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## Lithologo-facial, geochemical and sequence-stratigraphic sedimentation in Naunak suite (south-east Western Siberia)

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**Abstract.** The paper describes lithofacial, geochemical, sequence-stratigraphical research results of facial environment reconstruction and oil and evaluation gas – bearing capacity potential for Naunak suite in south-east Western Siberia.

### 1. Introduction

Nowadays, the deficiency of oil\gas productive formations in West Siberian central territories is quite significant, so more and more researchers are turning to the remote territories of this region. The main problem in oil\gas potential area identification in the south-east Western Siberia is considered to be the complicated reservoir distribution pattern due to the areal sedimentation genesis.

### 2. Materials and research methods

The target of this research is Naunak suite of Late Bathonian-Callovian-Oxfordian, formed during the intermediate sedimentogenesis in south-east Western Siberia [5]. The research is based on detailed core analysis of newly drilled wells in Snezhnaya area (figure).

Backstripping and effective forecasting of natural oil\gas reservoirs are based on the detailed comprehensive core analysis with the use of lithologo-petrographic, geochemical, luminescent-microscopic, X-ray-fluorescent, biostratigraphic, sequence – stratigraphy methods were applied, as well as geophysical survey interpretation [4]. The sequence – stratigraphy method has been applied due to the fact that Naunak suite was formed during the intermediate sedimentogenesis. Lithologo-facial depositional changes in vertically studied wells are due to the adjacent sea level fluctuations and sediments entry into accumulation area [7].

### 3. Research results

As a result of comprehensive study of deposits, the following factors were defined: lithofacial rock groups of silt-sandstones, sandstones, silt-mudstones; genetic features of these sediments; backstripping for this period of time and oil\gas-bearing potential have been determined [1, 2].

Silt-sandstones were formed in lacustrine-alluvial environments. The structure is uniform, sub-oriented due to the orientation of flattened fragments parallel to the bedding plane. There are rare clayey intraclasts (fragment size from 0.2-0.5 to 1.0-3.0 cm) and carboniferous plant detritus is plentiful. Fragments of ferns, *Czekanowskia* torn leaves and coniferous indicate their burial history in rough hydrodynamic environment. The texture is aleuro-psammitic. Fragment size varies from 0.05-0.12 mm, but the predominate size is 0.08-0.01 mm. Fragments make up 90% of the rock volume. Clastic fragments sorting are medium. Fragment shape is subangular, subrounded, and rarely angular. The mineral composition of the fragments is the following: quartz, feldspars (mostly potassium –



orthoclase and microcline, rarely acid plagioclase), while rock fragments are presented by microquartzite and quartz – sericite schists. Cement comprises 10% of the rock volume where its structure is porous-pedicular. Hydromica dominates in the cement, however, chlorite, sericite, muscovite, kaolinite, bituminous substances occur rarely.

The bituminous substance is dark-brown and fills interstitials, penetrating into the cementing mass as skins around the grains.

Under the fluorescence microscope the rock has a cemented and porous bituminous structure, where bitumen content is 0.04-0.06%. Bitumen composition varies from resins and asphaltine components to oily whereas bitumen of oily and oily resinous composition predominate (light-yellow and light-brown luminescence). Hydrocarbons have an odor.

Rock have been subjected to epigenetic changes defined in quartz fragments corrosion and regeneration. Plastic deformation pronounced by the bending of chlorite, muscovite and sericite flakes, as well catalysis and feldspar grain decomposition forming silicon-kaolinite aggregates. These sediments could be potentially oil-gas productive.

