

# Structural Relationships and Development of the Pay-Khoy and Polar Urals Fold Belts, Russia\*

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## Abstract

The Pay-Khoy and Polar Urals fold belts separate the Timan Pechora and West Siberian basins. They strike orthogonally flanking the indenting northeastern part of the Timan Pechora basin. Structural relationships and development of these fold belts discussed by many researchers based largely on surface geology, petrography, remote sensing, potential fields, and very limited subsurface data (e.g., Hamilton, 1970; Zonenshain, 1990; Yudin, 1990). An integrated regional study involving seismic and borehole data acquired in the course of petroleum exploration over the last decade provide new insight into the structural settings of these fold belts. This allows better understanding of timing and plausible causes of deformation.

Regional seismic interpretation shows surprisingly similar structural styles of foreland deformation. In both fold belts sedimentary and basement rocks are involved in multi-level imbricate thrusting and disharmonic folding. The most efficient detachment level was provided by the Upper Ordovician evaporites. It facilitated a large-scale decoupling of the sedimentary section and tectonic transportation of thrust sheets forward toward the foreland, producing piggy-back basins. The semblance of structural styles of deformation of the Pay-Khoy and Polar Urals fold belts are thought to be related to the continuity of the foreland sedimentary section, with similarities of its rheological characteristics reacting to tectonic stress in a similar fashion. This often was viewed as evidence of the tectonic affinity of these fold belts.

Differences in the fold belts are recognized by general composition of the fold belts, timing and causes of deformation. The Urals show distinctive segmentation involving continental and oceanic parts, broad development of Carboniferous-Permian collisional granite magmatism, and a high level of exhumation (e.g., Puchkov, 2003). The initial arc-continent collision in the Urals is assumed to have occurred in the Late Devonian (Fammenian). It was followed by several pulses of oblique collisional events that resulted from accretion of various units of the Altaid collage to the East European platform. The multi-phase collision and its obliquity accounted for the diachronous onset of the thrust-loaded subsidence in the foreland. In the southern Uralian foreland it commenced in the Late Bashkirian (Middle Carboniferous), resulting in drowning of carbonate platforms. The foreland subsidence was getting progressively younger to the north. The final onset of compression recorded by a rapid increase of foredeep subsidence occurred in the Late Artinskian-Kungurian (Early Permian). The Uralian fold belt provided large volumes of clastic material, sufficient to fill the Uralian foredeep as well as the East Barents basin.

The Pay-Khoy fold belt consists dominantly of the Paleozoic-Triassic sediments deposited at the continental margin with notable absence of the rocks of the oceanic affinity (e.g., ophiolites) and the Upper Paleozoic granites (e.g., Scott et al., 2010). The Late Permian deformation in the Pay-Khoy fold belt is limited to a narrow NW-trending zone of transpression in the core of the Pay-Khoy anticlinorium. It constitutes a segment of the Transuralian sinistral strike-slip zone separating the Altaid collage from terranes of the East Siberian affinity and extending toward Novaya Zemlya (Sobornov and Yakubchuk, 2004). Study of provenance of clastic material of Upper Permian-Triassic deposits suggests that the Pay-Khoy had not existed as a topographically uplifted domain prior to the Late Triassic. The major thrust faulting in the Pay-Khoy region took place in the Late Triassic-Early Jurassic. Seismic data show that there are no significant angular unconformities in the Upper Paleozoic-Triassic section, and Triassic deposits are involved in folding and are sealed by the Jurassic unconformity (e.g., Fossum et al., 2013; Sobornov, 2013). Folding in the Pay-Khoy foreland overprinted the Late Paleozoic structures of the Polar Urals. This is indicated in the Chernov swell area where the Pay-Khoy structures override the foredeep of the Polar Urals.

The Late Triassic-Early Jurassic deformation in the Pay-Khoy fold belt is interpreted to have resulted from a 'soft' collision of the northeastern margin Pechora plate with the South Kara – Yamal plate. The latter made a southwesterly lateral "escape" from the collision zone between the Taymyr fold belt and East Siberian platform (Sobornov, 2013). This is evidenced by seismic data showing that the South Kara – Yamal plate is bounded by strike-slip zones allowing its SW movement. Within the South Kara – Yamal plate there are zones of compressional folding and southwest-vergent thrusting sealed by the Jurassic unconformity. This interpretation is also in line with paleomagnetic data showing SW-directed movement of this plate and its counterclockwise rotation after the Early Triassic (Iosifidi and Khramov, 2010). The Late Triassic deformation is overprinted by intraplate transpressional deformation in the Early Cretaceous and Tertiary.

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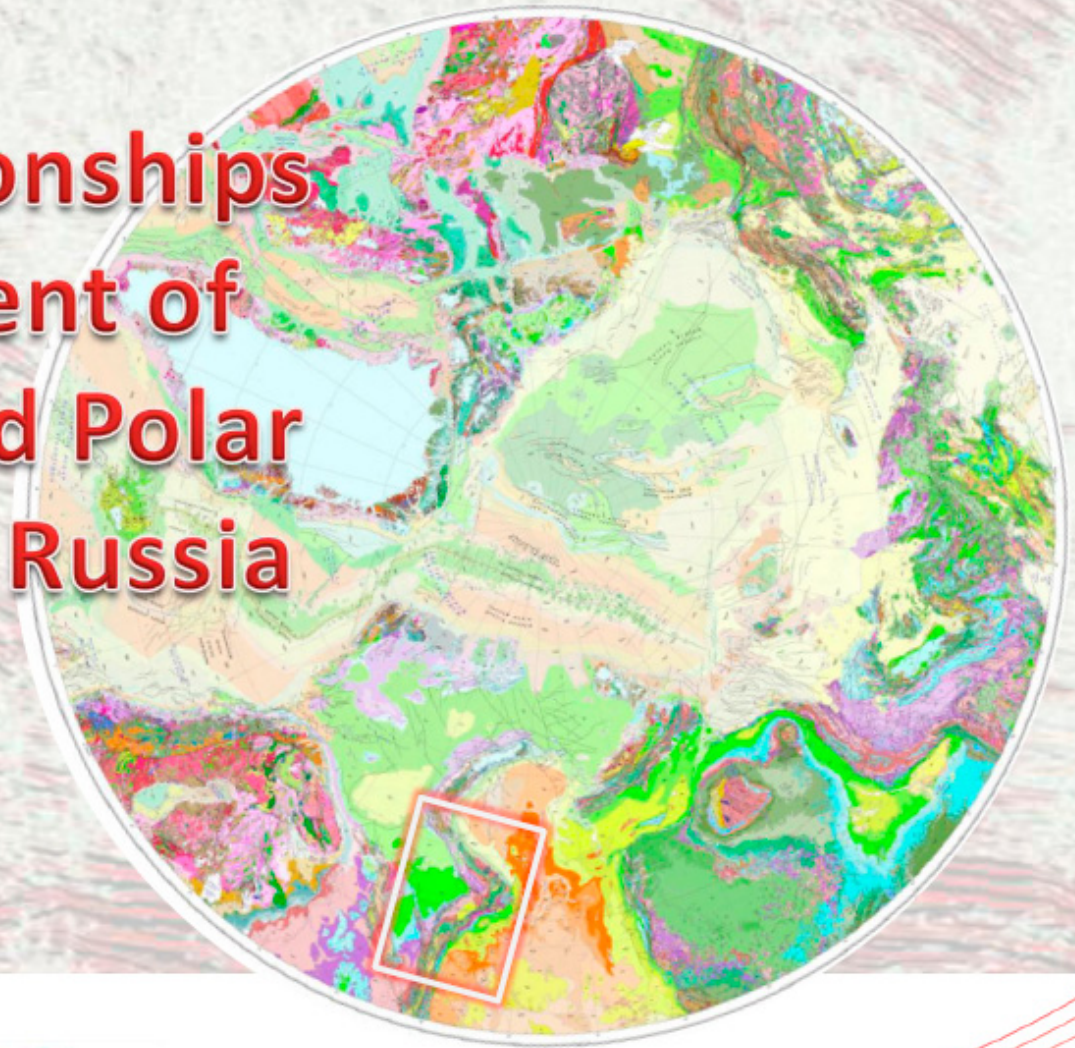
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Konstantin SOBORNOV



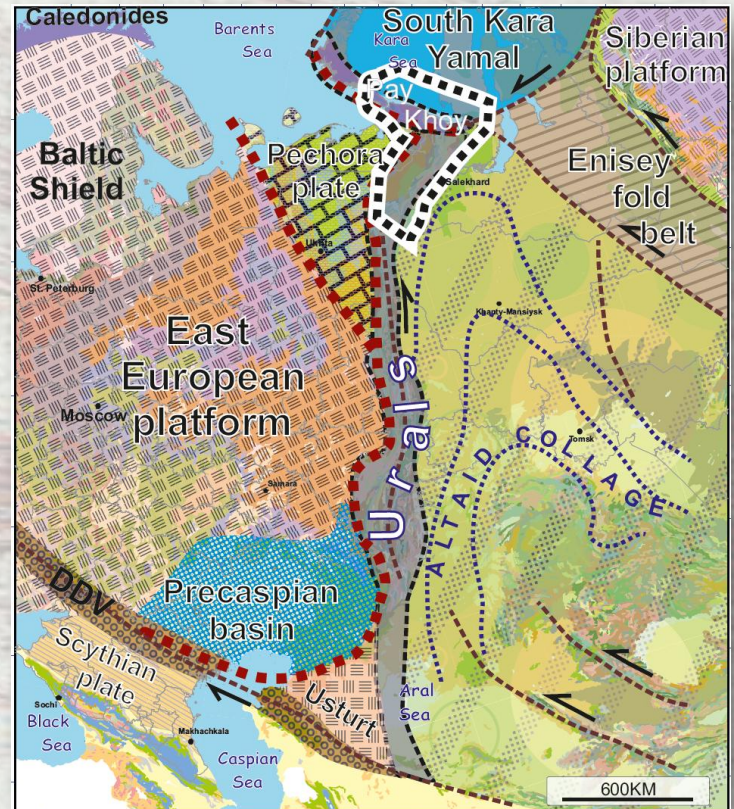
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Conference & Exhibition

