

# **Triassic – Early Cretaceous Structural Development of the Central Part of the Northern Eurasia\***

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## **Abstract**

The Central Part of the Northern Eurasia comprises parts of the Timan Pechora, West Siberia, Enisey-Khatanga basins, surrounded by the Urals, Pay-Khoy – Novaya Zemlya, and Taymyr fold belts. An integrated regional study has been conducted in order to constrain the regional geological model and upgrade understanding of the petroleum systems. It was based on an extensive database including vintage and new seismic surveys, potential field data, drilling information, geological mapping etc. Key objectives of the study were identification of megasequences and structural styles, correlations of the Mesozoic unconformities, mapping of the clinoformal progradation in the Lower Cretaceous section. The following sequence of the principal Mesozoic structural events is recognized based on the integrated regional study: (1) post-orogenic collapse in the Early Triassic, (2) transpression and thrusting in the late Triassic, and (3) reactivation of the preexisting fault systems in the Early Cretaceous.

The post-orogenic collapse occurred in the Early Triassic following the Pangea assembly. It was coupled with outbreak of flood basaltic magmatism. The interpretation of regional seismic data supported by geological and non-seismic geophysical data show the occurrence of a system of deep elongated subbasins overprinting the pre-existing folded terrains of the NC Eurasia. They are documented in the Enisey-Khatanga Basin, Kara Sea, and northern part of the West Siberian Basin. These subbasins provided accommodation space for the rapid dominantly clastic sedimentation in the West Siberian Basin and Enisey-Khatanga trough during Early-Middle Triassic.

The Late Triassic structural development includes thrusting in the Taymyr and Pay-Khoy, as well as transpression in the 1500 km-long zone spanning for about 1500 km from the Laptev Sea to the Pay-Khoy (the Enisey Transpression zone (ETZ)), and along Novaya Zemlya. The transpression zones are manifested in arrays of restraining bends with high-relief pop-ups. Seismic interpretation suggests that the transpression included a significant element of inversion of the pre-existing early Triassic grabens. Our review of the regional G&G dataset including paleomagnetic data (Iosifidi and Khramov, 2010) shows that the regional Late Triassic structural pattern fit well into the lateral escape kinematic model (Sobornov, 2013, 2015). It suggested the south-western displacement of the South Kara – Yamal block from the zone of

collision between the Siberian Platform and Taymyr to the south-west, coupled with 10°-20° counterclockwise rotation of this block around an Euler pole in the eastern part of the West Siberian Basin.

The Early Cretaceous folding is largely following the Late Triassic fault pattern. It is manifested in the pronounced thickness variations of the Lower Cretaceous deposits. The reactivation of the pre-existing fault zones is interpretably attributed to the Verkhoyansk orogeny along the eastern flank of the Siberian platform.

The Early Mesozoic structural events provided considerable effect on the petroleum systems. The Enisey transpression zone formed northern boundary of the restricted anoxic basin where the prolific Bazhenov source rock was deposited. It also acted as a structural barrier during deposition of the Lower Cretaceous syntectonic clinoformal complexes, which host large parts of the oil and gas deposits of the West Siberian Basin. This resulted in deposition of the main volumes of the mature quartz-rich reservoir sands to the south of this fault zone. The Lower Cretaceous section of the northern part of the West Siberian Basin, corresponding to the South Kara -Yamal area, has large input of clastic material shed from the surrounding fold belts. Quality of the Lower Cretaceous reservoirs in this area is deteriorating due to the lower quartz content and poorer sorting of sands.

Interpretation of high-resolution seismic data provided evidence subsurface sediment remobilization and fluid flow processes. These include the presence of sand injectites, mud volcanoes, and polygonal faulting. The sand injectites and polygonal faulting tend to occur mainly in the deep troughs formed by the post-collision extension and transpression and filled by thick clastic sequences. These features may affect integrity of the main reservoirs and their productivity. The mud volcanoes are interpreted in zones of inversion and transpression. They are likely produced by deeply buried Triassic and Jurassic overpressured shale packages subjected to compression.

