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Stratigraphy and correlation of Lower-Middle Jurassic sediments in SE West-Siberian petroleum-bearing province

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Abstract. Based on the investigation of Lower-Middle Jurassic sediments in SW Siberia, isochron reference clay and coal horizons confined to the roof of chronostratigraphic units were identified; bed series from pre-Jurassic formation bottom to U_{10} coal layer were divided; structural features and distribution of regional cyclites J_{10}-J_{17} in the sequences and throughout the area were determined.

1. Introduction

The studied area is located within the south-east of Tomsk Oblast, whereas, in terms of tectonic relationship - within the SE West-Siberian platform, to the north of Kalgach meso-block, including Boltnoe, Kazan, Ponomarev, Rogalev, West-Somov and Novosomol uplifting (figure 1).

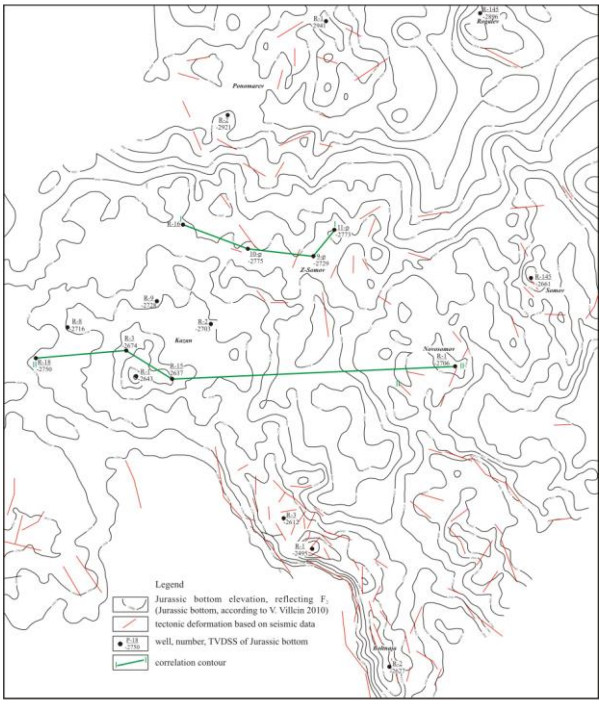

Figure 1. Structural map of reflecting horizon F_2 (Jurassic bottom, according to V Vilkin, 2010)

Hydrocarbon potential of this territory is correlated with Upper Jurassic sediments, where Kazan and Boltnoe oil fields are being developed. In recent years special consideration is being given to Early Middle Jurassic rocks which are potentially hydrocarbon bearing, in view of limited oil flow recovery and flow properties observed throughout thickness sequence.

The major target of the following research includes dismembering and correlation of the Lower - Middle Jurassic sediments in the sequences, as well as profile planning.

2. Initial data

Research data included the following: structural map of reflecting horizon F_2 (Jurassic bottom, according to V Vilkin, 2010); spontaneous potential (SP) diagrams, apparent resistivity, (AR), induction resistivity (IR), natural radioactivity (NR), and neutron loggings and core samples.

Pre-Jurassic formation surface embraces dismembered relief and numerous tectonic deformations (figure 1). Currently, 19 drilled wells have entered pre-Jurassic formation within the studied area. However, these wells are wide-spaced which hampers the possible correlation of geological sections and further investigation of rock distribution in profile plan.

Lower-Middle Jurassic sediments are marked by vertical and horizontal inhomogeneity. Due to the lack of paleontological data, layering is based on the results of geologic-geophysical surveys, spore-pollen analysis, and analogy with contemporaneous rocks containing marine organism remains. The following researchers gave a detailed stratigraphic description of Lower and Middle Jurassic formations in SE West Siberia: F.G. Gurari, V.P. Devjatov, A.M. Kazak, L.V. Smirnov, A.E. Ekhanin, V.I. Moskvin, L.I. Egorov, R.V. Belov, O.S. Chernov, V.A. Kontorovich, et al [1, 2, 3, 4, 6, 8, 9, 10, 11, 12]. Lower Jurassic sediments were tapped in SE West Siberian petroleum province within Ust-Tym, Nurolsk, Barchar and other mega-depressions. However, Middle Jurassic sediments (J_{15} and upwards) have been investigated to a lesser extent.