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# Outlines

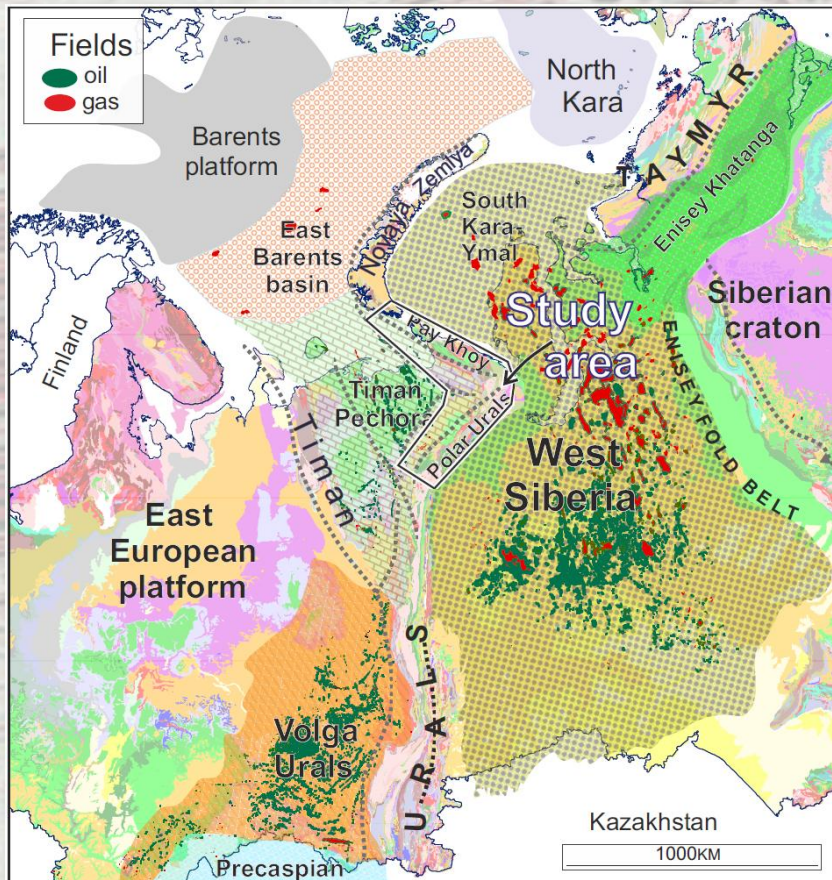
- Regional setting
- Comparison of the Polar Urals and Pay-Khoy foreland fold belts
- Timing and causes of deformation
- Conclusions





# Regional setting

Fold-and-thrust belts separating the northeastern margin of East European platform from the West Siberian basin.



This study is a part of a bigger project which involves reinterpretation and updating structural model of the fold belts flanking the East European platform from South and East.

## Database

Vintage and new seismic data  
Data from potential fields  
Drilling data  
Geological maps  
Public domain data  
Etc.

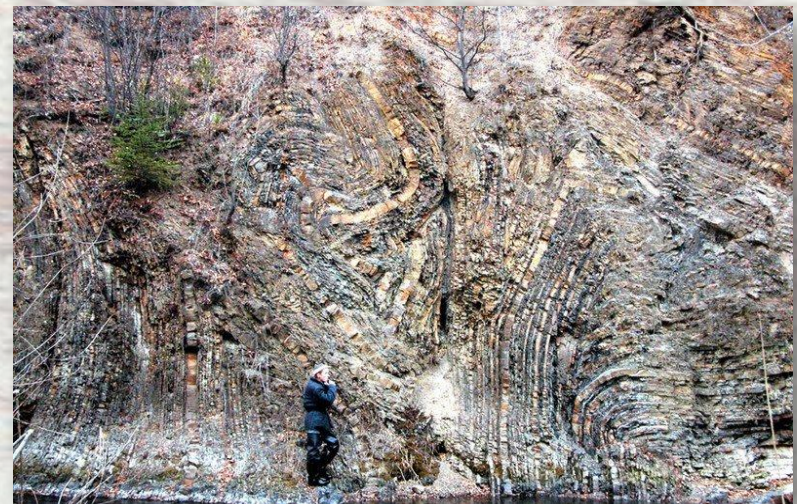


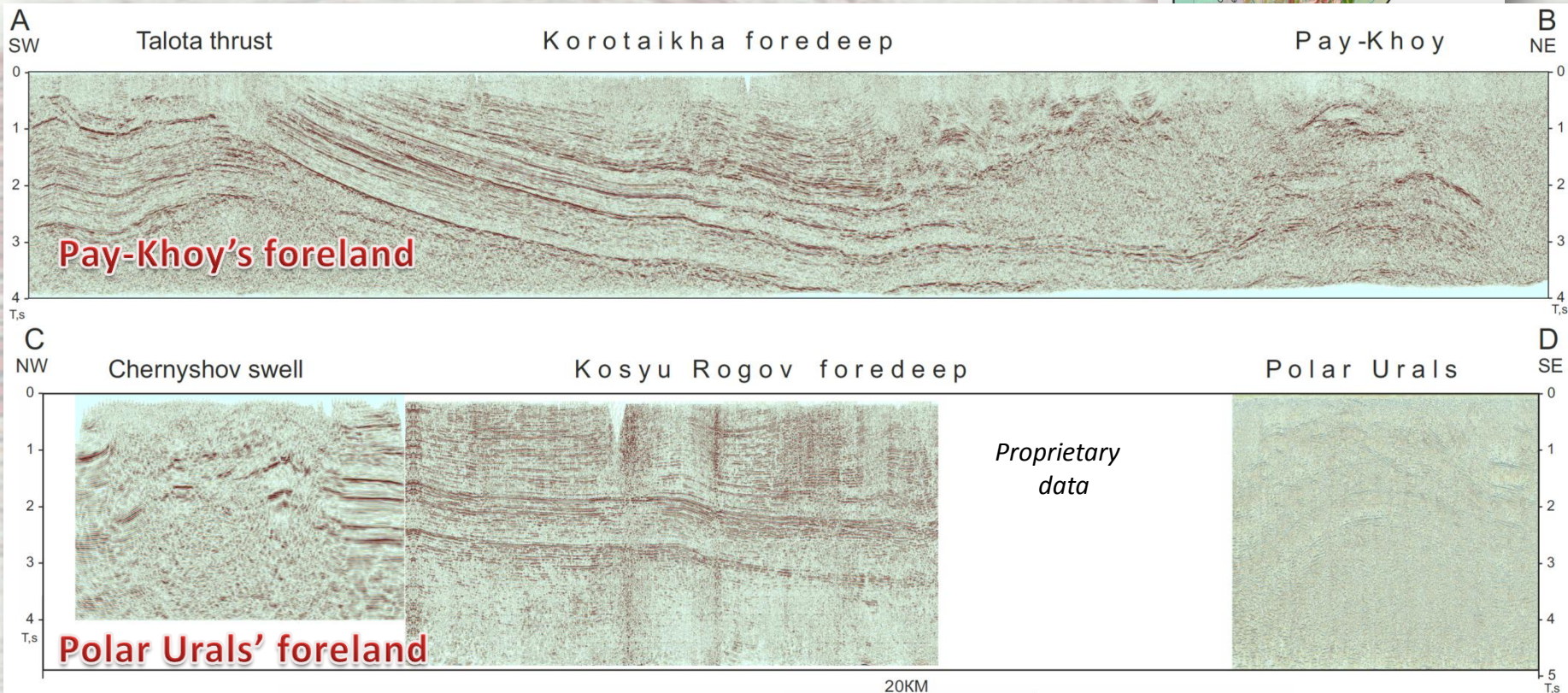
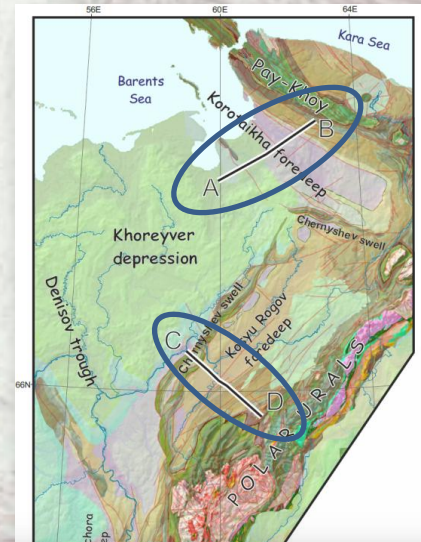
Photo by I. Kolokolova



# Comparative structure

## Similar structural styles

- ✓ Detachment thrusting, disharmonic folding
- ✓ Piggy-back basins

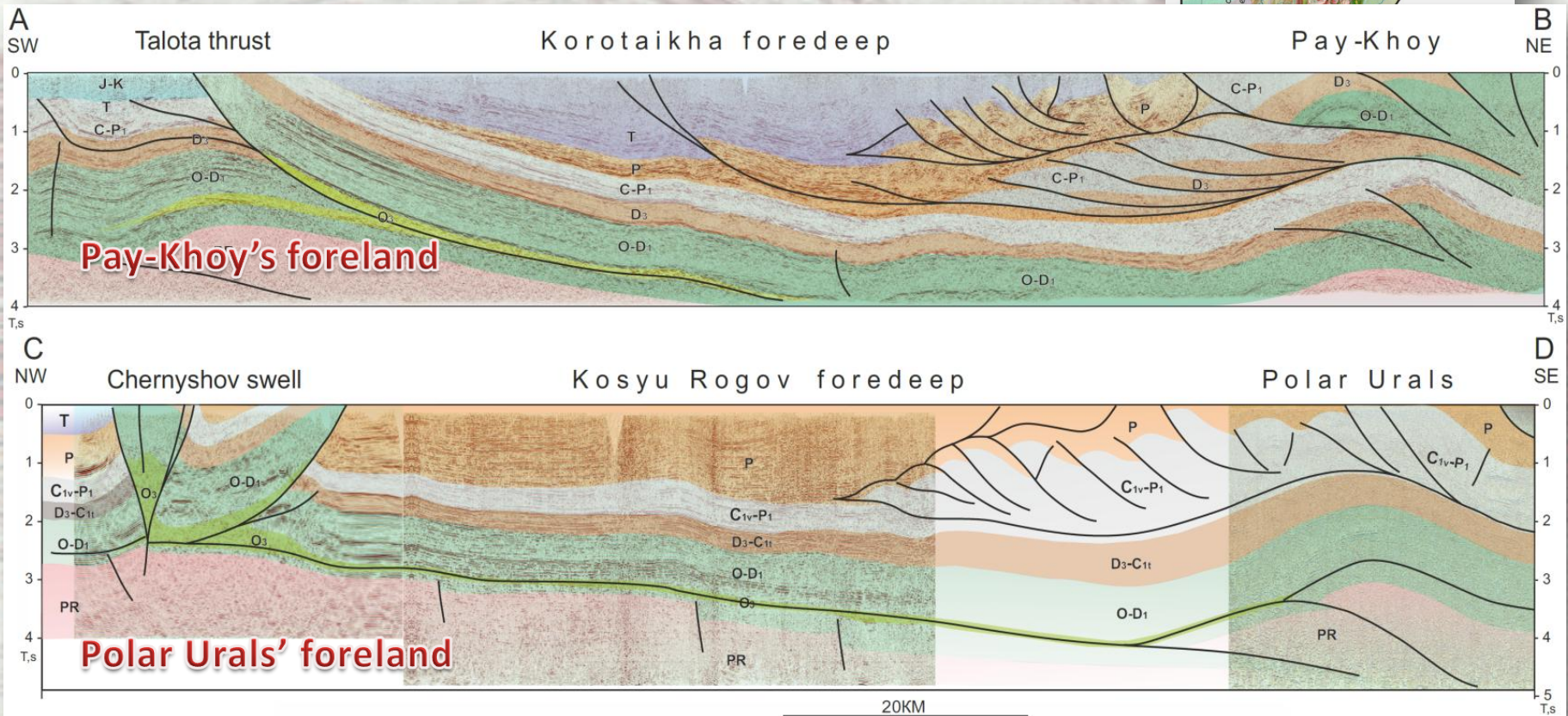
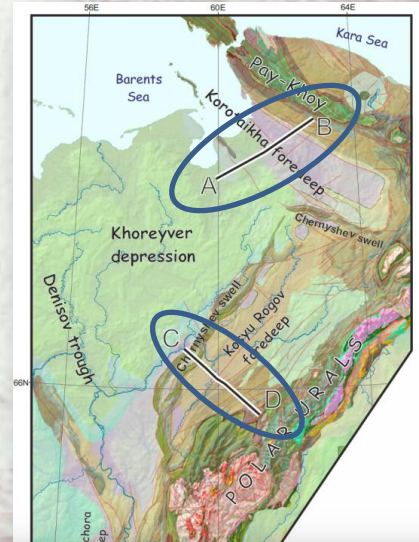




