

# P022 The Structural Evolution and Tectonic Development of the Laptev Sea Region in Mesozoic and Cenozoic

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# SUMMARY

This study is based on the series of field works on Bel kov Island (Eastern Laptev Sea region) and Khatanga Bay area (Western Laptev Sea region). It is widely known, that the Laptev Sea region is one of the remote and geologically complex areas of Russian Eastern Arctic. According to the existing seismic data, a number of large offshore sedimentary basins with significant proposed hydrocarbon potential, but very controversial in age and composition, were revealed on its shelf. No offshore wells were drilled there so far, thus all the information on the regional geology, is based on the very limited amount of marine seismic profiles and our knowledge on adjoining near-coastal areas. Here we are focusing on the problems of structural geology of the region studied. During the field works we have collected significant amount of structural-geological data, which allowed us to restore the main stages of structural/tectonic evolution of the Western and Eastern Laptev Sea region.



#### Introduction

This study is based on the series of field works of 2002 (Bel'kov Island, Eastern Laptev Sea region) and 2008-2009 (Khatanga Bay area, Western Laptev Sea region) (Figure 1) and is a part of TGS-NOPEC Geophysical Company / St Petersburg State University joint project on Geology and Hydrocarbon systems of Northern Siberia. It is widely known, that the Laptev Sea region is one of the remote and geologically complex areas of Russian Eastern Arctic. According to the existing seismic data, a number of large offshore sedimentary basins with significant proposed hydrocarbon potential, but very controversial in age and composition, were revealed on its shelf (Drachev et al., 1998; Franke et al., 2001; 2008; Sekretov, 2002, etc). No offshore wells were drilled there so far, thus all the information on the regional geology, is based on the very limited amount of marine seismic profiles and our knowledge on adjoining near-coastal areas.

#### Method

Here we are focusing on the problems of structural geology of the region studied. During the field works we have collected significant amount of structural-geological data, including observations and mass-measurements of bedding/cleavage planes, elements of folds, faults and shear fractures, extensional veins, etc. The data obtained allowed us to restore the main stages of structural/tectonic evolution of the Western and Eastern Laptev Sea region.



*Figure 1* Main structural elements of the Laptev Sea shelf (Drachev et al., 1998; Drachev, 2000). The black rectangles outline the areas, covered by field works and described in this paper.

# Eastern Laptev Sea region, Bel'kov Island

Bel'kov island is located in the NE Laptev Sea region and belongs to extended Bel'kov horst of the Late Cretaceous (?) - Cenozoic Laptev Sea rift system (e.g. Drachev et al., 1998; Drachev, Geotectonics, 2000). The Island is mostly composed of Upper Palaeozoic sedimentary sequences (Kos'ko et al., 1985; Kos'ko, Korago, 2009), intruded by basic plutons of Permain-Triassic age (252±2 Ma) (Kuzmichev, Goldyrev, 2005; Kuzmichev, Pease, 2007), synchronous with famous traps of Siberian craton. It is commonly believed, that general NW-SE trending fold and thrust fault structural pattern of Bel'kov and adjacent Kotel'ny Islands was formed in late Jurassic-Early Cretaceous (Neocomian) as a result of South Anyui oceanic basin closure and Eurasia / Chukchi-New Siberian block collision along South Anyui-Lyakhov suture zone. The timing of deformation is



known from Upper Jurassic-Neocomian syncollisional clastic sediments, exposed on the Stlobovoy, Bolshoy and Maliy lyakhov Islands (Kuzmichev et al., 2006; Danukalova, 2009) and the angular unconformity at the base of Aptian, described on the Kotel'ny Island (Kos'ko et al., 1985; Kos'ko, Korago, 2009; Parfenov, Kuz'min (eds), 2001).

Mesostructural investigations were carried out along the western coast of central Bel'kov Island.Synsedimentary (slump) folds were identified and measured in the Middle Carboniferous clastic formation. It supposed, that they mark the paleooceanic slope setting of New Siberian Islands - Chukotka platform (block) and were formed (on its southern margin) during initial (rifted) stages of South Anyui oceanic basin development. Analysis of fold axes distribution (after their rotation along the strike line of bedding up to horizontal), showed main average axis strike ~ 345-165 and, therefore, main slump direction to ~ 255 (WSW). This result confirms the ideas, that South Anyui suture changing its strike from WNW-SES in Chukotka Region to NNW-SSE in the Eastern Laptev Sea (1) and that Bel'kov-Svyatoi Nos rift is superimposed on the suture (2) (e.g., Drachev, 2002). Nevertheless, due to the absence of paleomagnetic data, this result seems not reliable enough, because of possible strike-slip related block rotations (along subvertical axis) during subsequent different stages of tectonic development of the region.