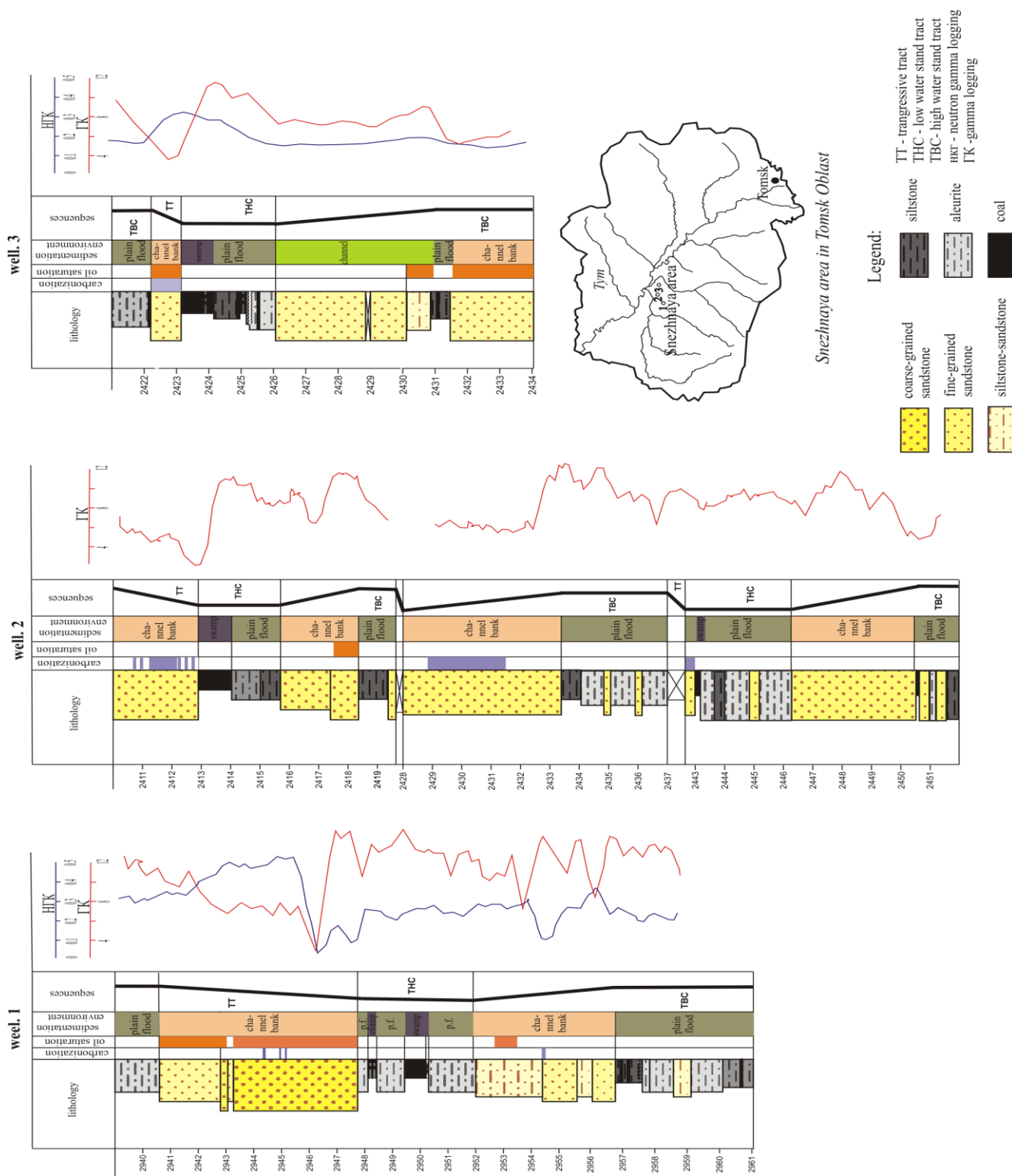
The second lithofacial group includes sandstones and feldspar greywackes formed in the river bed environment (meander bars, river bed shoals, levees). The rock texture is poorly oriented due to the orientation of flattened fragments parallel to the bedding plane. Thin cracks less than 0.01 mm filled by dark-brown bituminous substance occur along these lines. The rocks have low angle-wave-like, horizontal, lenticular bedding due to micaceous-coaly-clayey material inwash. Coal lenticules (0.1-0.2 cm) occur rarely. In places the bedding is deformed by elements of slumping. Sandstone texture is medium-fine-grained. The fragments content is 85% of the rock volume. The fragment sorting is medium where the fragment size varies from 0.05-0.04 mm with predominate sizes of 0.2-0.3 mm. Fragment mineral composition is the following: quartz (60%), feldspars (20%) (orthoclase, microcline, plagioclase rarely) while the remaining mass is characterized by microquartzite, zircon (individual grains). Quartz occurs in sub-angular and sub-rounded fragments. The extinction is cloudy and rarely mosaic. Feldspar fragments are sub-rounded, often tabular in shape. Microquartzite fragments are sub-rounded composed of coarse-crystalline quartz aggregates. The cementing mass is 15% of the rock volume. The cement structure is porous-pedicular. The mineral cement composition is mainly hydromica with sericite, chlorite, and carbonates inclusions of dark-brown bituminous substance. The bituminous substance fills the interstitials penetrating into the cementing mass.