### **Acknowledgements**

The author would like to thank V. Baldin, V. Igoshkin, A. Nikishin, and G. Palladino for helpful discussions and suggestions regarding the geology of the study area. Geotech, TaymyrGeofizika, SMNG, MAGE provided geophysical data.

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# Triassic – Early Cretaceous Structural Development of the Central Part of the Northern Eurasia

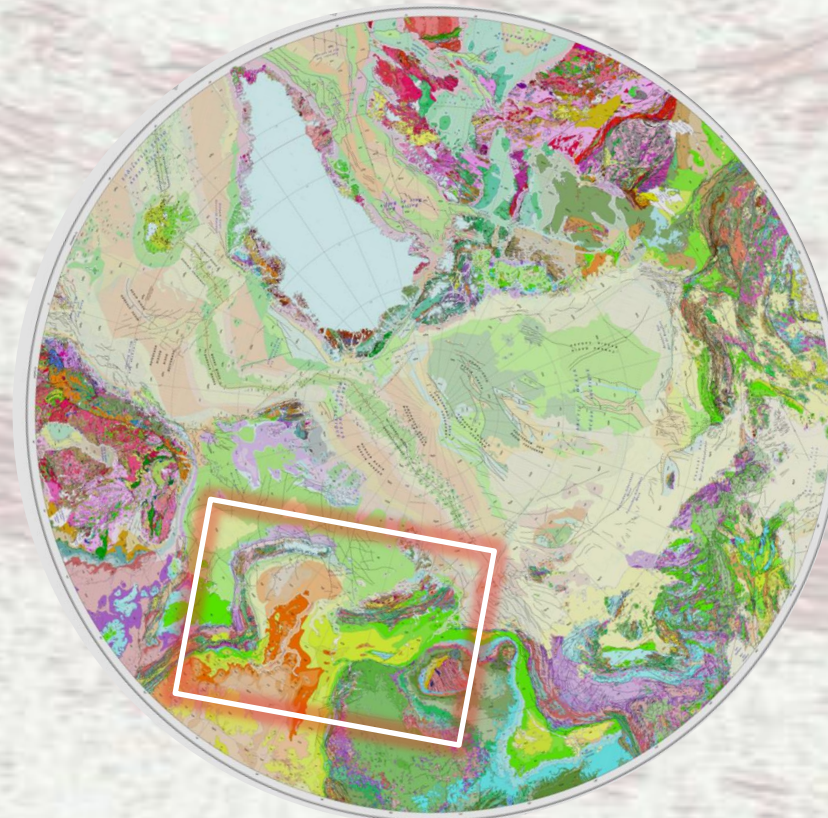
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Aleksandr Afanasenkov\*\*,