# Comparative structure

## Similar structural styles

- ✓ Detachment thrusting, disharmonic folding
- ✓ Piggy-back basins

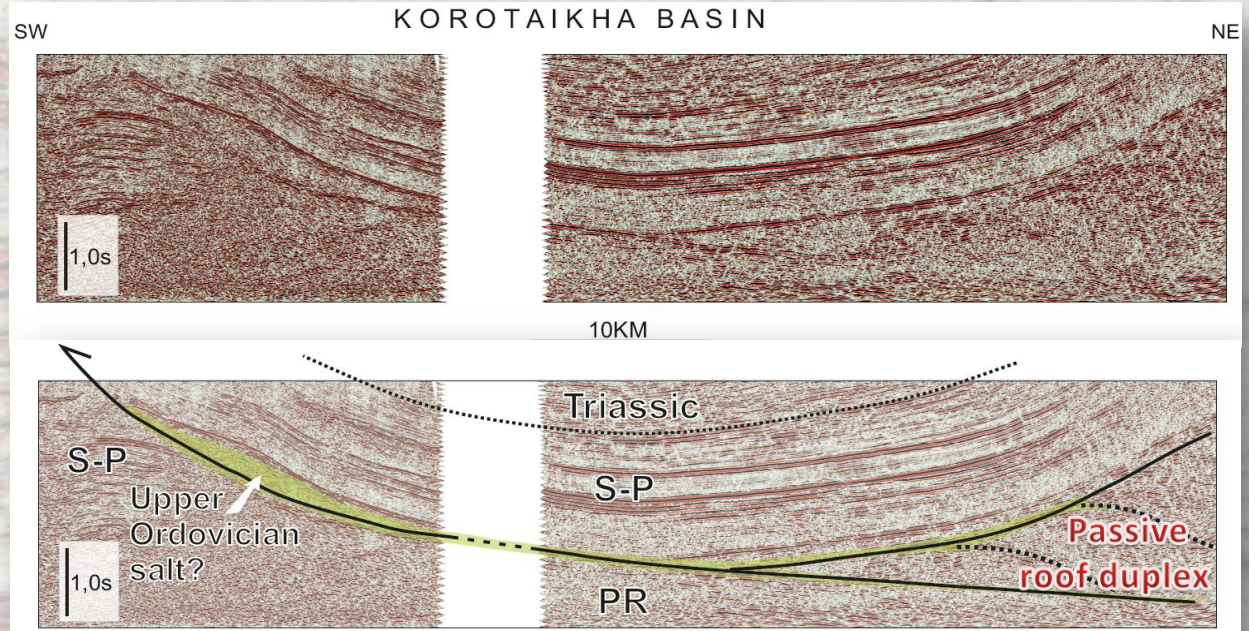
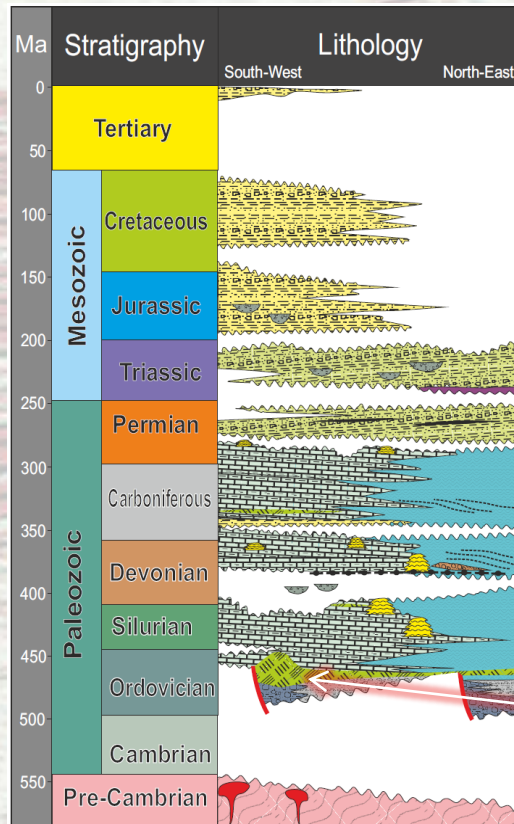




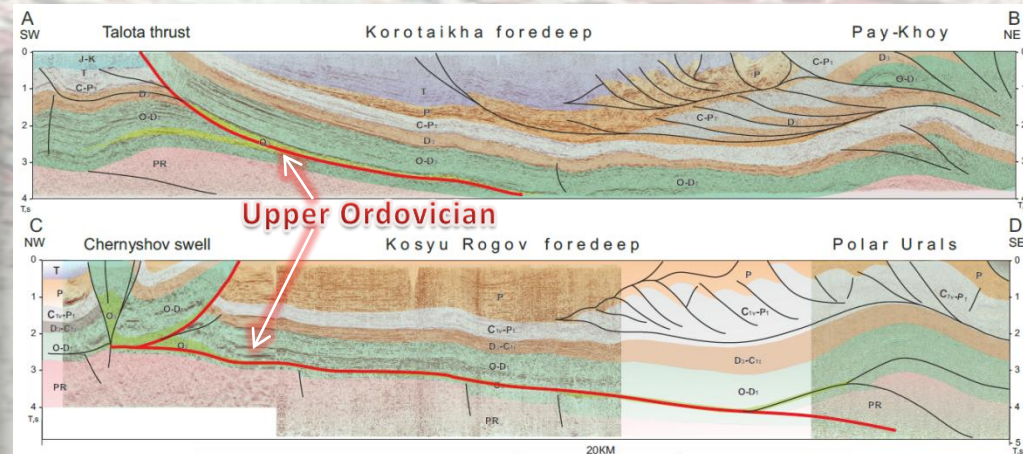
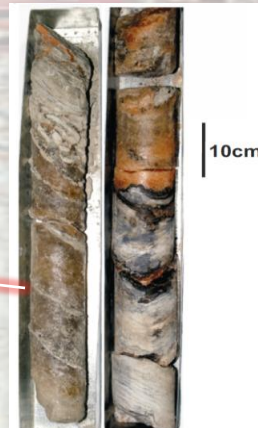
# Tectonostratigraphy

Several levels of structural delamination.  
The most efficient –  
Upper Ordovician salt.

