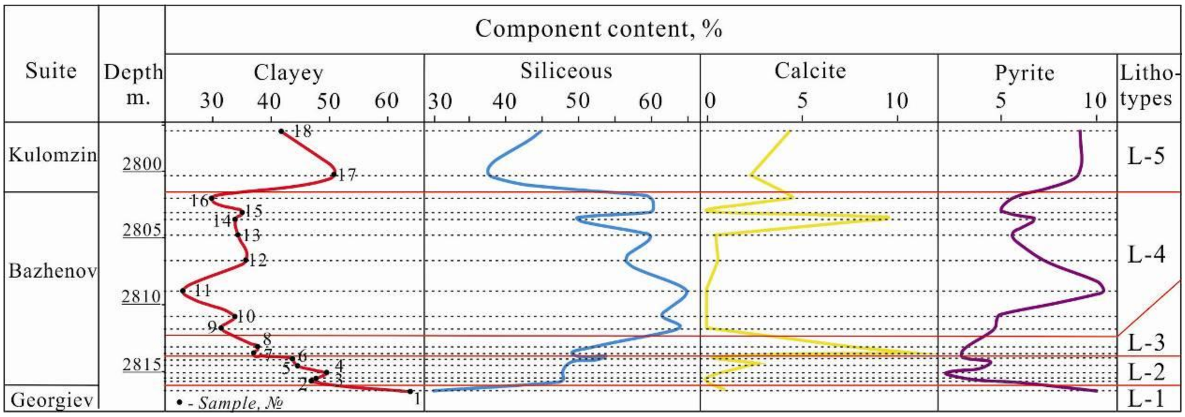


Figure 7. Argillite component composition in Georgiev, Bazhenov and Kulomzin suites in Western-Kvenzersk (well № 4), according to X-ray diffraction analysis data.

5. Voids and bitumen

There are layer-by-layer, sub-parallel and cross-cutting bedding fractures of 0.01–0.02 mm. in the argillites. They are exclusively confined to the lithotypes distinguishing Bazhenov suite. Their formation could be associated with pressure relief, which, in its turn, is conditioned by oil-gas generation within the Bazhenov argillite thicknesses. The factual evidence of this is based on the fluorescence-microscopy analysis results which determined the presence of a wide bitumen spectrum: from light (bluish fluorescence) to resin-asphaltine (dark brown fluorescence), having dotty, uniform, scattered, spotty, and fractured distribution. The Bazhenov argillites are marked by a high content and presence of syngenetic (in rocks) and epigenetic (in cracks) composite bitumen, where resinous (light-yellow fluorescence) bitumen is predominate. The argillaceous suite rocks also contain composite bitumen; however, highly light mobile (blue and light yellow fluorescence) and greasy (yellow fluorescence) epi-bitumen are rather predominate here, having a scattered, dotty and fracture-type distribution. Redistribution of bitumen occurs not only within the Bazhenov formation (where rather light bitumen is located in the cracks), but also via the bitumen migration path: bitumen migrates from Bazhenov suite argillites to underlying and overlying rocks in Georgiev and Kulomzin suites.

6. Discussion

According to the widely-accepted concept, the accumulation of Bazhenov suite rocks is associated with the conditions of Late Jurassic-Early Cretaceous intensive sea basin transgression. Whereas, Georgiev suite sediments deposited under the conditions of low oxygen saturated near-bottom waters (traces of sediment-dwelling organisms); Bazhenov suite sediments deposited under the intensive restoration conditions of depositional environments and stagnant water basins, the indicators of which are the following two facts: finely-dispersed rock and a high content of the indicator mineral-pyrite. Clayey silt was enriched by biogenic and chemical siliceous and carbonate matter and dispersed organic matter as well, and resulted in the formation of the bitumen thickness of fine-washed and laminated argillite source rocks with composite syngenetic bitumen composition, which, in its turn, deposited in areas of relatively deep silt depressions. Sediments in the lower Kulomzin suite accumulated in a stable environment with low hydrodynamic activity, and under more or less deep water conditions (terrigenous impurities, plant detritus).

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