According to plate tectonic reconstructions, the opening of the North Atlantic and Eurasian oceanic basins during the Late Cretaceous and Cenozoic affected to the tectonic development of the Laptev Sea Region (e.g. Savostin, Drachev, 1988; Gaina et al., 2002), representing the northern part of diffuse plate boundary between North American and Eurasian plates (Gordon, 1998). Gaina et al. (2002) have showed, that Laptev Sea segment of mentioned above boundary was developed in the Late Cretaceous in compressional setting (79-69 Ma, Campanian-Maastrichtian), followed by extension and transtension during latest Late Cretaceous – Middle Miocene (69-11 Ma).

The well-defined N-S trending subvertical (steeply dipping to the West) penetrative cleavage and related orthogonal extensional calcite veins, diagonal strike-slip faults, E- and W-verging reverse faults were observed in the Devonian and Carboniferous carbonate and clastic formations (Figure 2). Author suppose, that these structures, superimposed on the Early Cretaceous structural pattern, reflect the postcollisional E-W (WNW-ESE) compression and may correspond to predicted Late Cretaceous compressional event (Gaina et al., 2002). It is interesting to note, that secondary sinistral strike-slip slickensides were identified on the plains of NE-verging reverse faults, corresponding to the general Neocomian (collisional) structural pattern. It is possible to assume, that this transformation took place during namely E-W compressional stage.



*Figure 2 Ffold and thrust fault structural pattern of Bel'kov Island (A – Upper Devonian?-Carboniferous-Permian? clastic sequence; B – Upper Devonian clastic-carbonate sequence).* 

The next step of structural evolution is expressed in the numerous ~ N-S trending normal faults with various sinistral strike-slip component and sinistral strike-slip faults, superimposed on the cleavage plains. The strike-slip related pull-apart basins (dimensions up to tens of centimeters), filled by calcite, were also locally observed. These structures reflect ~ NE-SW extensional setting and correspond to the various substages of Laptev Sea rift system development. The analysis of space distribution of poles to normal faults without visible or significant strike-slip component revealed the presence of two main populations, corresponding to extension directions ~ 45-225 (NE-SW) and 70-



250 (ENE-WSE), roughly orthogonal to the Laptev Sea rift system and Gakkel spreading ridge. Thus, this is the independent evidence for the active influence of Eurasian basin opening on the Cenosoic structure of Laptev Sea Arctic margin.

## Western Laptev Sea region, Khatanga Bay area

According to the previous results of marine seismic data, directly to the East of Southeastern Taimyr, the existence of ~ south-vergent frontal thrust fault and fold zone, separating deformed complexes of Taimyr fold belt from almost undeformed Paleozoic(?)-Mesozoic sediments of offshore part of Enisey-Khatanga basin (Drachev et al., 2002). Field observations revealed no obvious frontal thrust and fold zone, but we found, that the intensity of the compressional deformation gradually decreases southward from older (Permian, Triassic) to younger (Jurassic-Cretaceous) sequences, towards the offshore part of Enisey-Khatanga basin. Permian strata are deformed in tight to isoclinal folds, complicated by thrusts, often with flat and ramp geometry. Triassic sediments are characterised by open to tight folding with minor thrust faulting. On Paksa Peninsula/Anabar River mouth and Bolshoy Begichev Island the Triassic-Jurassic-Neocomian clastic sequences are involved only in very gentle open folding, complicated by low-amplitude minor opposite-vergent reverse and thrust faults (Figure 3).



**Figure 3** The geological link between onshore and offshore of the central part of Enisey-Khatanga basin: slightly deformed Lower Cretaceous (Valanginian) strata, gently dipping to the North (Northernmost Nordvik Peninsula, Paksa Cape). (A). B – the section with some elements of interpretation of A. Approximate location of the photo is shown on C.