Stratigraphy of the NE Timan Pechora

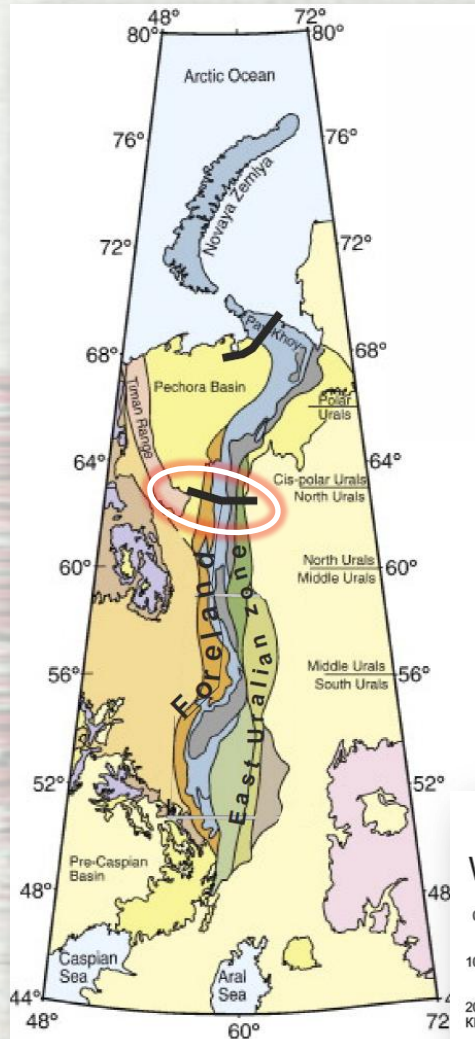


Upper Ordovician salt





# The Urals



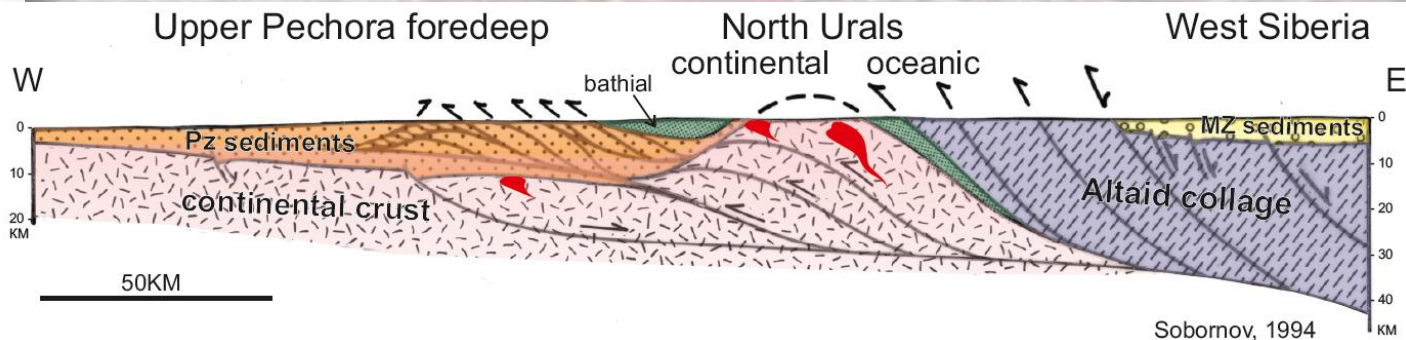
Brown et al., 2008 with modifications



Şengör et al., 1993

## The Urals:

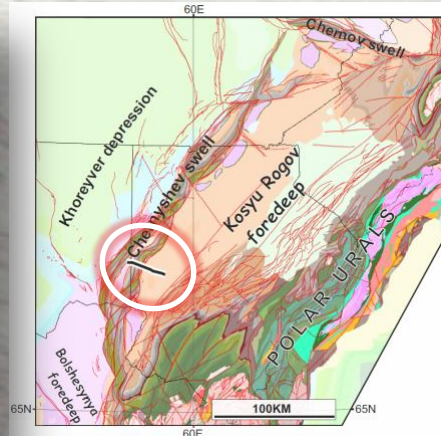
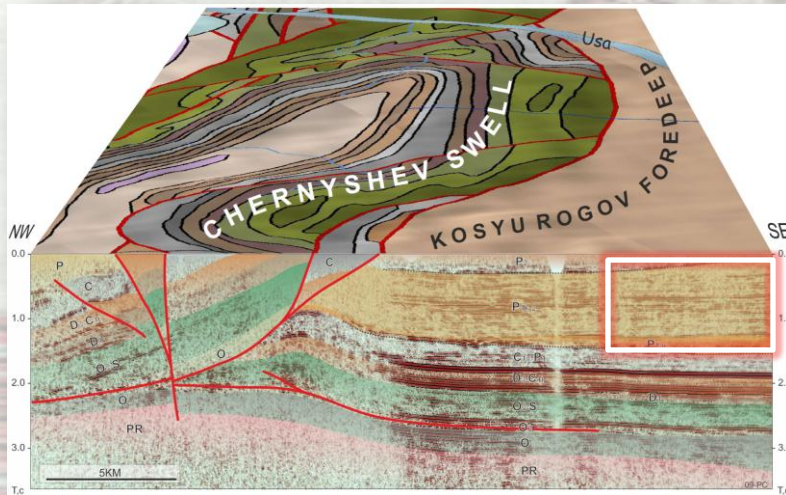
- ✓ N-S-trending continental suture records the accretion and convergence of the East European platform and Altai collage
- ✓ Distinctive segmentation: continental (west), oceanic (east) parts
- ✓ High level of exhumation
- ✓ Principal folding in the Late Paleozoic, Tertiary reactivation



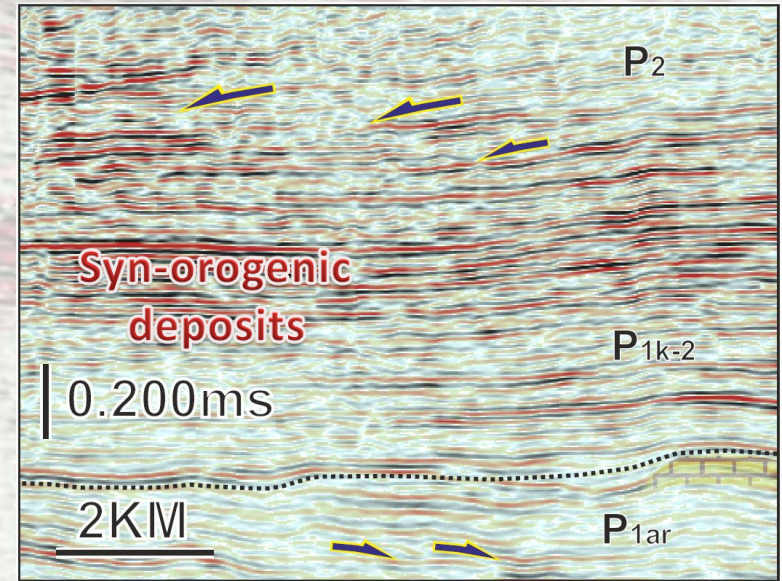
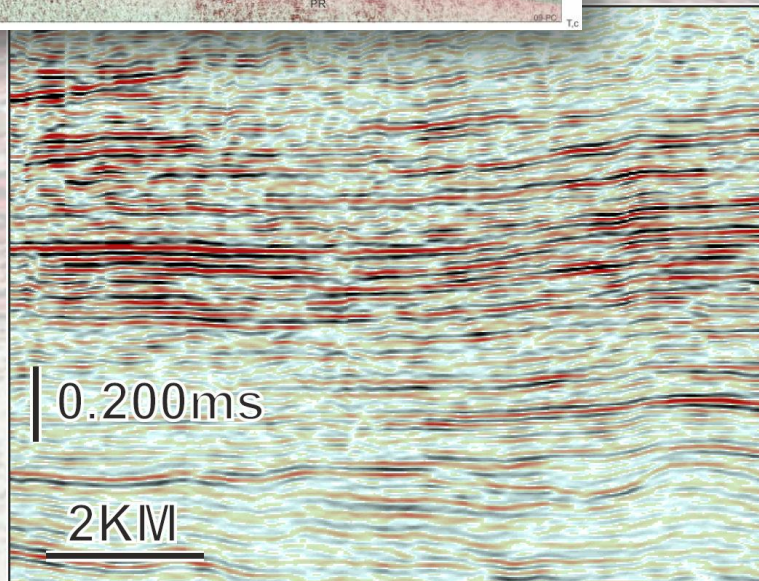
Sobornov, 1994



# Uralian syn-orogenic deposition



- ✓ Syn-orogenic mega-sequence of basin-dipping clinoforms.
- ✓ The Uralian provenance of the Permian clastics.

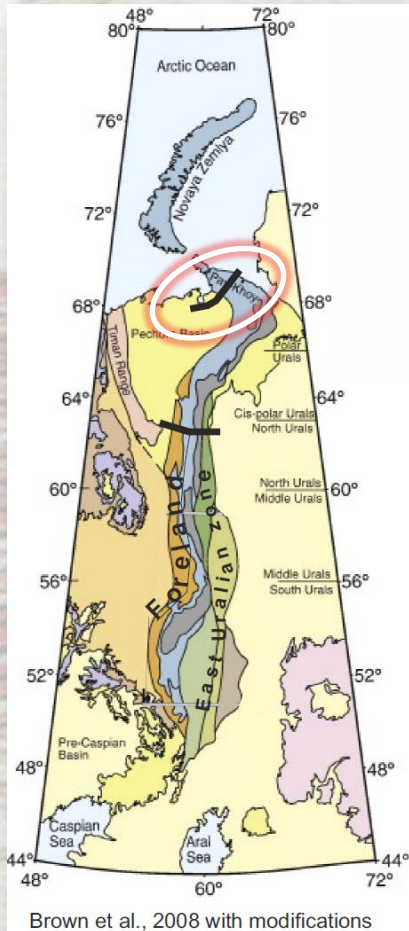




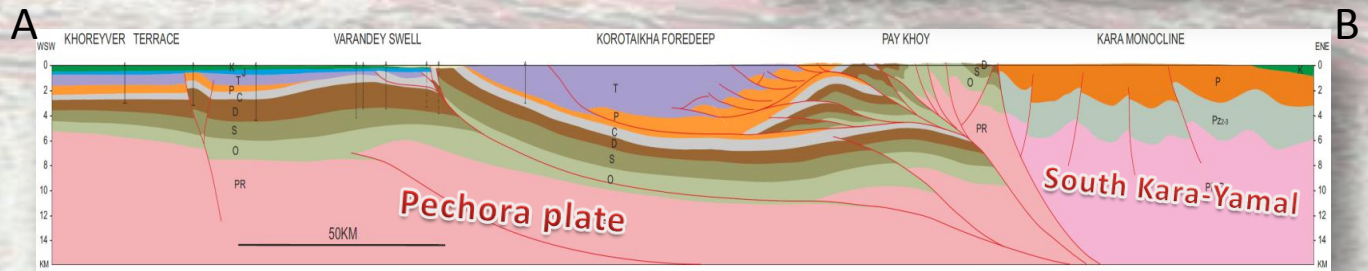
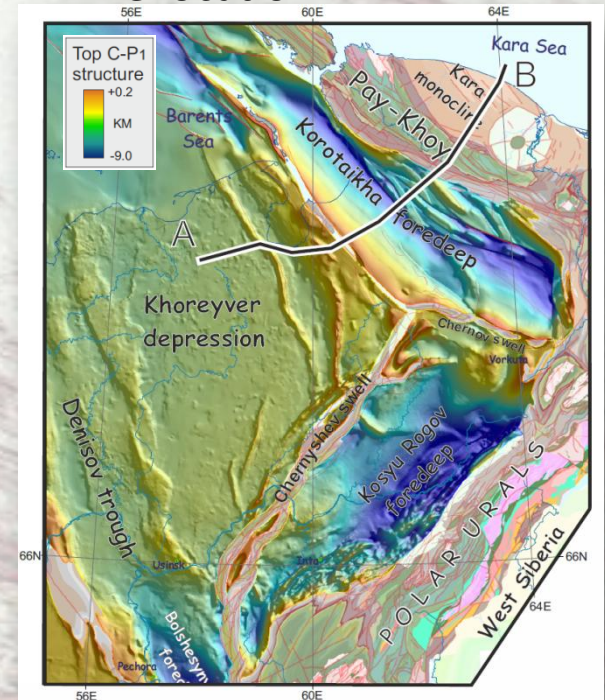
# Pay-Khoy

## The Pay-Khoy:

- ✓ NW-trending fold belt, records the sinistral transpression in the Late Permian and convergence of the East European platform and South Kara – Yamal in the Triassic-Early Jurassic
- ✓ Little exhumation, notable absence of collisional granites and oceanic segment



