Structure and Petroleum Habitat of the Pay Khoy-Novaya Zemlya Foreland Fold Belt, Timan Pechora, Russia*

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Search and Discovery Article #10554 (2013)**
Posted December 9, 2013

*Adapted from an oral presentation given at AAPG 3P Arctic Polar Petroleum Potential Conference & Exhibition, Stavanger, Norway, October 15-18, 2013
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Abstract

The study is based on integrated interpretation of geological and geophysical data on the Pay Khoy-Novaya Zemlya foreland fold belt. It strikes for 700 km off the southwestern coast of Novaya Zemlya extending onshore into the north-eastern part of Timan Pechora. It is observed that in the northwestern part of the belt is dominated by transpressional deformations. Typically they involve high-relief flower structures with limited shortening. To the south-east of the fold belt it gradually passes into a typical thin-skinned thrust belt. Structuring there is controlled by multiple delamination of the Paleozoic-Triassic sedimentary section, thrust imbrications, and disharmonic folding. The main detachment level is interpreted to be related to the Upper Ordovician evaporates. Estimated total amount of shortening across the fold belt may well exceed 50 km. Strike-slip deformations in this part of the fold belt have limited development.

Study seismic and geological data permitted the identification of the main episodes of structuring in the Pay Khoy – Novaya Zemlya fold belt. The Middle Devonian-Early Frasnian folding took place in the northern part of the study area. It is marked by the prominent pre-Frasnian unconformity which is getting less important in the southern part of the study area. In the Late Permian the fold belt experienced large-scale sinistral strike-slip along the Tran-Eurasian fault system, which created transpressional structures and led to the drastic bending and curvature of the Urals-Pay Khoy – Novaya Zemlya suture (Sobornov and Yakubchuk, 2004). Shortly afterwards it was followed by an episode of large-scale folding and thrusting in the Triassic. It led to detachment faulting widely developed in the Pay Khoy foreland sealed by the pre-Jurassic unconformity. It is interpreted that it was driven by the south-west lateral escape of the South Kara plate from a collision of the Siberia and North Kara plates, which produced the Taymyr orogen. In the Late Tertiary the fold belt was subjected to a compressional reactivation and general uplift.

The lateral segmentation along the fold belt is likely due to the following control factors. Firstly, they may have resulted from the sinistral displacement on the Trans-Eurasian fault which is oriented obliquely to the fold belt. Secondly, it was preconditioned by the interpreted heterogeneity of the structural grain of the Pechora foreland juxtaposed against the fold belt. Thirdly the structure of the fold belt was controlled by the shape and stress orientation produced by the lateral escape of the Kara plate. The structural appearance of the northwestern segment of the foreland was mainly governed by the sinistral strike-slip transpression. In addition it was to a much greater degree affected by
foreland structure produced by the pre-Frasnian folding. The presence of a structural high in front of the northern segment of the fold belt had likely concealed the detachment folding. The southern segment of the fold belt was mainly shaped by SW-oriented compression during the Triassic escape of the South Kara plate. The development of the Upper Ordovician evaporates facilitated delamination of the sedimentary fill with the wide development thin-skinned trusting.

The structural segmentation of the fold belt provides diverse types of hydrocarbon traps. Of prime interest are thrust related 4-dip closures, flower structures, carbonate build-ups, pinch-outs, and karstified carbonates subcropping the pre-Frasnian unconformity. The latter are exemplified by the largest known commercial deposits in the area - Titov and Trebs fields. The prominent tectonic thickening and subsequent erosion of the sedimentary section due to thrusting in the inner part of the Pay Khoy segment may account for a greater content of gas.

**Selected References**


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Reasons to study this area

- Still poorly understood fold belt
- Untested part of a prolific petroleum province
- New data, new constrains
Outlines

- Review of structural geology
- Timing of events, geodynamic development
- Petroleum habitat
General setting

North-Central Eurasia tectonic domains

Mature province

Unexplored

From Sobornov, Nikishin, 2009 with modifications
Off South Novaya Zemlya

The area is dominated by strike-slip features and high angle thrust faults. The Upper Devonian – Lower Permian section in relatively thin. The is a pronounced unconformity in the base of this section.
The interpretation proposes a detachment following the O3 salt level. The Korotaikha basin could be referred to as a piggy back basin, there is passive roof duplex in the east.
Multiple delamination and disharmonic folding are interpreted in the eastern part of the area. The prominent structural culmination in the west is related to the far travelling thrust sheet with detachment in the O3 evaporites.
The map schematically shows main structural features based on available dataset involving mainly seismic data. Detachment faulting is widely developed in the SE part of the fold belt. The NW section is dominated by strike-slips deformation. Central part represents a transitional zone between the two.
Timing of events, megasequences

Interpretation of seismic data in the foreland west of the fold belt allows to put constraints on timing of events. Several major unconformities are interpreted in the foreland of the thrust belt. They are: Pre-Frasnian, Artinskian, pre-Triassic and pre-Jurassic. Last but not least – the late Tertiary uplift.
Plate tectonic evolution

A. Future Tung-Mongol Vendian 630 Ma arc
B. Late Silurian 420 Ma
C. Mid Devonian 385 Ma
D. Late Permian 255 Ma
E. Late Triassic 220 Ma
F. Paleocene 65 Ma

Cratons
Neoproterozoic crust
Paleozoic and partly Mesozoic accretionary wedges
Vendian to Paleozoic immature arcs
Sedimentary depocenters
Subduction zones
Backarc spreading
Rift
Fault
Direction of plate rotation
Trap bazalts

Sobornov, Yakubchuk, 2004 with modifications
Upper Ordovician salt

The salt layer provided an efficient detachment facilitating delamination of the sedimentary cover in the south of the belt.
The NW strike-slip dominated structural segment appears to be related to the pronounced pre-Frasnian angular unconformity clearly seen in the South NZ foreland. Up to several kilometers of deposits had been removed prior to the onset of the Frasnian transgression. It would suggest the existence of a folded terrain which later influenced the shape of the Novaya Zemlya fold belt limiting detachment faulting.
Late Permian strike-slip

The Late Permian sinistral transpression is seen as principal process shaping the fold belt. This transpressional zone is a result of relative movement of the two principal domains in the North Eurasia – East European and Siberian Platforms.
The clock-vice rotation of Siberia and its progressive collision with the Kara forced the South Kara to escape and producing thrusting and folding in the Pay Khoy and Novaya Zemlya.
Triassic, South Kara escape

The south flank of the South Kara block is marked by an en-echelon of high-relief swells reactivated in Tertiary.
Structural analog?

From Zanchi et al., 2012
Map of Zagros is mirrored and rotated
Petroleum habitat

Good calibration onshore. Multiple source rocks, several oil families.

Offshore: risk of a degradation of the Domanic petroleum system, increasing importance of the pre-Frasnian (Silurian) and Mesozoic offshore sources.

Modified after Swirydczuk et al., 2003
Petroleum habitat

Principal conventional trap types

- thrust–related 4-dips
- flower structures
- carbonate build-ups
- subcropping unconformities
- pinch-out
• Complex, laterally segmented fold belt
• Main structuration drivers:
  – Pre-Frasnian folding in the north
  – Late Permian transpression
  – Triassic thrusting, the South Kara escape
  – Presence of the Upper Ordovician salt in the Pay Khoy foreland
• Large petroleum potential
  – Multiple petroleum systems
  – Diverse trap types
Thank you!

Acknowledgement
TP NIC, SMNG, NMSR, A. Nikishin