Dismembering and correlation of Lower-Middle Jurassic sediments (from pre-Jurassic formation bottom to coal layer U_{10}) were based on the principle of sedimentation cycle [7,5], including the following:

1) unified sedimentation sequence, not involving perturbation and concealing of large stratigraphic unit sections, has been observed;
2) horizon markers showing isochrohism features within a relatively limited area and well-defined field-geophysical characteristics have been identified in the sequences.

3. Results and discussion

Horizon markers in studied sequences are defined as coal layers (U_{10}, U_{11}, U_{12}, U_{13}, U_{14}, U_{15}), argillaceous formations (Togur suite and middle subsuite of Urman suite) and Jurassic sediments with crust weathering rocks – Paleozoic sediments contact. Chronostratigraphic units in correlating the sequences are cyclites wherein the top are either underlying coal marker layers of continental sedimentation and / or argillaceous formations formed in marine fresh lake basins.

Basically, regional cyclites are composed of small priority cyclites (zonal and local) which exhibit changing composition orientation from layer to layer and complex texture, i.e. these cyclites are composed of rock layers or beds with gradual and/or sharp boundaries. Accordingly, it should be noted that there is a difference in the two terms: “cyclite” and “layer”. The latter is homogeneous three-dimension geological body, bounded above and below by subparallel surfaces. Cyclite – association of at least two layers (beds) recurring in time and space and being the composition reflection of a specific sedimentation cycle. Relating cyclites as chronostratigraphic units of different priorities significantly improves reliable correlation of sedimentary formations, especially for changing lateral continental formations, whereas, reality, sand layers formed at different periods are correlated.

Indexing regional cyclites (as described in previous research [5]) is based on the number of coal layer underlying corresponding formation roof. Genetic relation of sand and coal layers within cyclites can be explained by the facies-phase and facies-cycle sedimentation models: rock unit alteration in sequences, consistent with two phases-tectonic activities in the bottom and tectonic quiescence in the roof. It is well-known that regional continuous coal layers formed during a period of maximum tectonic quiescence, relief leveling and minimum water environment dynamic are relevant to the completion of large sedimentation cycles, which, in its turn, indicates the interstratified rock system of priority regional cyclites.

Integrating all stratigraphic research data of previous years, a conceptually updated stratigraphic chart of Lower-Middle Jurassic sediments (figure 2) was compiled which included the alignment and correlation of the sequences (figures 3 and 4).