## Line location

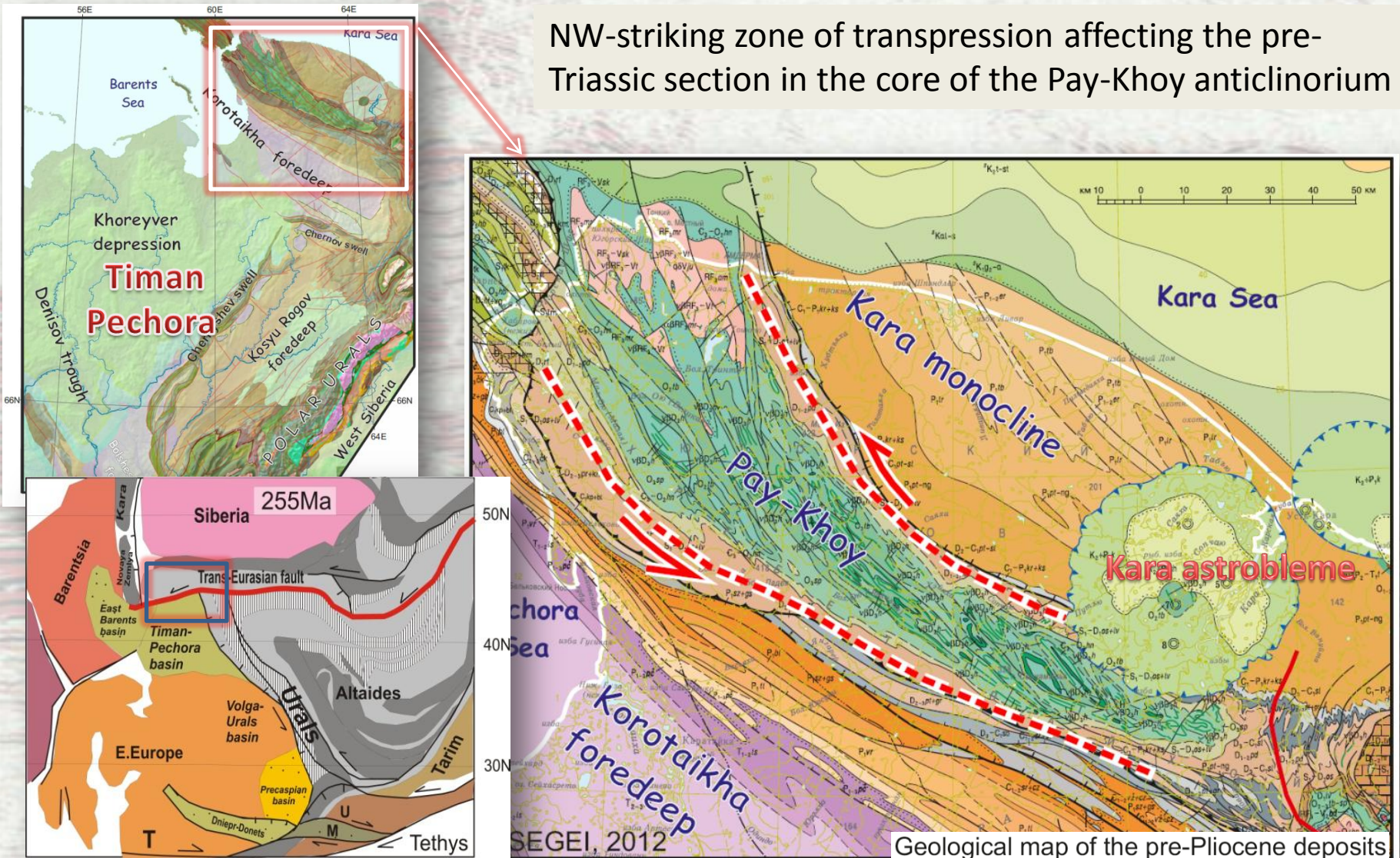




# The Pay-Khoy

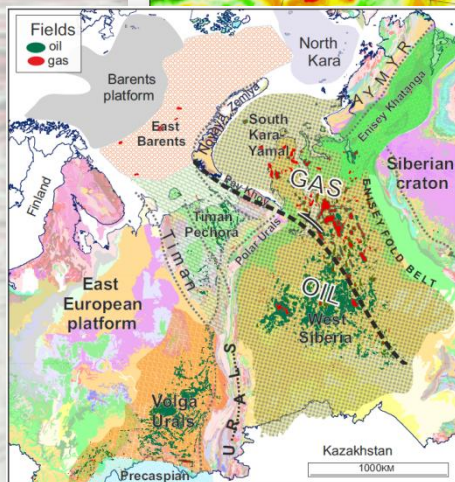
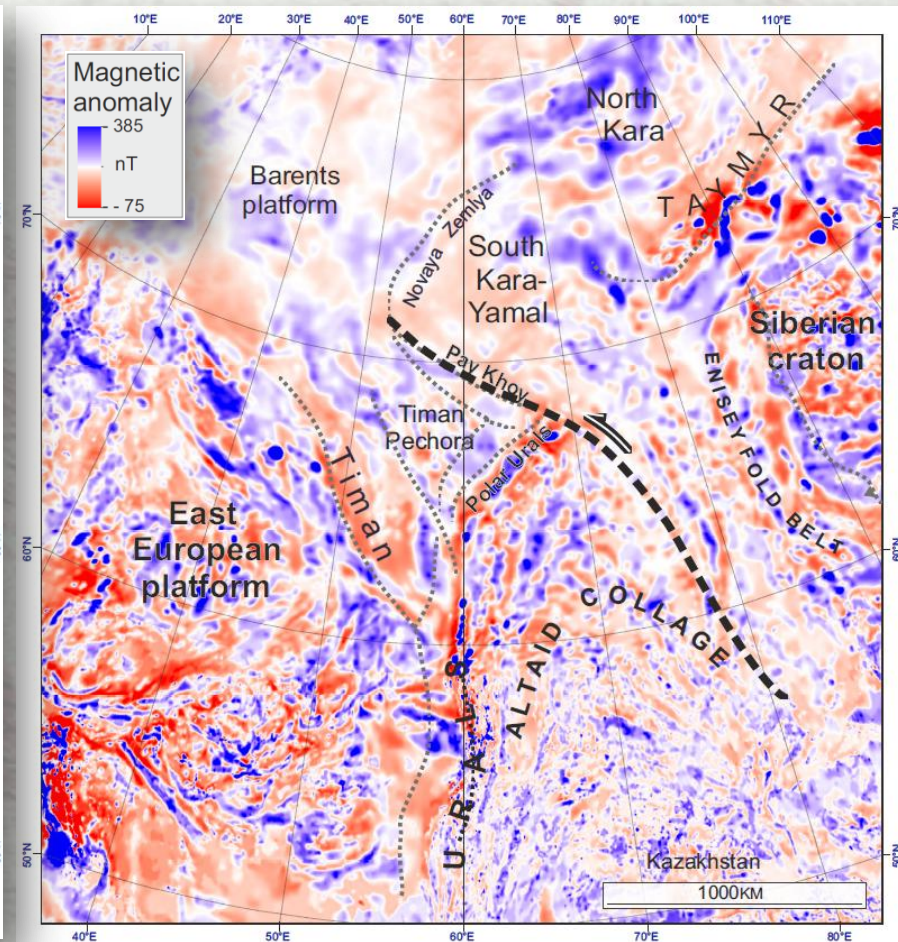
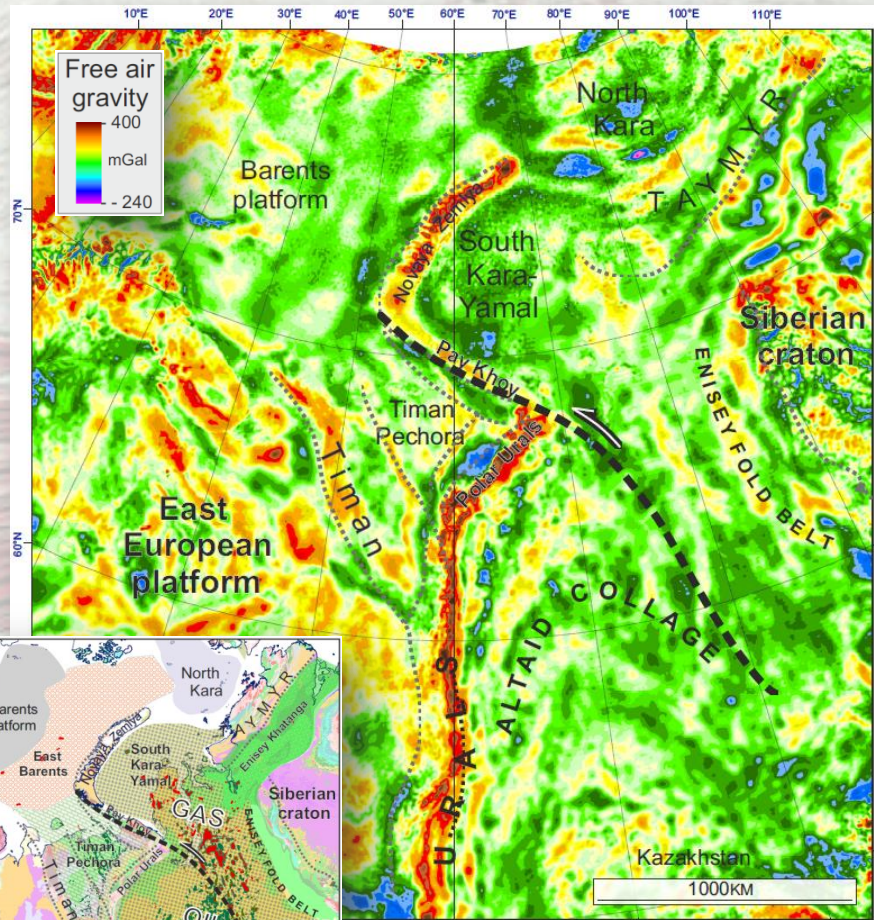
## Late Paleozoic deformation

NW-striking zone of transpression affecting the pre-Triassic section in the core of the Pay-Khoy anticlinorium





# The Transeurasian strike-slip fault in potential fields

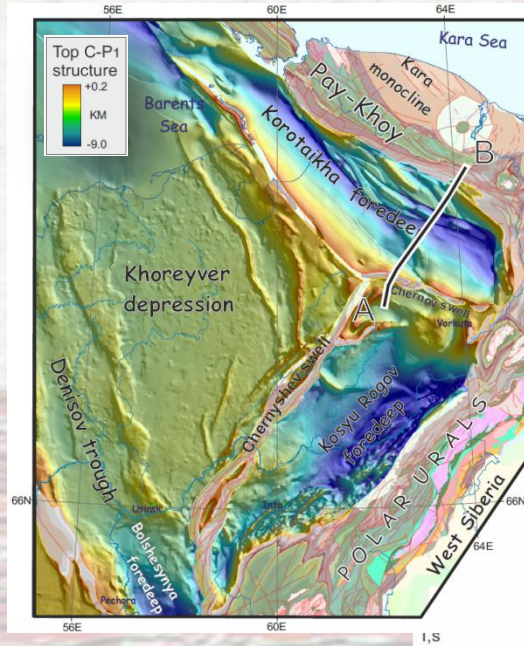


Prominent sinistral strike-slip fault system separating the EEP and Altaiids from amalgamated terranes of Siberian affinity, circa 255 Ma. Location of the fault system is schematic. It is overprinted by younger fault generations.

