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The Northern Siberia Geology and Hydrocarbon Systems - Project and the First Results

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SUMMARY

The northern Siberia occupies a wide area with several sedimentary basins with high hydrocarbon potential. To the north from it there is the Laptev Sea rift basin which is believed to be one of the most promising offshore areas for hydrocarbon discoveries, but is very poorly studied due to absence of offshore wells and sparse grid of seismic lines. We believe that deciphering the tectonic history of the study area will be resulted in more accurate interpretation of offshore seismic data, and here we present the main results of our structural studies. We interpret widely distributed pre-Jurassic unconformity as a result of extensional tectonics with a set of normal faults and some block rotation. The main compressional event occurred in late Mesozoic, overprinted previously formed extensional structures. Post-orogenic small-scale normal faults have been identified throughout the study area. The latest extensional event is represented by regular system of north-south-trending joints which are sub-parallel to normal faults forming the Laptev Sea rift system to the east from the study area. We interpret the north-south-trending joints as the western continuation of the Laptev Sea rift system.

The northern Siberia occupies a wide area with several sedimentary basins with high hydrocarbon potential. The most important tectonic domains are (Figure 1):

- Siberian craton with crystalline basement exposures (Anabar shield and Olenek uplift) and Mesoproterozoic to Mesozoic sedimentary cover;
- Enisey-Khatanga and Anabar-Lena depressions filled in with Mesozoic clastic rocks;
- Mesozoic Priverkhoyansk foredeep sedimentary basin filled in with clastic rocks;
- Taimyr, Olenek and Verkhoyansk fold belts;
- Grabens filled with Paleogene clastic rocks.

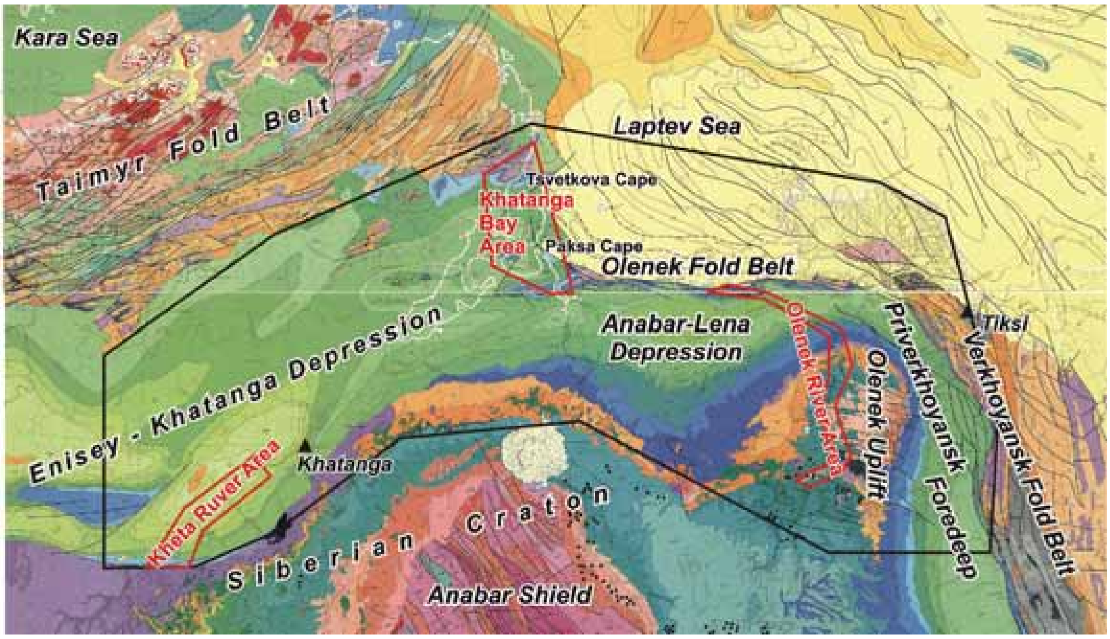

Figure 1 *Geological map of the northern Siberia (Petrov (ed.) 2004) and tectonic setting of the study area: black polygon is the project study area, red polygons with titles in red are the fieldwork-08 study areas.*