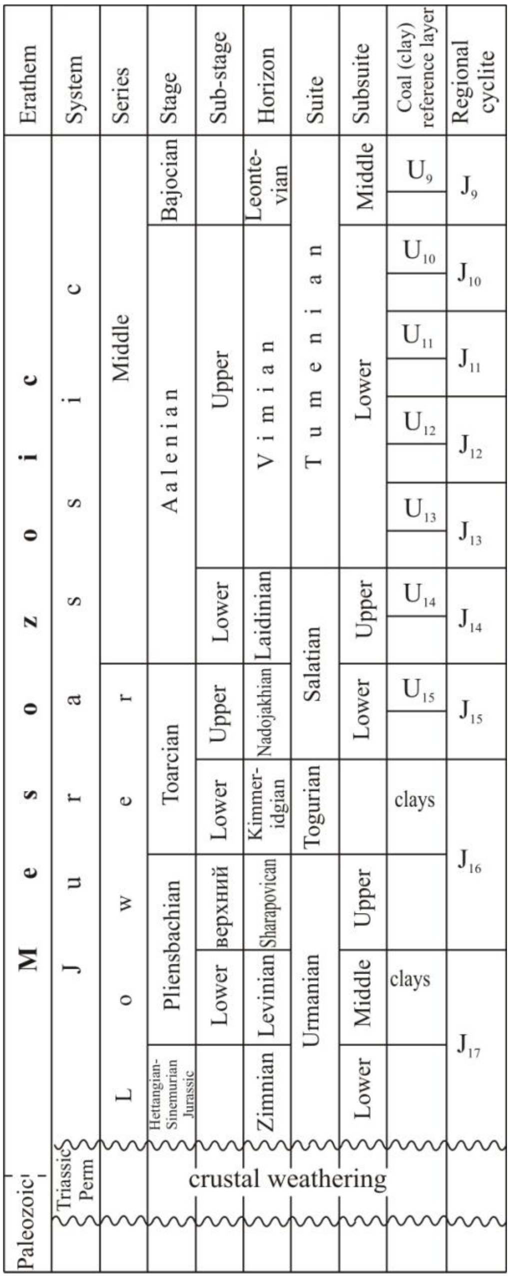

Figure 2. Stratigraphic chart of Lower Middle Jurassic sediments in SE West-Siberian platform (compiled by A Ezhova, 2013)