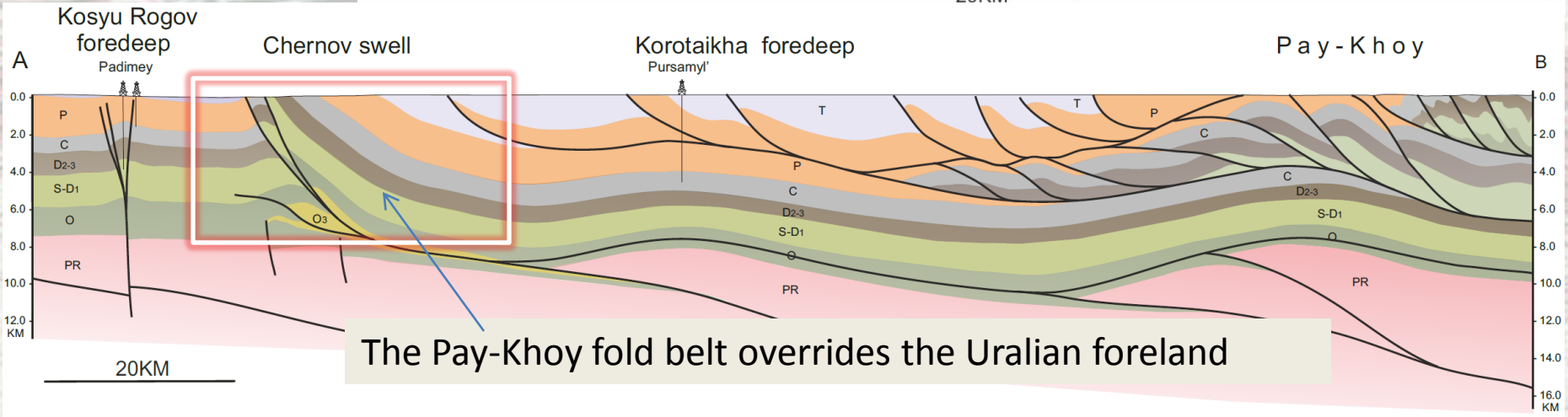
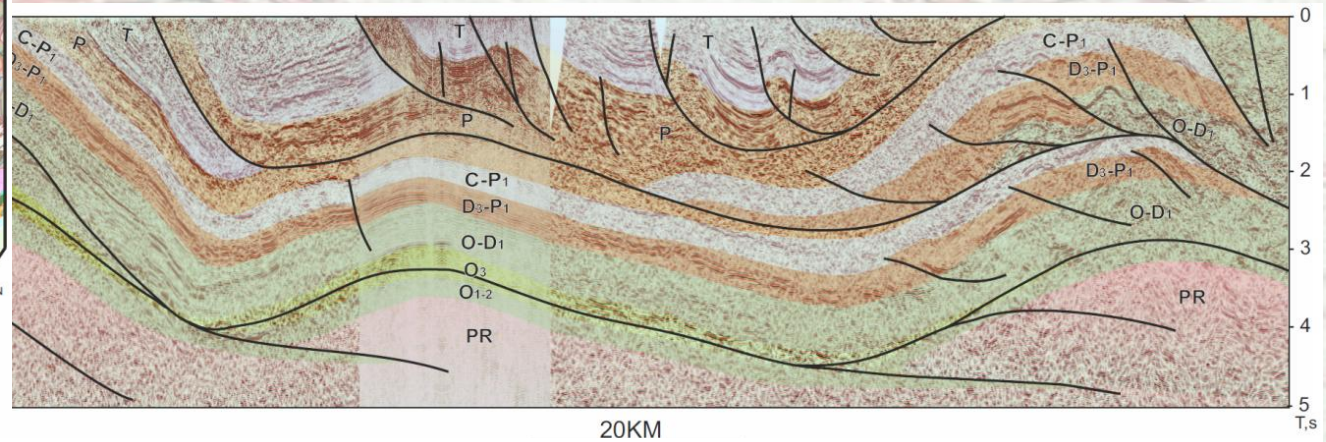


# Pay-Khoy

## Post Triassic thrusting

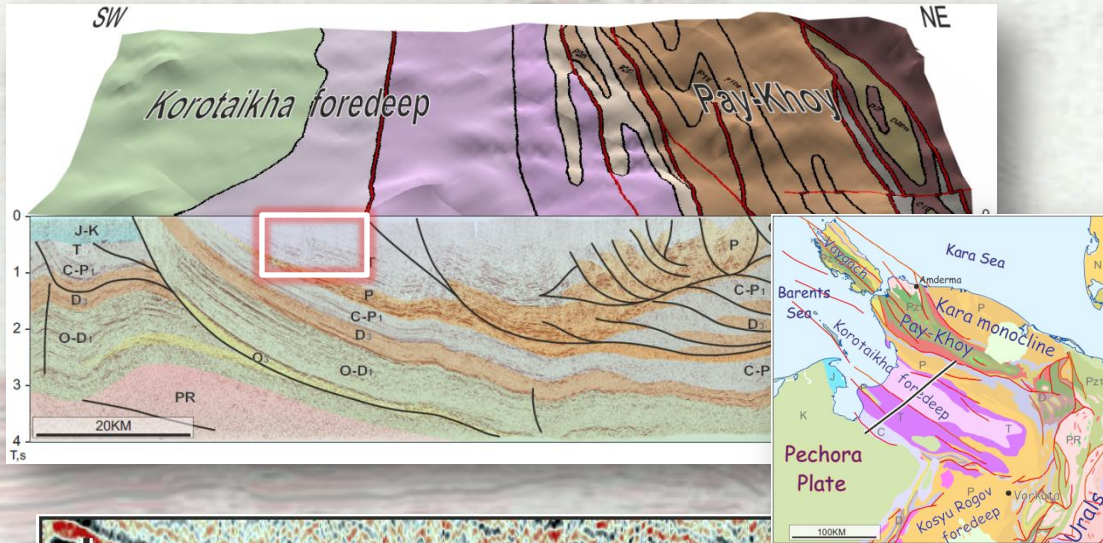


- ✓ No major unconformities in the Paleozoic-Triassic section
- ✓ The Triassic section is involved in foreland thrusting

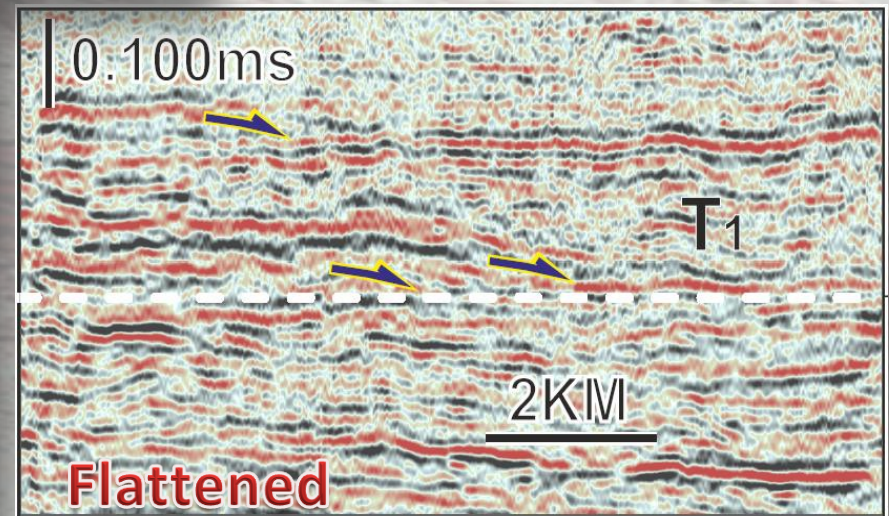
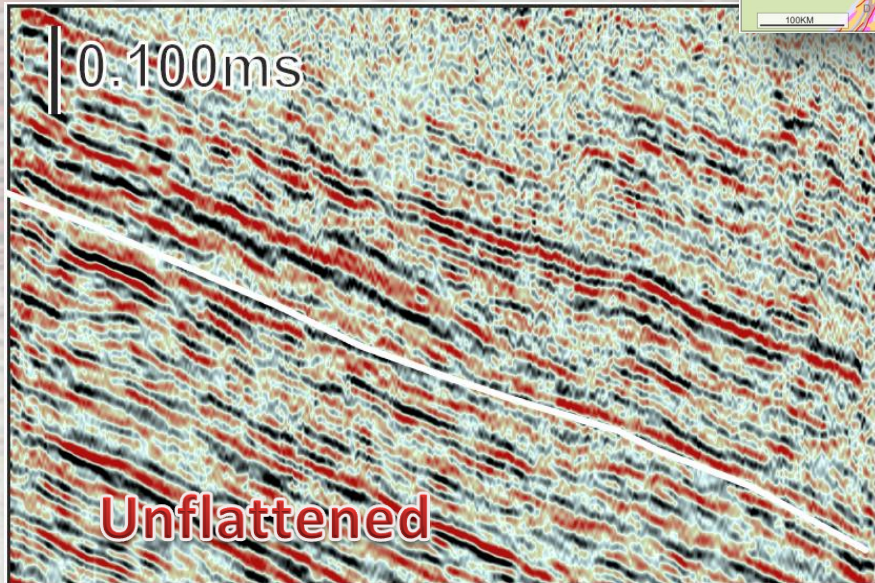




# Pay-Khoy syn-orogenic deposition



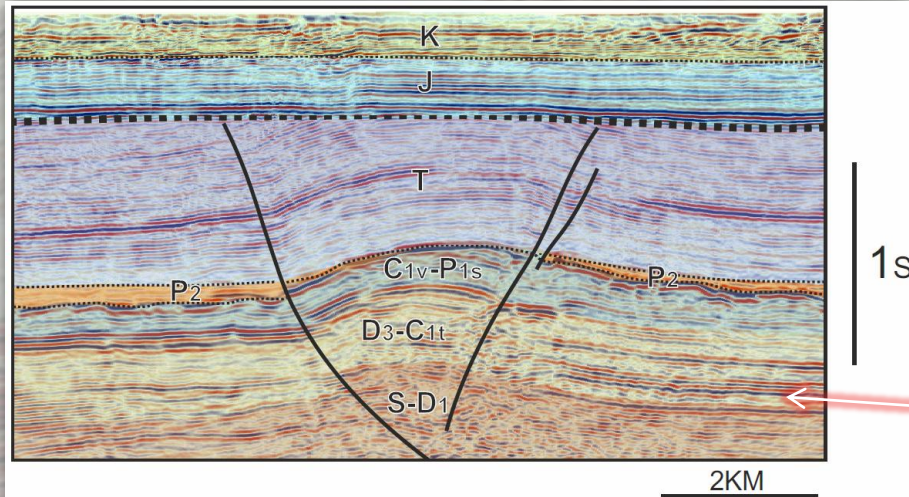
NE progradation of clinoforms in the Lower Triassic: deposition predated uplift of the Pay-Khoy