Sedimentary successions of the Siberian craton, Enisey-Khatanga and Anabar-Lena depressions as well as Priverkhoyansk foredeep basin contain both source rocks and collectors. Taimyr, Olenek and Verkhoyansk fold belts contain sedimentary and magmatic rocks varying in age from Mesoproterozoic to Mesozoic and show a multistage deformation history with the main compressional event in late Mesozoic.
The Northern Siberia Geology and Hydrocarbon Systems Project is carried out by geologists from several geological institutions from St. Petersburg, Moscow, Yakutsk and TGS-NOPEC Geophysical Company. The project is focused on the geological and hydrocarbon system study of sedimentary basins which framework the Siberian craton from north (Enisey-Khatanga and Anabar-Lena depressions) and east (Priverkhoyansk foredeep basin), as well as the Olenek fold belt.
Just to the north from the study area there is the Laptev Sea rift basin which is believed to be one of the most promising offshore areas for hydrocarbon discoveries, but is very poorly studied due to absence of offshore wells and sparse grid of seismic lines. However, geological map in the Figure 1 clearly shows that tectonic structures of the Taimyr, Olenek and Verkhoyansk fold belts are cut by the Laptev Sea shoreline, and margins of the Laptev Sea rift sedimentary basin overlap onshore structures of fold belts. Rifting and formation of grabens in the near-shore areas are coeval with rifting and formation of the Laptev Sea rift system. Therefore, structural style and Mesozoic to Cenozoic sedimentary succession of the onshore tectonic domains reflects a complicated history of interaction between onshore tectonic domains and Laptev Sea rift sedimentary basin, and onshore structural and

sedimentary studies will provide more insight into understanding of the Laptev Sea offshore rift basin evolution.

Key issues to be studied during the project implementation are:

- Late Proterozoic-Early Paleozoic geology and hydrocarbon systems of the northern margin of Siberia craton;
- Late Paleozoic and Mesozoic geology, hydrocarbon systems and play elements;
- Tectonic events in the Taimyr, Olenek and Verkhoyansk fold belts;
- Main uplift/cooling/erosion pulses in the fold belts and adjacent parts of Siberian craton;
- Main pathways of sediment supply into Priverkhoyansk foredeep basin and Enisey-Khatanga and Lena-Anabar depressions;
- History of the Paleo-Lena River drainage.

During decades of regional geological mapping and other geological studies carried out in 1950-1980 the study area was extensively studied in terms of stratigraphy and lithology. Therefore, we focus our fieldwork on sampling the sedimentary succession to study collected samples using state-of-art equipment not available previously, and on studying sedimentary structures and structural elements to restore paleo-depositional environments and structural evolution of the region in accordance with modern geological concepts.

We believe that deciphering the tectonic history of the study area will be resulted in more accurate interpretation of offshore seismic data, as it may help to delineate seismic complexes and their inferred age, and here we present the main results of our structural studies.

One of the most important results of our fieldwork along the Olenek River was establishing an angular unconformity within Middle Triassic rocks, most likely between Ladinian and Anisian stages (Figure 2). This unconformity has neither been mapped previously, nor discussed in available publications. However, it points to a Middle Triassic tectonic event not documented earlier. Interpretation of this tectonic event is not clear; it may represent both local compression and rifting-related block rotation. The unconformity was only recognized in outcrops located close to the mouth of the Olenek River, outside this area we did not see any evidence for angular unconformities within Triassic rocks.