Under the luminescence the sandstones have a porous, cement, and fissure- bituminous texture. The bitumen composition varies from resins and asphaltene components to oily ones, where bitumen of oily and oily resinous composition predominate (light-yellow and light-brown luminescence). The bitumen in fissures are of resinous - asphaltene composition where bitumen migration from the fissures into the rock is observed. Epibitumen content is 0.08%. As the rock has a hydrocarbon odour it could be considered as a reservoir.

Epigenetic changes in the rock are more intensive than those of the first lithofacial group, which, in its turn, shows significant eroded and regenerated quartz fragments. Feldspars are disintegrated with further silicon-clayey aggregate formation. There is an increased erosion and corrosion and regeneration level of silicon material in the horizons saturated by bituminous substance.

Silt-mudstones of the third lithofacial group were formed in lacustrine - swamp environments. The structure is oriented due to the orientation of flattened quartz fragments having siltstone size and parallel to the bedding plane. Orientation of clayey minerals and micro fissures filled by bituminous substance is in the same direction. Rock structures are aleurite and pelite. Stratification in the sediments is poorly identified – sub-horizontal, lenticular, wave-like, deformed by turbidity and embodied with light-grey siltstone inclusions. There are pyrite intraclasts from “loose” to lenticular of 0.6-0.8 cm. The rock is comprised of clayey minerals (mainly hydromicas) with detrital impurities (up to 15%) and individual zircon grains. Aleurite material is mostly comprised of unrounded and sub-rounded quartz fragments (size of 0.01-0.03 mm), rarely feldspars and microquartzites. Quartz fragments are poorly eroded and regenerated. Clayey materials are mainly hydromicas and sericite as

mixed-layered formations. The sections rich in clayey minerals are saturated by the bituminous substance providing the brown color. There are individual grains and pyrite globus (0.11-1.5 mm).



**Figure.** Baskstrippingb of facies enveronmeny in Naunak suite.

Under the fluorescence microscope the rocks have an irregular dispersed, spotted and fractured bituminous structures. Bitumen composition varies from resins and asphaltene components (dark-brown luminescence) to light ones (bluish luminescence). The bulk rock is dominated by bitumen of resinous composition (brownish luminescence). In the thin fissures (0.01-0.02 mm) predominate resinous asphaltene bitumens, rarely of oily composition (yellowish luminescence). The fissures are oriented sub-parallel to the stratification surface. According to the relationships, the bitumen entry in rock occurred continuously. The bitumen content is 0.06%. By the genesis the bitumens are mixed. In the bulk they are syngenetic, in the fissures - epibitumens. These sediments are considered to be oil\gas generating.

The above-described rocks of lithofacial groups are comprised of a rich complex of plant ichnofossils, which can be related to Naunak phytohorizon. The vegetation community includes horsetails (*Equisetites lateralis*), ferns (*Coniopteris latilobus*, *C. burejensis*), gymnosperms (*Phoenicopsis sibirica*, *Czekanowskia tomskiensis*, *Nilssonina urmanica*) and also numerous seeds (*Carpolites cinctus*). The coal bands and coaly rocks are determined in the rocks. There is pyrite which is an indicator of sedimentation condition reduction. There is thin carboniferous detritus inwash in the rocks which characterizes stratification.

Application of geochemical methods for studied wells provides more accurate classification, sedimentation reconstruction features, physico-chemical and geodynamic sedimentation environment. Lithochemical calculation of the modules according to Y Yudovich [3, 6] furthered the reconstruction of sedimentation conditions (table).

Lithofacial group		Al <sub>2</sub> O <sub>3</sub>	SiO <sub>2</sub>	K <sub>2</sub> O	TiO <sub>2</sub>	Fe <sub>2</sub> O <sub>3</sub>	TM	PM	AM	FM
Siltstone-mudstone	Siltstone	13.67	78.6	3.29	0.89	3.55	0.017	0.24	0.17	0.05
	Mudstone	19.48	74.21	1.48	0.57	4.25	0.029	0.08	0.26	0.06
		18.78	70.31	4.73	0.59	5.58	0.030	0.25	0.27	0.08
		21.71	69.07	3.94	0.49	4.8	0.020	0.18	0.31	0.07
		17.2	71.32	5.2	1.16	5.3	0.068	0.31	0.24	0.07
	Mudstone	23.88	67.69	4.2	0.67	3.56	0.030	0.18	0.35	0.05
Sandstone			71.54			2.63				0.04
	Sandstone	28.97	64.16	4.51		2.36	0.038	0.16	0.45	0.04
	Sandstone	17.17	75.68	3.84	0.91	2.4	0.050	0.22	0.23	0.03
Siltstone-Sandstone		20.01	79.99						0.25	
		13.17	86.66			0.17			0.15	0.002
		13.91	23.6		59.23	2.54	0.042		0.59	0.11
		16.74	75.32	2.45	0.81	4.68	0.048	0.14	0.22	0.06
	Siltstone	16.91	75.73	2.82	0.12	4.41	0.070	0.17	0.22	0.06