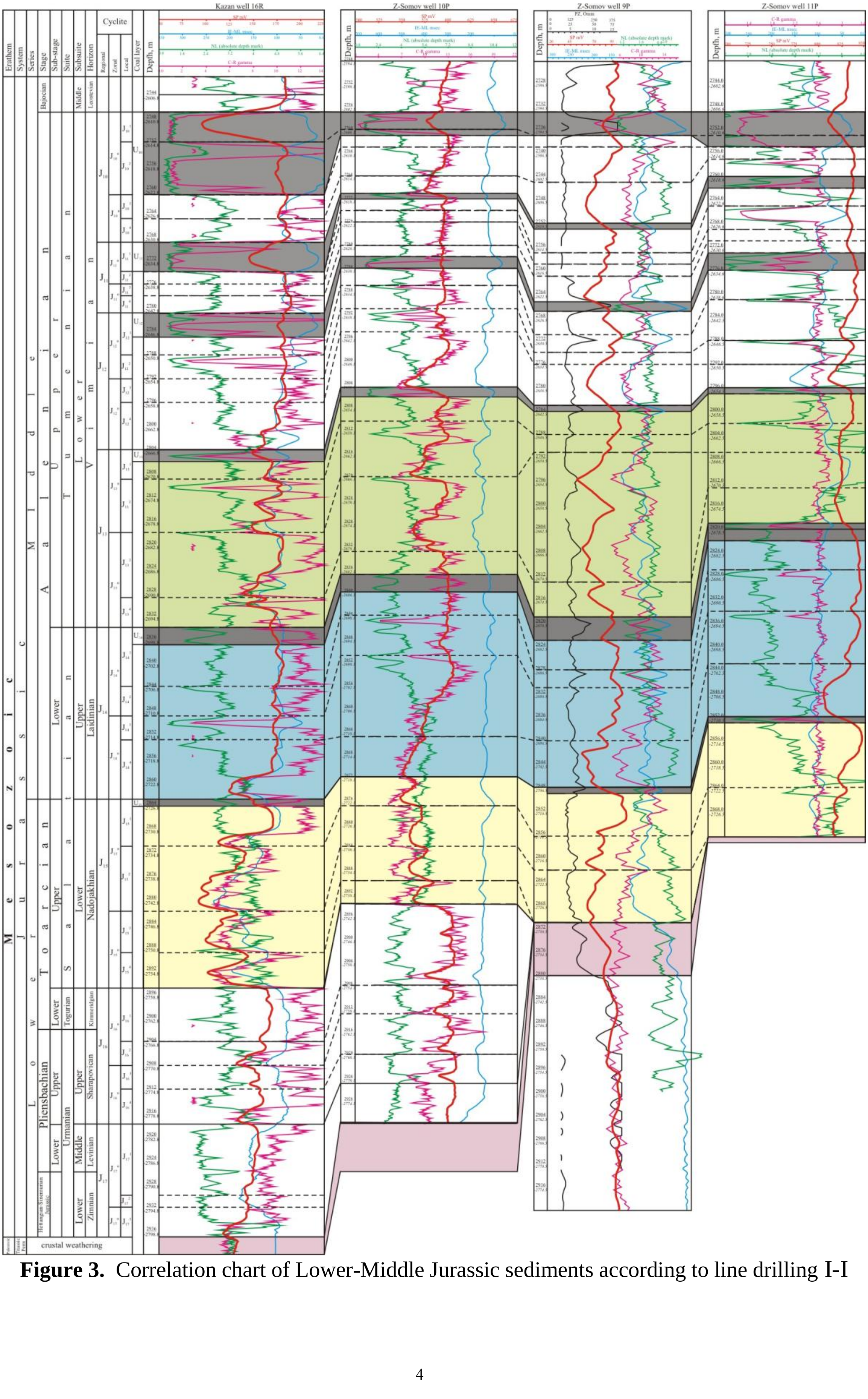

Figure 3. Correlation chart of Lower-Middle Jurassic sediments according to line drilling I-I