Figure 2 *The angular unconformity (red line) within Middle Triassic, most likely at the base of Ladinian sandstones.*

Pre-Lower Jurassic unconformity was mapped throughout the project study area, and is typically represented by erosional contact at the base of conglomeratic unit. In the Tsvetkova Cape area regional-scale maps shows significant truncation of the Triassic section, and locally the Lower Jurassic conglomerates overlies Lower Triassic rocks. Estimation of the pre-Jurassic erosion magnitude based on biostratigraphic correlations shows that on a distance of 6 km at least 300 m of Triassic rocks were eroded. This corresponds to approximately 3º angular unconformity that should to be recognized as a low-angle unconformity in the outcrop. However, detailed study of relationship between the Lower Jurassic conglomerates and underlying Triassic rocks in several outcrops shows that beds in both units are parallel to each other with no evidence for truncation of the Triassic beds. Therefore, we interpret pre-Jurassic tectonic event as predominantly extensional one with a set of horst- and graben-like structures with highly variable amount of erosion in adjacent blocks and absence or very low angular unconformity related to some block rotation (Figure 3).

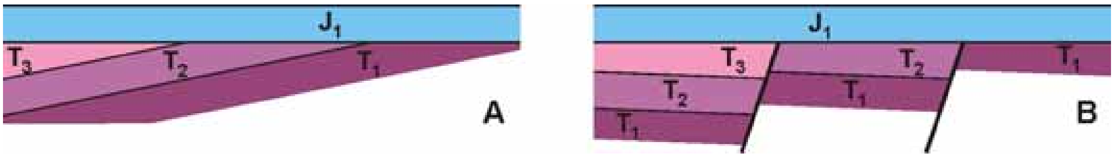

Figure 3 *Two possible interpretations of relationship between the Lower Jurassic conglomerates and Triassic rocks: (A) angular unconformity and (B) extensional fault tectonics. Our observations support extensional fault tectonics interpretation.*

The main compressional event occurred in late Mesozoic, overprinted previously formed structures and created presently observed structural style represented by open to tight folds and thrusts typical for the Olenek fold belt and the Tsvetkova Cape area. The latter is located on the boundary between the southern margin of the Taimyr fold belt and Enisey-Khatanga depression.

Timing of the main compressional event is not clear. In both Olenek fold belt and the Tsvetkova Cape area no clear angular unconformities have been documented in the Jurassic – Lower Cretaceous section, although intensity of folding is getting lower in the southern direction and from old rock to young. Local distribution of a thick Upper Jurassic conglomerate unit in the Tsvetkova Cape area points to significant erosion in the Taimyr fold belt. We interpret it as an evidence for the earliest stages of the late Mesozoic orogeny. In the Enisey-Khatanga and Anabar-Lena depressions transition from marine shale and sandstone facies to molasse-like units is not synchronous, but occurred in late Early Cretaceous likely marking the beginning of the late Mesozoic orogeny in the Taimyr and Olenek fold belts.

Post-orogenic extension has been identified throughout the study area, and extensional structures are superimposed on the general compression fabric. Most typical examples of post-orogenic extension are small-scale normal faults identified by slickenside striation study or by beds offset (Figure 4).

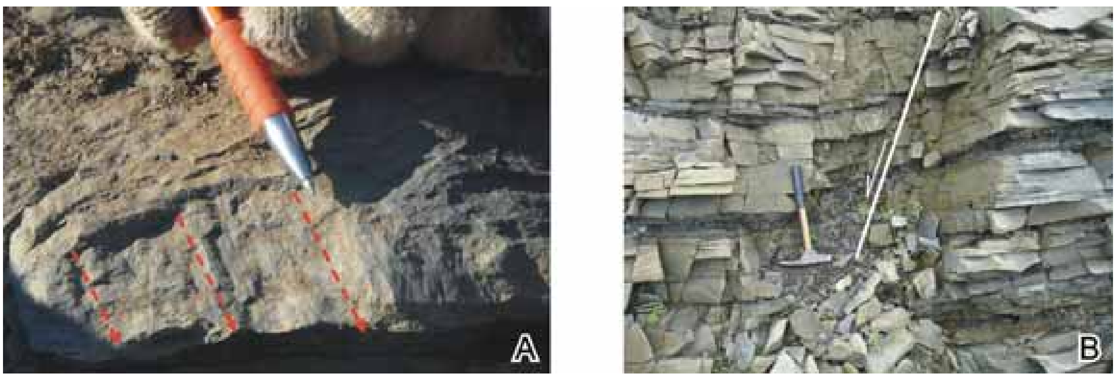

Figure 4 *Post-orogenic extensional tectonics: (A) slickensides with normal sense of shearing, Tsvetkova Cape area, and (B) normal fault with small-scale beds offset, Olenek fold belt. In both pictures arrows show hanging wall displacement.*