**Table.** Lithochemical data analysis.

Titanium module (TM = TiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub>) of clayey rocks proved to be higher than that of arenaceous ones and comprises 0.17-0.38 to 0.038-0.050. Besides, the increased module TM with values of 0.068-0.070 is associated to humid climates of sedimentation while the values 0.017-0.050 – to the semiarid climate. Against the background of the dominated semiarid environment in the studied area, humidization and crust weathering prevailed, where there was an increased iron content. The crust weathering fostered the formation of terrigenous rocks accumulating through time. The humid climate is related to transgressive sedimentation stages and is found in the sediments of wells close to the sea.

Increased humidity of the sea coast resulted in the growth of hydrophilous vegetation: horsetails, ferns and *Czekanowskia*. If the humidization is analyzed vertically then it refers to the early Naunak suite formation, i.e. Late Bathonian. Aridization is a characteristic feature of Callovian-Oxfordian sedimentation.

Based on the calculations of the alumo-silicon module ( $AM=SiO_2/Al_2O_3$ ), showing the rate of chemical weathering, the rocks formed due to the crust weathering destruction were identified. High values of AM (0.35-0.59) indicate the humid crust weathering washout.

The femic module ( $FM=Fe_2O_3/SiO_2$ ) was used to identify the products of igneous rocks redeposition. The calculation shows the absence of pyroclastic material in rock formation.

The analysis of elemental composition of studied sediments characterized the paliosalinity of the depositional basin. The absence of B, Cl, Na, Rb, Ca elements in the spectra and high content of Fe characterize its desalting, which was proved by the lithologo-facial and biostratigraphical analyses.

The potassium module ( $KM=K_2O/Al_2O_3$ ) [4] was calculated for oil\gas strata forecasting. The rocks with the coefficient 0.10-0.30 (sandstones of the river bed facies) may be considered to be oil\gas-bearing potential.

Geophysical data interpretation defined the reservoir properties and productive hydrocarbon formations.

Decreased values (on gamma-ray logging) and increased values (on neutron-gamma logging) indicated possible reservoirs.

Sequence-stratigraphic sectional layering method was applied to identify the structure and formation relationships in Naunak suite within Snezhnaya cross-section are related to the changeable migrating coast - line. Three main tracts were defined tracts of sedimentation systems conditioned by transgression and regression:

(1) tract of low water stand involves siltstones-mudstones with prograded bedding. During its formation the following were formed- flood plain facies, oxbow-lake facies and swamp facies. Singenetic bituminous rocks were found in the sediments of low water stand. The roof of this tract coincides with the transgressive surface, which is formed during the sea level rise and general transgression towards the continent.

(2) transgressive tract includes sandstones having retrograded bedding formed during fast sea level rise. Deposits of this tract are thought to be potentially oil-gas-bearing ones.

(3) tract of high water stand includes siltstones – sandstones, sandstones and siltstones. In calm hydrodynamic sea basin these deposits are flood plane facies and levees, and characterized by aggraded bedding.

#### 4. Conclusions

Based on the analysis of lithologo-facial, geochemical and sequence-stratigraphic structure features of Naunak suite in well cross-sections of Snezhnaya area the polyfacial conditions of their formation was defined. Three lithofacial groups of deposits have been defined. They characterize various conditions of continental basin sedimentation which were influenced by transgressive-regressive marine activity.

Sand bodies formed in the intermediate sedimentation conditions during the transgressive tract formation could be potential hydrocarbon accumulations in Naunak suite. At this time channel facies formed which was proved by geophysical research.

The horizons of the syngenetic bituminous siltstones-mudstones of the lacustrine-swamp facies formed during the low sea level conditions can be related to oil\gas source rocks.

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