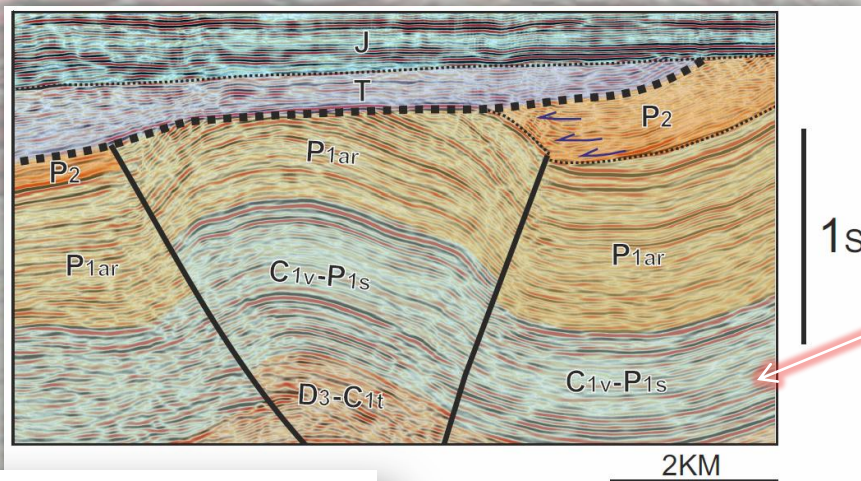


# Timing of folding

Pay-Khoy foreland

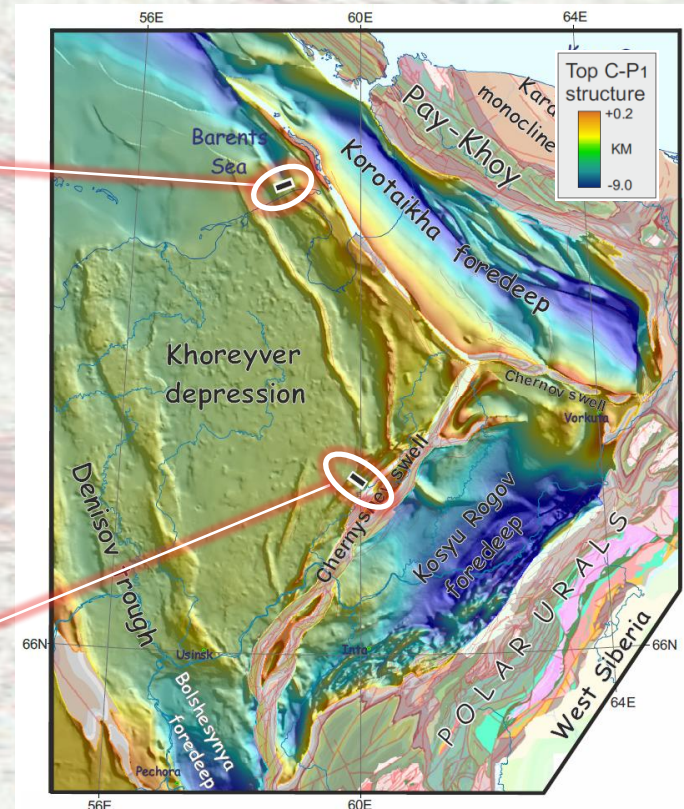


Polar Urals foreland



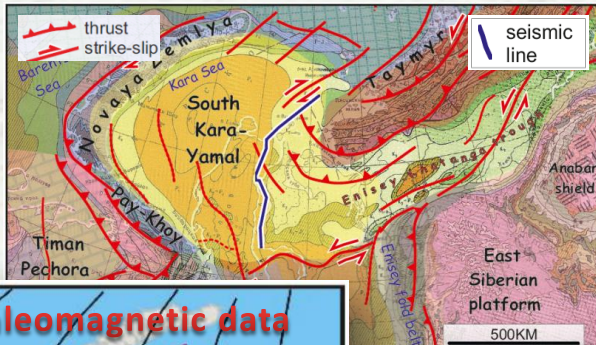
## Main phases of foreland folding:

- ✓ Pay-Khoy – Late Triassic-Early Jurassic
- ✓ Polar Urals – Late Permian-Early Triassic

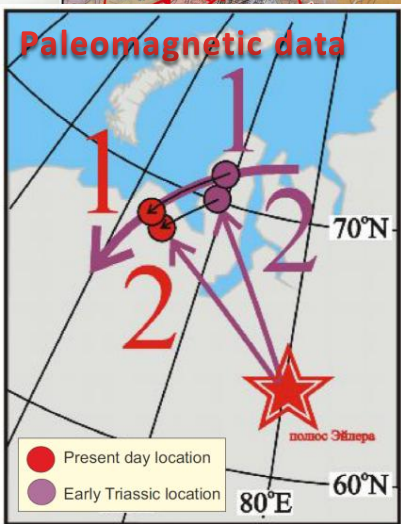




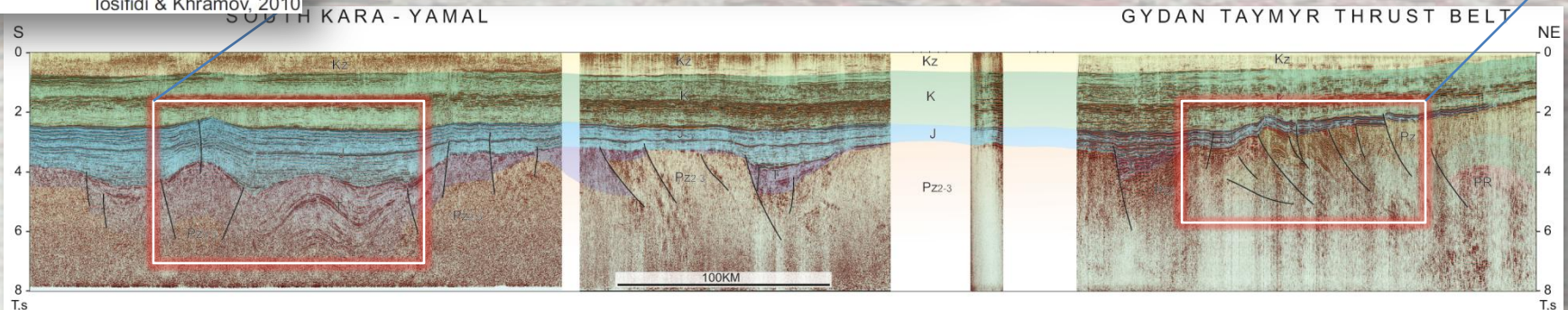
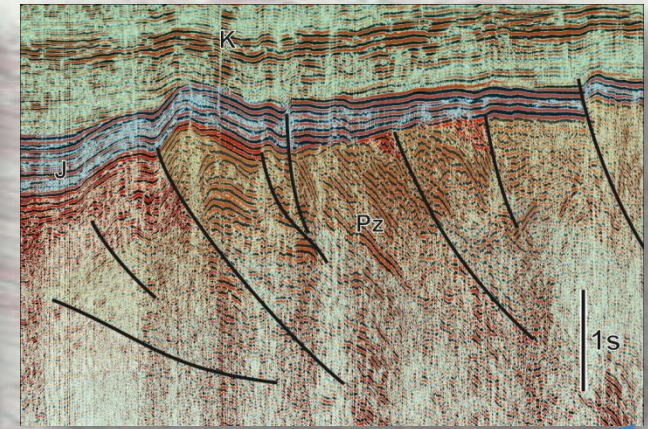
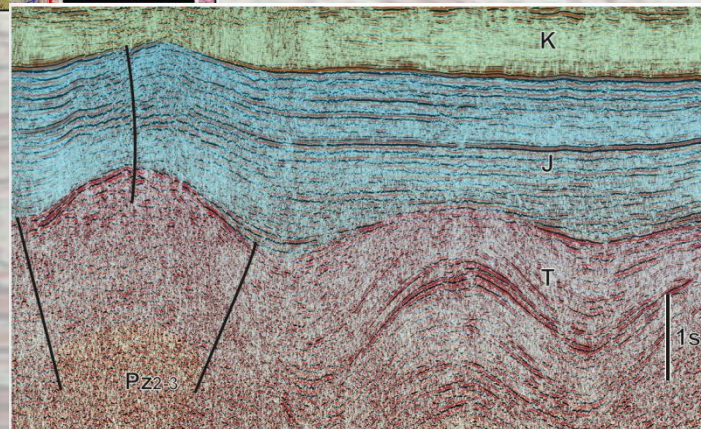
# Cause of the Late Triassic thrusting in Pay-Khoy



- ✓ SW-vergent deformation in the South Kara-Yamal, compressional folding and thrusting sealed by the Jurassic unconformity, Early Cretaceous and Tertiary reactivation
- ✓ paleomagnetic evidence of the South Kara-Yamal counter-clockwise rotation and SW movement