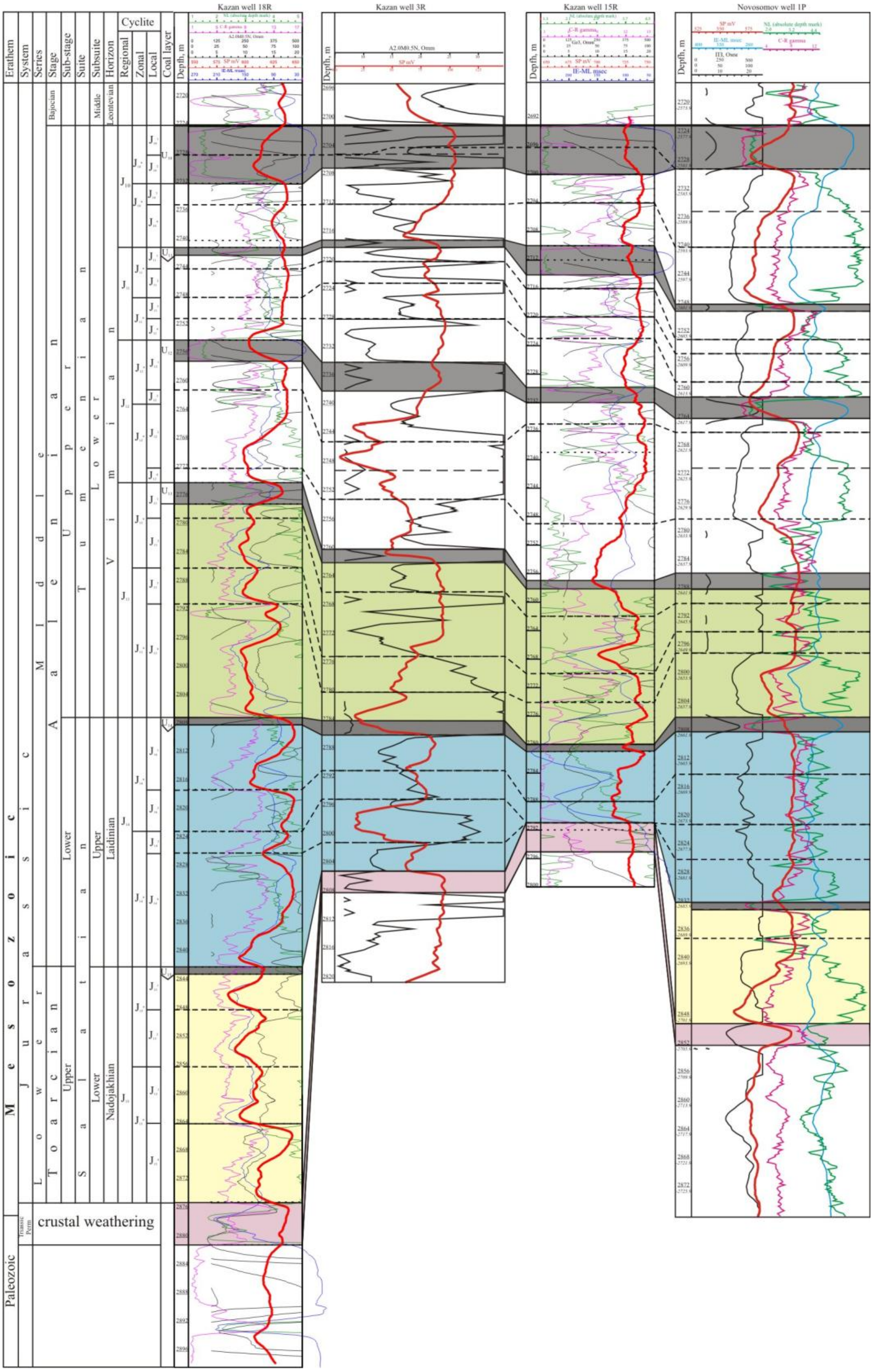

Figure 4. Correlation chart of Lower-Middle Jurassic sediments according to line drilling II-II

The flattening line is the roof of U_{10} coal layer which is considered to be the regional horizon marker in SE West Siberia. According to palynology data U_{10} layer roof is related to Aalenian sediments [3] and is the interface between the lower and middle subsuite of Tumen suite, as well as Vimian stratigraphic horizon roof [6, 2].

Logging response show that U_{10} layer exhibits low values, gamma ray and neutron logging curves, high resistance, low electroconductivity and frequent deep reversed-polarised anomaly. Layer thickness changes from 3 to 14 m, moreover, this layer delaminates and is separated by clay bands.

The regional *cyclite* J_{10} thickness in Kazan uplift embraces 16-22m; in Zapadno-Somov uplift - 12-19m; in NovoSomov and Somov uplifts increases from 25 to 28m; in Ponomarev uplift - sharply increases from 32 to 33m; while in Rogalev and Boltnoe areas decreases down to 19 and 15m., respectively.

The regional cyclite J_{10} is, in some cases, distinctly or conventionally subdivided into zonal $J_{10}^{в}$ (upper) and $J_{10}^{н}$ (lower) cyclites, whereas, further they are divided into local cyclites J_{10}^{1}, J_{10}^{2}, J_{10}^{3} and J_{10}^{4}.

More or less, practically in all sequences of the local cyclite bottoms, especially J_{10}^{4} sandstones, frequently, with carbonate cement, are deposited (pertaining to core sample from Ponomarev well 1P and increased neutron logging values).

Coal layer U_{11} thickness is 1m., increasing up to 5m. in Kazan 16R and Somov 145R wells, while in Ponomarev wells 1P and 2P from 3 to 4m. Regional *cyclite* J_{11}, as described above, is divided into 4 local cyclites, in the bottom of which, sandstones or aleurolites are deposited, while in the top – thin coal interlayers.Cyclite U_{11} thickness ranges from 11 to 20 m., increases up to 22-31 m within Ponomarev and Somov areas, while in Boltnoe well 3-only 6 m.

Coal layer U_{12} with thickness of 2-4 m is rather distinct in the sequences with minimum values of gamma ray and neutron logging, high resistance and low electroconductivity. Regional cyclite J_{12} has inconsistent thickness – from 14 to 33 m and is divided into local cyclites, where sandstones, and even gravelstones are deposited in the bottom (according to core-log data correlation from Zapadno-Somov 9P and Ponomarev 1P wells) and distinct coal interlayers in the top (according to core-log data correlation).