Aleksandr Obukhov\*\*

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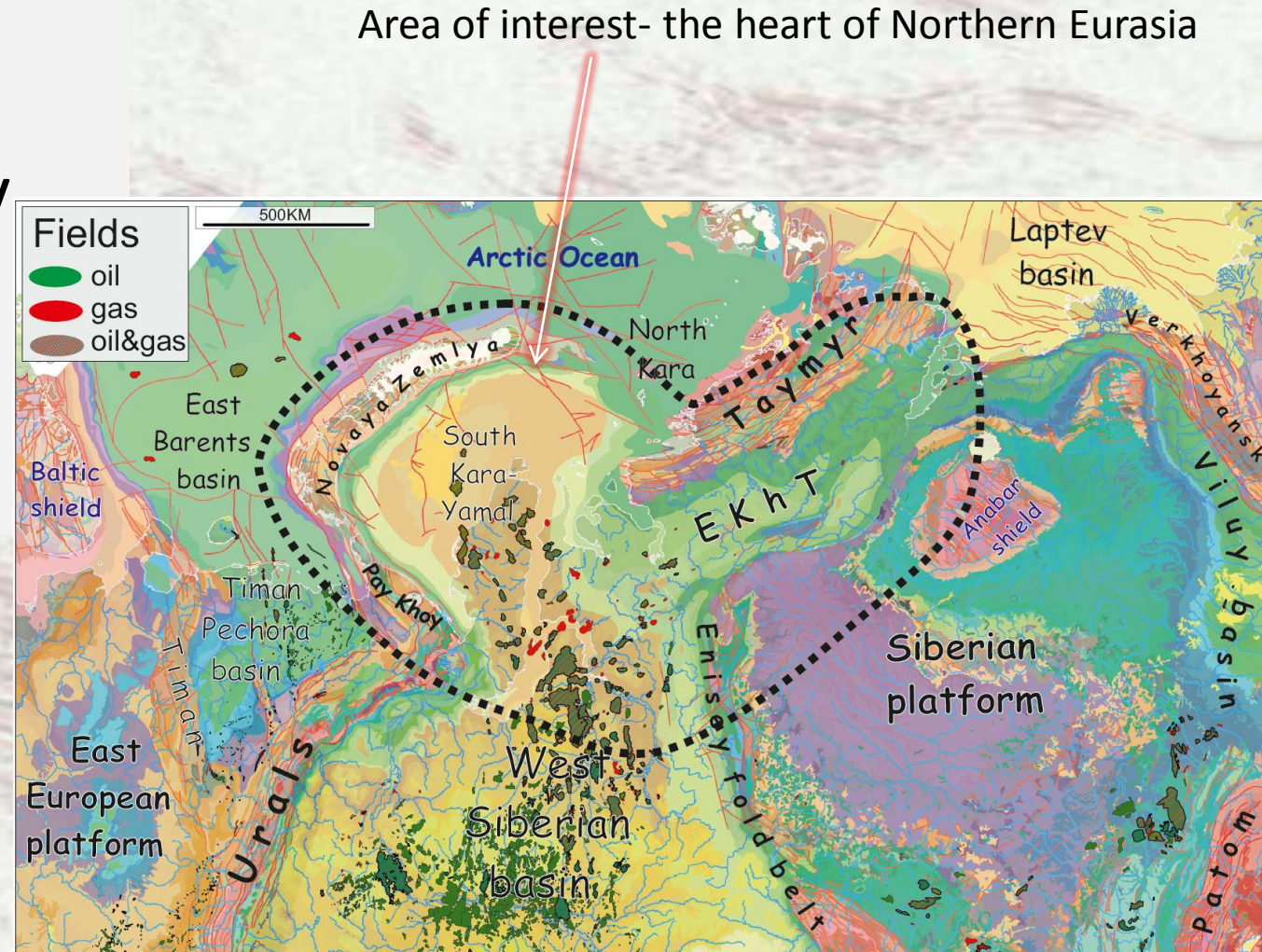
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# Outlines

- Study objectives & database
- Regional interpretation
- Implication for sedimentology and petroleum exploration
- Conclusions