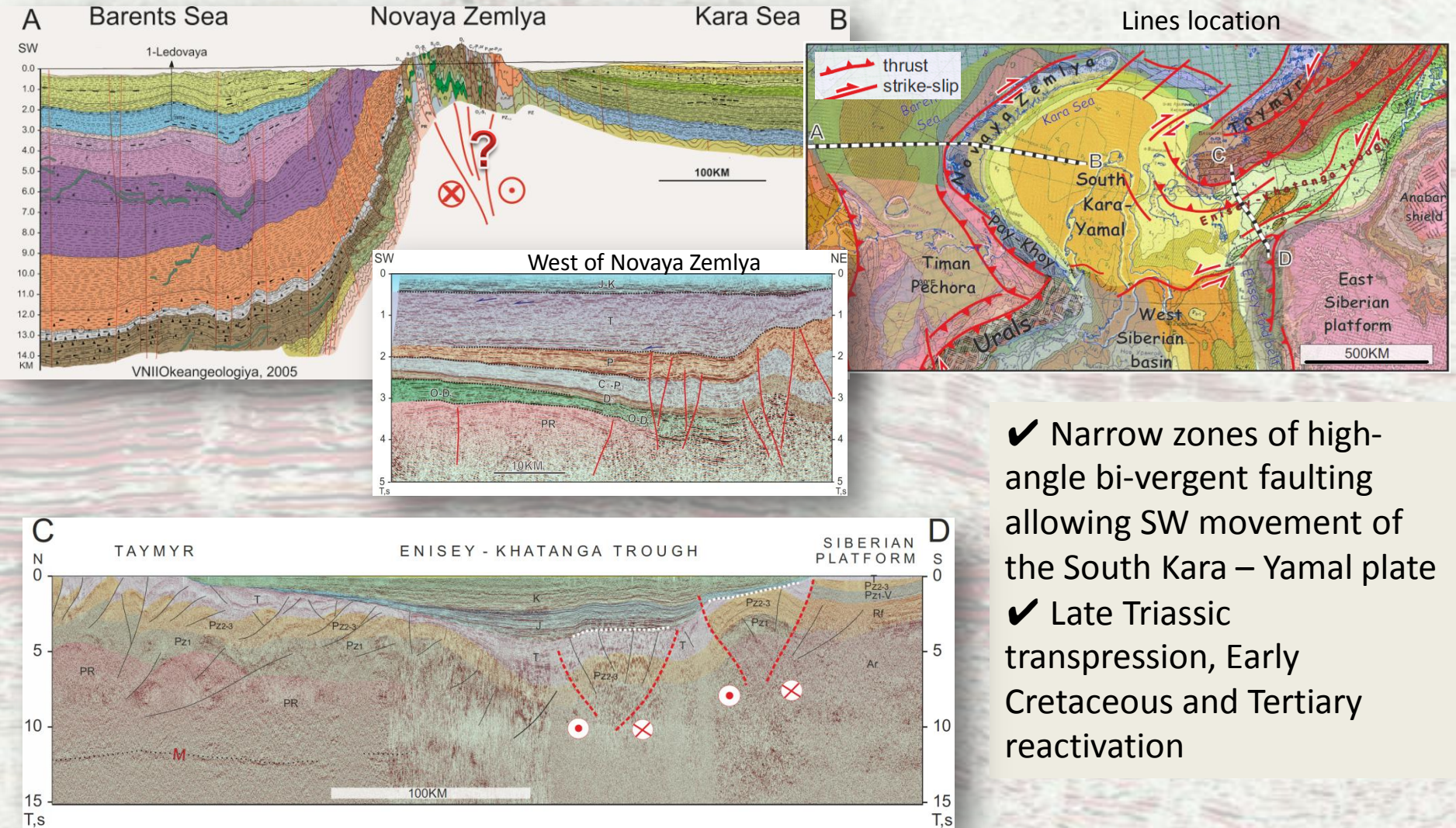


Iosifidi & Khramov, 2010





# Strike-slip zones flanking the South Kara-Yamal

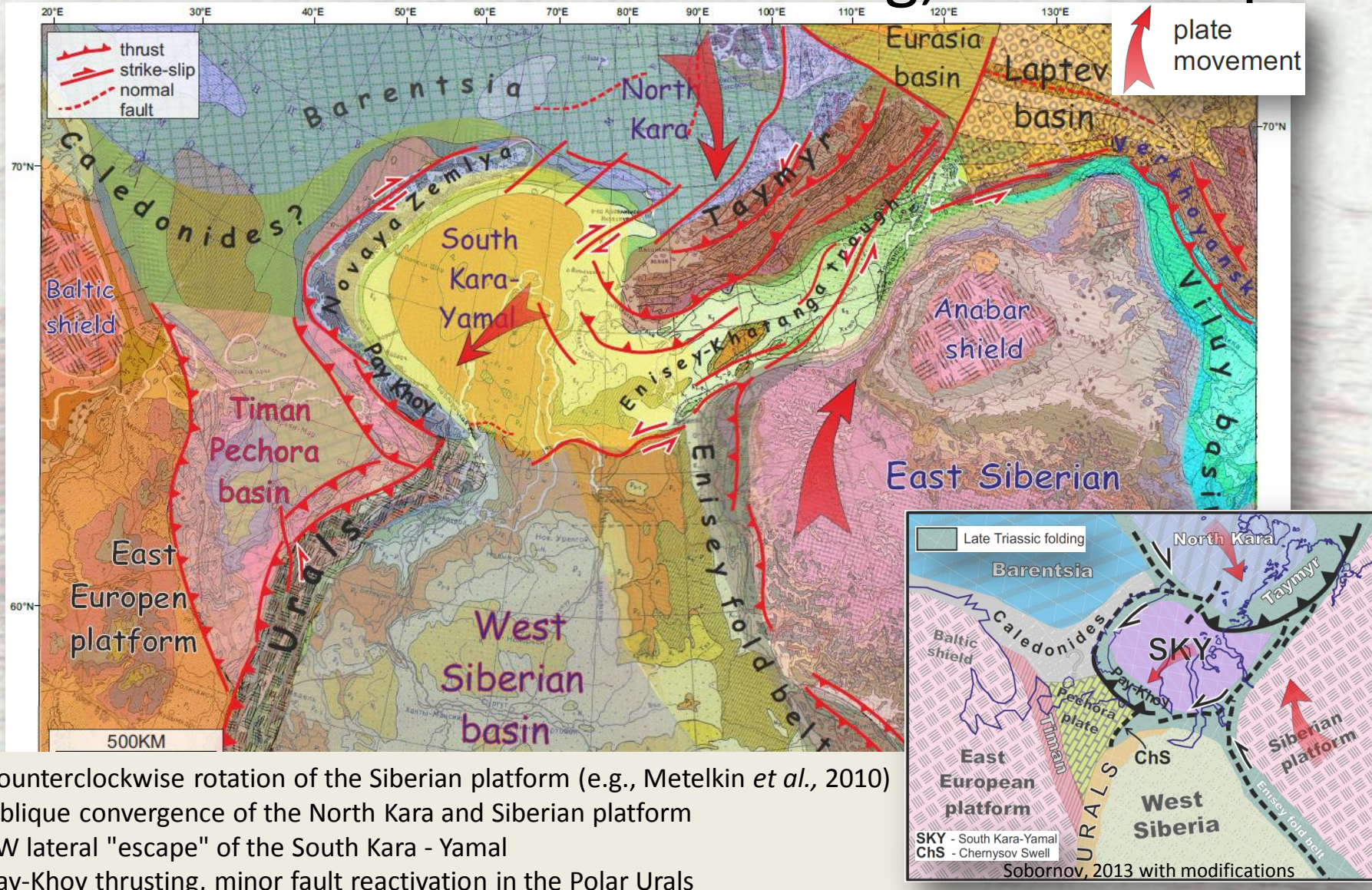


- ✓ Narrow zones of high-angle bi-vergent faulting allowing SW movement of the South Kara – Yamal plate
- ✓ Late Triassic transpression, Early Cretaceous and Tertiary reactivation



# North-Central Eurasia

## Late Triassic structural setting, SKY "escape"

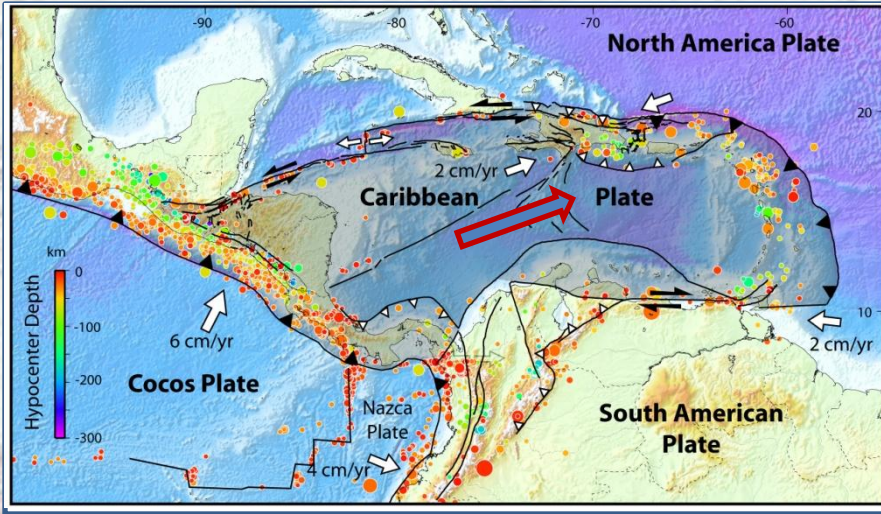


- ✓ Counterclockwise rotation of the Siberian platform (e.g., Metelkin *et al.*, 2010)
- ✓ Oblique convergence of the North Kara and Siberian platform
- ✓ SW lateral "escape" of the South Kara - Yamal
- ✓ Pay-Khoy thrusting, minor fault reactivation in the Polar Urals



# Lateral "escape" pattern, selected analogs

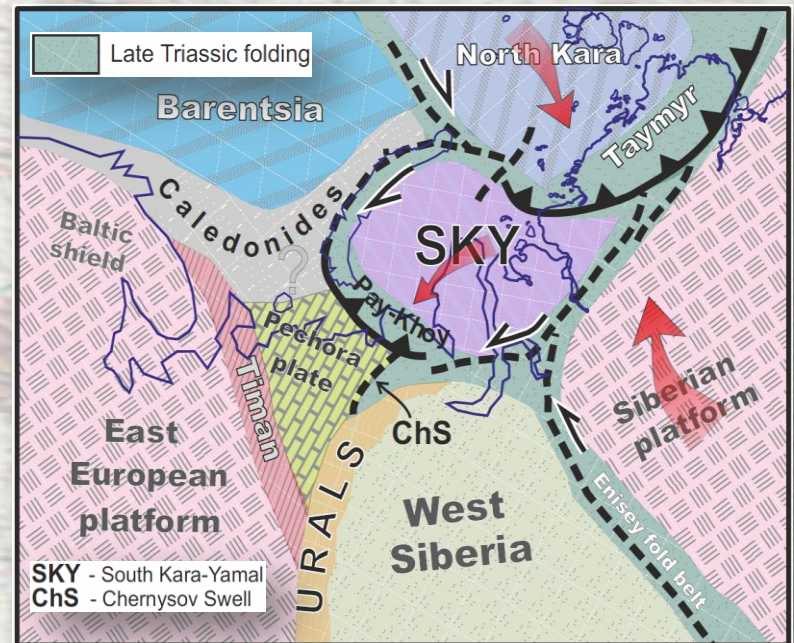
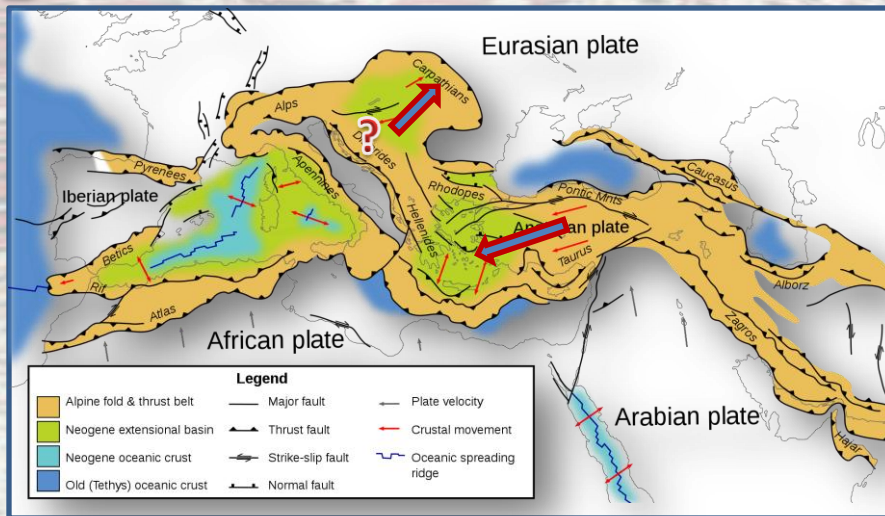
A



A – The Caribbean plate, Lesser Antilles  
B – The Anatolian plate, Panonnian basin-Carpathians (?)

North-Central Eurasia, Late Triassic

B





# Conclusions

- Many similar features in structural styles
  - ✓ detachment faulting
  - ✓ piggy-back basins
- Polar Urals
  - ✓ part of the Uralian suture, Late Paleozoic folding
  - ✓ reactivation in the Late Triassic
- Pay-Khoy
  - ✓ Late Paleozoic sinistral transpression
  - ✓ thrusting in the Late Triassic, Pay-Khoy- the leading edge of the South Kara - Yamal



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- VNIGRI
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# Thank you!