It is commonly believed, that formation of the Taimyr orogen, representing south-vergent thrust and fold belt, was caused by collision between Siberian craton and Kara microplate. The earliest syncollisional granitoides in the Northern Taimyr zone are dated as 306-275 Ma, corresponding to Late Carboniferous-Early Permian (Vernikovsky, 2009). In the Late Permian time (264-258 Ma) postcollisional granites and granodiorites were intruded into the deformed Precambrian and Paleozoic sequences of Northern- and Central Taimyr zones (Vernikovsky, 2009). Thus, the deformation occurred corresponds to Late Hercynian (Variscian) orogeny. Although Taimyr thrust and fold belt was in general formed to the end of Early Triassic, the deformation (inversion) was continuing during the whole Triassic period (Vernikovsky, 2009). On the basis on our field observations were concluded



earlier, that base-Jurassic unconformity is really exist here, but the basal conglomerates has local source and the could correspond not to compressional, but to extensional event (Khudoley et al., 2009). The discovery of a locally distributed thick Upper Jurassic conglomerate unit in the Tsvetkova Cape area of Southeastern Taimyr points to significant uplift and erosion in the Taimyr orogen, located directly to the North from the point of observations. We interpret it as an evidence for the earliest stages of the Late Kimmerian orogeny (Khudoley et al., 2009). South-dipping cross-bedding within conglomerate/sandstone beds strongly supports this idea. We also observed, that Jurassic and Neocomian sequences are also involved in the compressional deformation, but Aptian(?)-Albian sediments are close to subhorizontal and likely post-date the compressional deformation. It is interesting to note, that Messoyakh compressional-transpressional zone, complicating the internal structure of Enisey-Khatanga basin, was active during Late Jurassic-Neocomian time (Baldin, 2008; Kontorovich et al., 1994; Kontorovich, Kalinina, 2009).

Thus, it is really important, that the final stage of compressional deformation in the Western Laptev Sea Region corresponds to Late Kimmerian and so is roughly synchronous with those on the rest of Eastern Arctic area, including New Siberian Islands, Chukotka and Brooks Range (Alaska), where it took place in the Late Jurassic-Neocomian, pre-Aptian-Albian time (Kos'ko et al., 1985; Parfenov, 1984; Parfenov, Kuzmin, 2001; Sokolov et al., 2002; Kos'ko, Trufanov, 2002; Kuzmichev et al., 2006; Katkov et al., 2007; Zonenshain et al., 1990; Miller et al., 2002; Miller, Verzhbitsky, 2009). Based on the measurements of latest extensional mesostructures we proposed, that after the Late Kimmerian compression completion the area studied was underwent by ~ N-S extension and subsequent ~ E-W extension (Khudoley et al., 2009). The N-S extension in Khatanga Bay area may be related (paragenetic) with the postcollisional structural pattern of E-W compression, recognized Bel'kov Island. This result is necessary to take into consideration for compilation of any regional plate-tectonic reconstructions. The later extensional stage could take place as early as in Aptian-Albian time, but it is likely, that it was most active during rifting/spreading processes in Eurasia Basin/Gakkel Ridge in the latest Late Cretaceous-Cenozoic time.

## Conclusions

1. The final compressional/collisional event (pre-rifted stage) took place in both areas studied during Late Jurassic – Early Cretaceous (pre-Aptian-Albian). This event is in general synchronous with the Chukotkian-Brooks Range orogeny and thus is of regional significance for whole the Eastern Arctic region.

2. The principal stages and succession of the structural/tectonic evolution of the Western and Eastern part of Laptev Sea region appears to be pretty similar and/or comparable with each other. It is likely, that the main stages of Bel'kov Island and Khatanga Bay area postcollisional deformations reflect the North American and Eurasian Plates interaction in the Late Cretaceous-Cenozoic and comparable with the plate-tectonic reconstructions of Laptev Sea region for this period, based on the North Atlantic marine magnetic and gravity data (Gaina et al., 2002).

3. The Palaeozoic-Mesozoic (pre-Aptian-Albian) sequences in the Khatanga Bay (Western Laptev Sea) area are relatively weekly deformed and certainly constitute the part of the sedimentary cover on seismic lines. From the other hand, the sedimentary complexes of the same age of the eastern part of Laptev Sea are involved in the Late Mesozoic collisional deformation to a much greater extent and represent a part of New Siberian-Chukotka fold belt (Figures 2-3). Thus, pre-Aptian sequences should represent acoustic/folded basement for the sedimentary cover, identifiable on the seismic profiles (Drachev, 2002). This represents the principal structural difference between Western and Eastern parts of the Laptev Sea region and should be taken into consideration for future exploration.

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