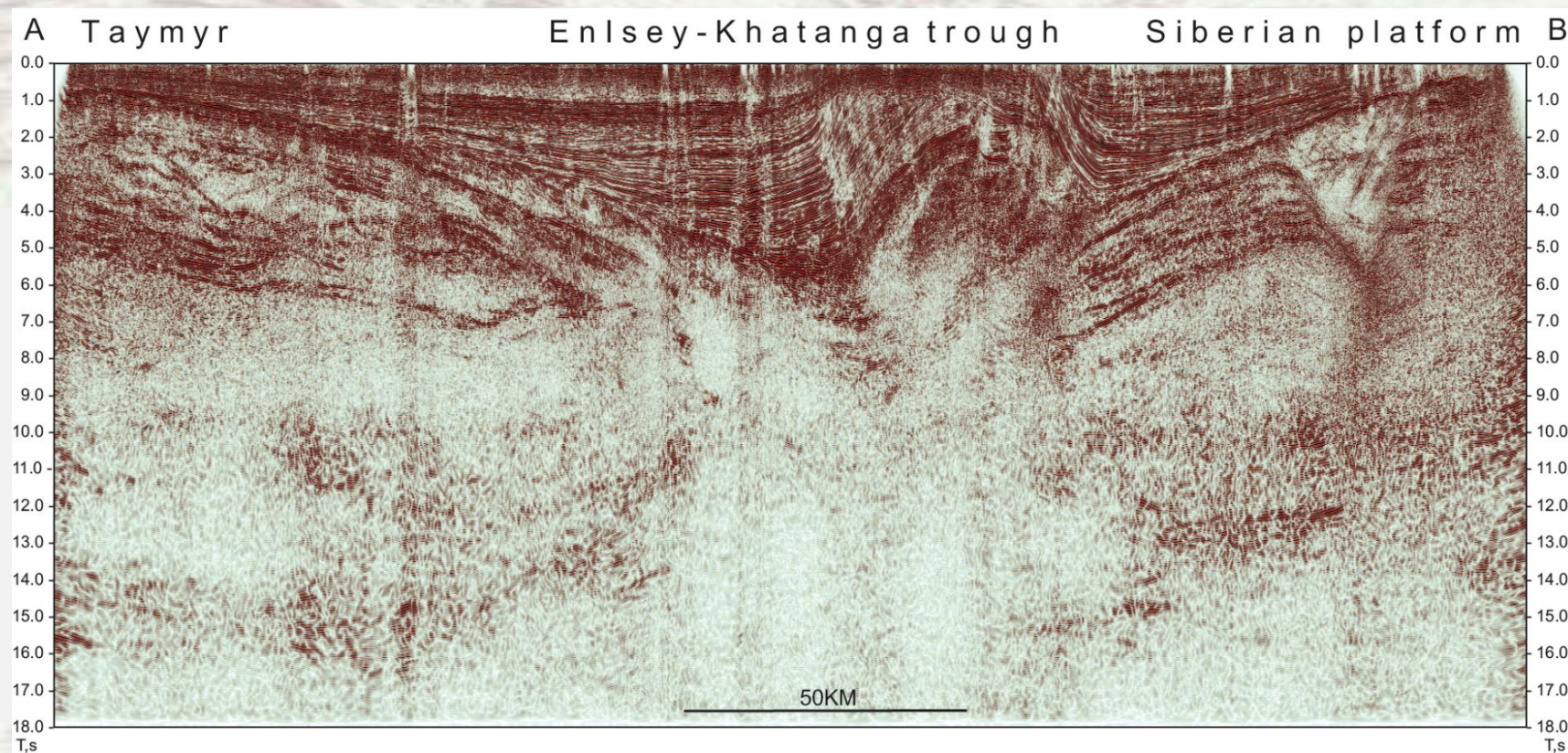
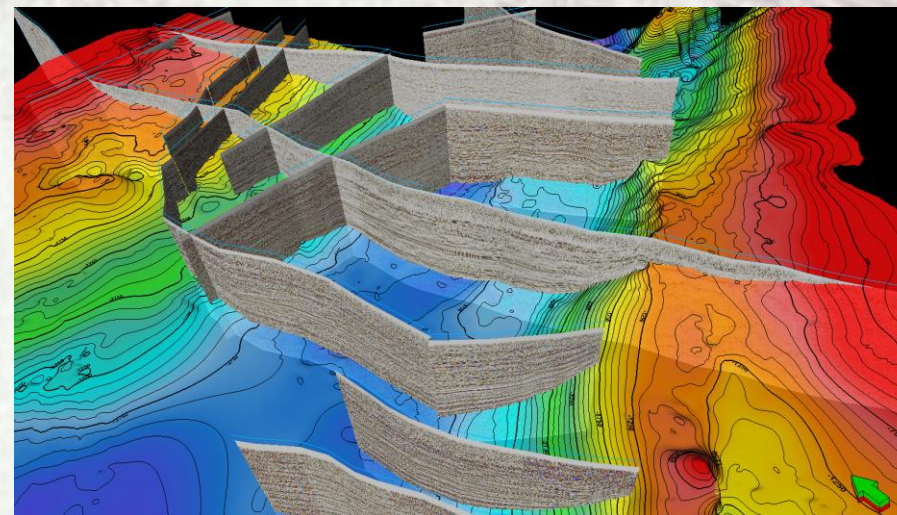
# Study objectives, database