Regional cyclite J_{13}, separated from overlying coal layer U_{13} sediments and having a thickness of 1-3 m embraces a sequence of sand (2-4 m), clay (1-3m) and coal (1 - 1.5-m) interlayers. Due to the existing differential lithological composition, the local cyclites J_{13}^{1}, J_{13}^{2}, J_{13}^{3} и J_{13}^{4} are distinctly identified within the sequences. The deep-seated anomaly is confined to cyclite J_{13}^{4}. The core samples from Zapadno-Somov 11R and Ponomarev 2P wells exhibited coarse-grained sandstones, while the core samples from Kazan 8R well- gravelstones and sandstones with pebbles. Thetre are sandstones, often with carbonate cement in the bottom of overlying local cyclites and clay and coal in the top. The total thickness of regional cyclite J_{13} ranges from 20-37 m., whereas in the cross-sections of Somov 145R and Boltnoe 2P wells, the cyclite J_{13} rocks overlie crust weathering formations having reduced thickness of 15m and 10m., respectively. The bottom of cyclite J_{13} is the lower interface of the upper substage of Aalenian sequence, lower subsuite of Tumen suite and Vimian stratigraphic horizon (figure 2).

The coal layer U_{14} is often splitted into two layers (Kazan 9R, 2R, 16R wells; Zapadno-Somov 10P, 9P and 11P wells; Ponomarev 1P well) having a thickness of 1-4m. Regional cyclite J_{14} is distinctly different from the above-described cyclite J_{13} in its argillaceous composition, and as the overlying cyclites, regional cyclite J_{14} is divided into local ones. However, in this case, sand sediments are mainly confined to the bottom- J_{13}^{4} , whereas, core samples from Zapadno-Somov 9R and Kazan 8R, 9R wells showed the presence of conglomerates, gravelites, sandstone with gravel, while core samples from NovoSomov 1P, Ponomarev 2P and Zapadno-Somov 11P – medium to fine grained sandstones. Fine-grained sandstones, and often aleurolites are deposited in the bottom of local cyclites J_{14}^{3}, J_{14}^{2}, J_{14}^{1}. The roof of these cyclites are apparently evident on interpretated logs and were verified by coal interlayers detected in core samples (Zapadno-Somov 9P, 10P, 11P, Kazan 16R, 18R and Ponomarev 2P wells).

However, the regional cyclite J_{14} has a rather distinct sand sequence as found in some wells, i.e. Kazan wells 18R, 8R, 3R, 9R, 2R and 15R. The layers in these wells have a rather profound SP amplitude and are confined to cyclites J_{14}^1, J_{14}^2 and J_{14}^3 whereas laminating coal interlayers are not well-pronounced. Total thickness of cyclite J_{14} involves 26‒38m. , while in Kazan 3R, 8R and 15R wells it decreases to 10‒21m., as eroded rocks lie on argillaceous-siliceous crust weathering sediments.

Stratigraphically, regional cyclite J_{14} is correlated to lower substage of Upper subsuite Salatian suite and Ladinian horizon (figure2).

The roof of regional cyclite J_{15} is determined by the coal layer U_{15} defined by core samples from Zapadno-Somov 9P, 11P, Kazan 9R, and NovoSomov 1P wells. According to the Zapadno-Somov 10P well cross-section, this cyclite is poorly-defined and the interface is determined relative to the clay roof. The regional cyclite J_{15} bottom is determined relative to the Togur suite clay roof (Kazan 16R, Zapadno-Somov 10P , Ponomarev 2P and 1P wells) and / or Pre-Jurassic formation roof (Zapadno-Somov 9P, 11P, Kazan 18R, 9R, NovoSomov 1P, Rogalev 145R wells). Erosion contact on the interface of cyclite J_{15} and pre-Jurassic formations (crust weathering) was described: breccia, conglomerate-breccia, gravelites overlie argillaceous-siliceous rocks (NovoSomov 1P, Zapadno-Somov 9P, 11P and Kazan 18R and 8R wells).