In the Tsvetkova Cape area normal faulting typically occurred along orogenic-related thrusts and reverse faults, pointing to important role of gravitational sliding along already formed fault surfaces, although some normal faults have significant strike-slip component of displacement. In the Olenek fold belt normal faults cut compressional structures and likely represent another extensional event.

The latest extensional event has been recognized in the Paksa Cape area. Here we identified several stages of deformation which were preliminary correlated with those in the Tsvetkova Cape area. However, in the Paksa Cape area all structures are cut by regular system of north-south-trending joints with well-preserved plumose pattern on the surface which points to predominance of extensional environments during the fracture system formation (Figure 5A,B). Joints are sub-parallel to the present-day shore. Therefore we believe that the eastern coastline of the Paksa Cape is controlled by offshore fault zone of extensional/transtensional kinematics. This fault system is parallel to normal faults forming the Laptev Sea rift system to the east from the study area. We interpret the north-south-trending joints on the east shore of the Paksa Cape as related to the westernmost normal faults of the Laptev Sea rift system (Figure 5C).

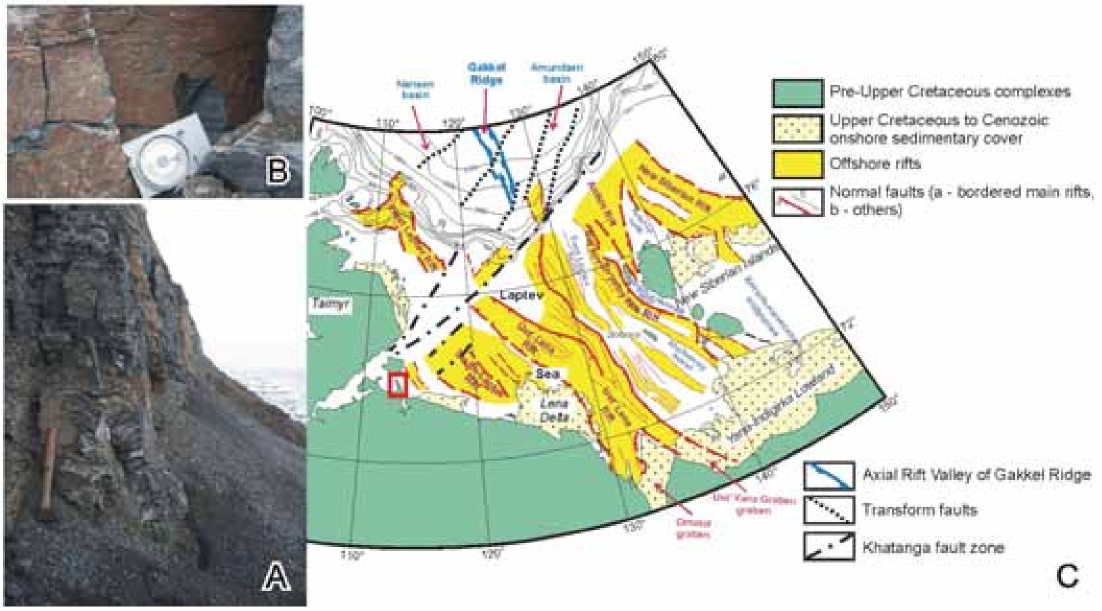

Figure 5 *North-south trending system of joints in the Paksa Cape area. A – joints system sub-parallel to the east coastline of Paksa Cape, view to the north, B –plumose pattern on the joint surface; C – main structural elements of the Laptev Sea shelf (Drachev et al., 1998; Drachev, 2000). Red rectangle shows location of the Paksa Cape study area.*

References

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