Regional cyclite J_{15} thickness is rather inconsistent: from 17 to 40m., while these sediments are absent in Kazan 2R, 3R, 8R and 15R wells. According to production logging data and investigated core samples, well-defined local cyclites J_{15}^1, J_{15}^2, J_{15}^3 and J_{15}^4 ,embracing clastics in the bottom and argillaceous-coal interlayers in the top, are observed in “total” regional cyclite J_{15} sequences (Kazan 16R, 18R, 9R, Ponomarev 2P, 1P wells).

Regional cyclite J_{15} is associated with upper substage of Toarcian stage, lower subsuite of Salatian suite and Nadojakhian horizon, while its roof is along the Lowerr and Middle Jurassic system series boundary (figure 2).

Togur suite (Kimmeridgian horizon) was revealed in Kazan 16R, Zapadno-Somov10P and Ponomarev 2P, 1P wells. Based on core sample description this suite involves dark gray, practically black thin – layered argillites with interlayers and lenses of aleurolites and coal, the age of which was determined as Lower Toarcian by analogy with relevant faunal marine genesis sequences [2,3,4, 6, 8, 10, 11, 12]. The thickness ranges from 7 to 27 m.

Interlaying rocks refer to Urman suite. Upper Urman subsuite has been identified as J_{16} layers [7, 8, 13, 23]. The authors propose to consider this sequence as regional cyclite $Ю_{16}$ being subdivided into local cyclites J_{16}^4, J_{16}^3, J_{16}^2 and J_{16}^1; the roof of the latter cyclite (according to cyclite identification classification [7]) is marine argillite sediments of Togur suite. This structure is well-defined on interpretated loggings and investigated core samples from cross-sections of Kazan 16R, Zapadno-Somov 10P and Ponomarev 2P wells, and probably, Ponomarev 1P well. The sand section of regional cyclite J_{16} (according to the stratigraphic chart) is identified as upper substage of Pleinsbachian stage, upper subsuite of Urman suite and Sharapavian horizon (figure 2). The thickness of regional cyclite J_{16} in the studied territory is 25‒46 m.

Underlying sequence is identified as regional cyclite J_{17} based on the description of investigated core samples from Ponomarev 2P and Kazan 16R well cross-sections. According to core sample description these sediments are subdivided into local cyclites, including aleurolites in the bottom and argillites in the top of each cyclite. Upper argillite sequence is identified as lower substage of Pleinsbachian stage and is related to middle subsuite of Urman suite and Levinian horizon. The core sample from Kazan 16R well at a depth of 2930m showed sandstone and along its bottom the lower boundary of local cyclite J_{17}^1 was defined.

Underlying Hettangian-Sinemurian rocks are probably of related to lower subsuite of Urman suite and Zimnian horizon. The total thickness of the regional cyclite J_1 in Ponomarev 2P is 46m and in Kazan 16R- 19m.

Pre-Jurassic formation in the investigated area is described as argillaceous-siliceous shales and probably related to crust weathering rocks. Paleozoic limestones have been identified in the core samples from Kazan 18R well (depth-2882m.), 8R (depth-2855m.) wells, as well as from Kazan 15R (depth – 2791m.) and 3R (depth-2808m.) wells and Zapadno-Somov 9P (depth-2880m.).

4. Conclusion

1. Penetrated thickness in investigated Lower-Middle Jurassic sediment sequence (from pre-Jurassic formation to the top of coal layer U_{10}) changes from 45 to 199m., while the total thickness in Ponomarev 2P well is 276m.

2. Application of sedimentation cyclite principles in studying the Lower-Middle Jurassic formation provided the further identification of chronostratigraphic units and possible observation of their horizontal and vertical sequence development.

3. In terms of hydrocarbon potential the most significant are cyclite J_{13}, J_{14} and J_{15} rocks. The alteration of sandstone reservoir rocks and argillite screen rocks shows oil-saturation characteristic features.

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