## Objectives

- ✓ development of the regional geological model
- ✓ upgrade understanding of the petroleum systems

## Database

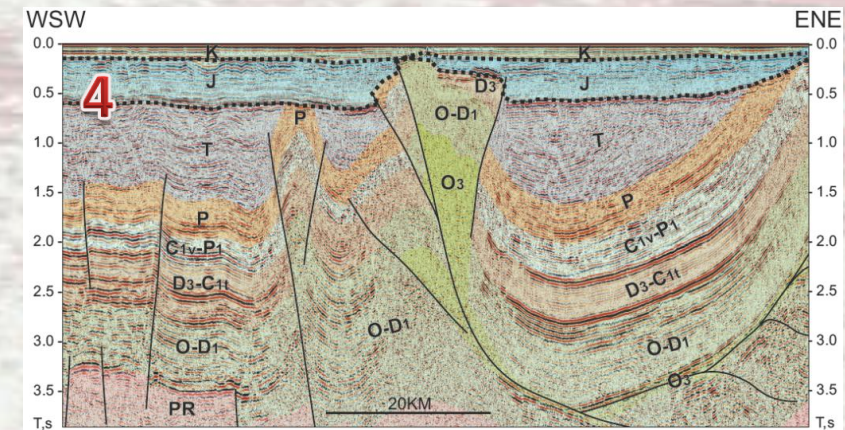
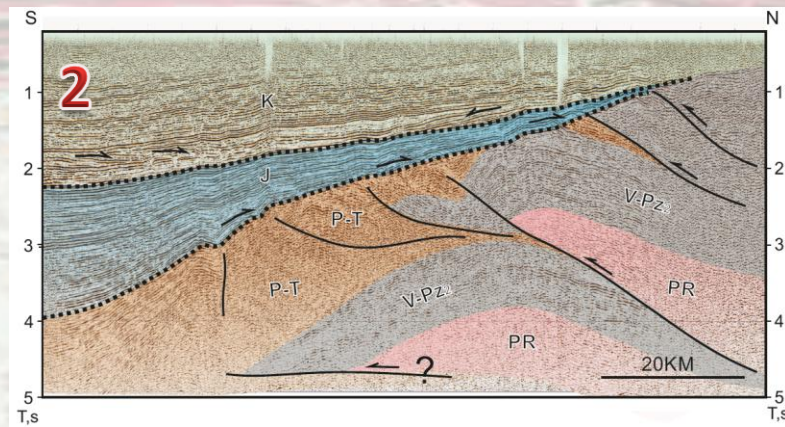
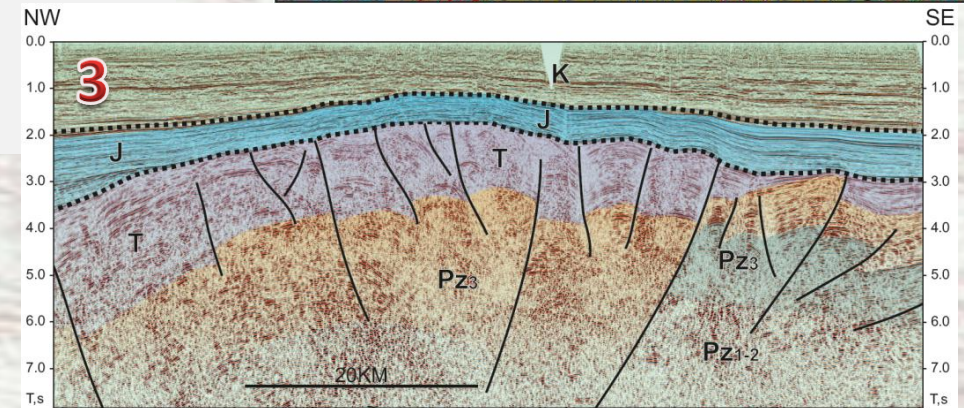
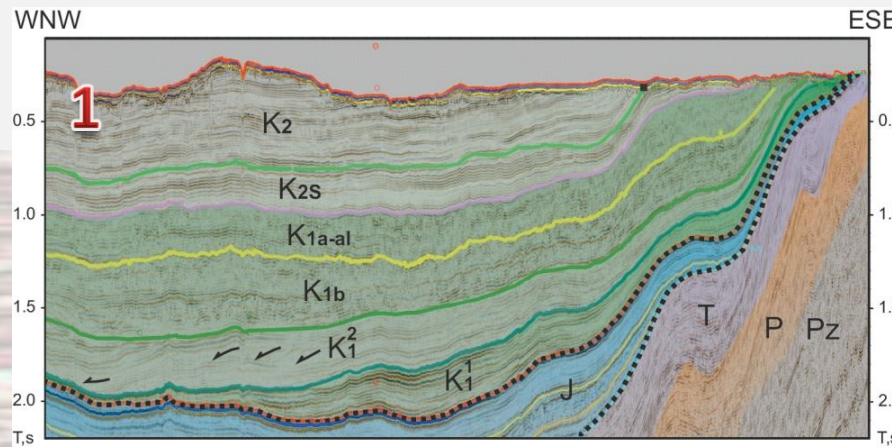
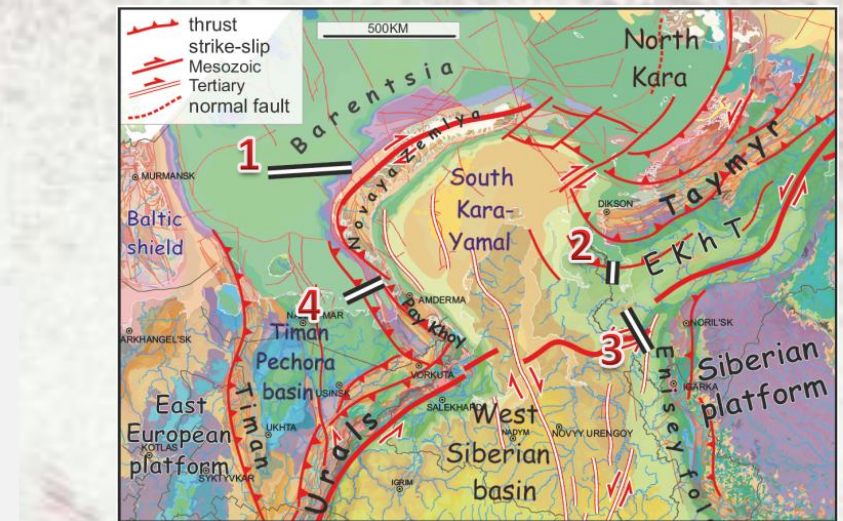
- ✓ vintage and new seismic surveys
- ✓ potential fields
- ✓ drilling information
- ✓ geological mapping
- ✓ public domain data etc.





# Regional seismic interpretation, key objectives

- ✓ identification of megasequences and structural styles
- ✓ correlations of the Mesozoic unconformities
- ✓ mapping of the clinoformal progradation in the K1 section

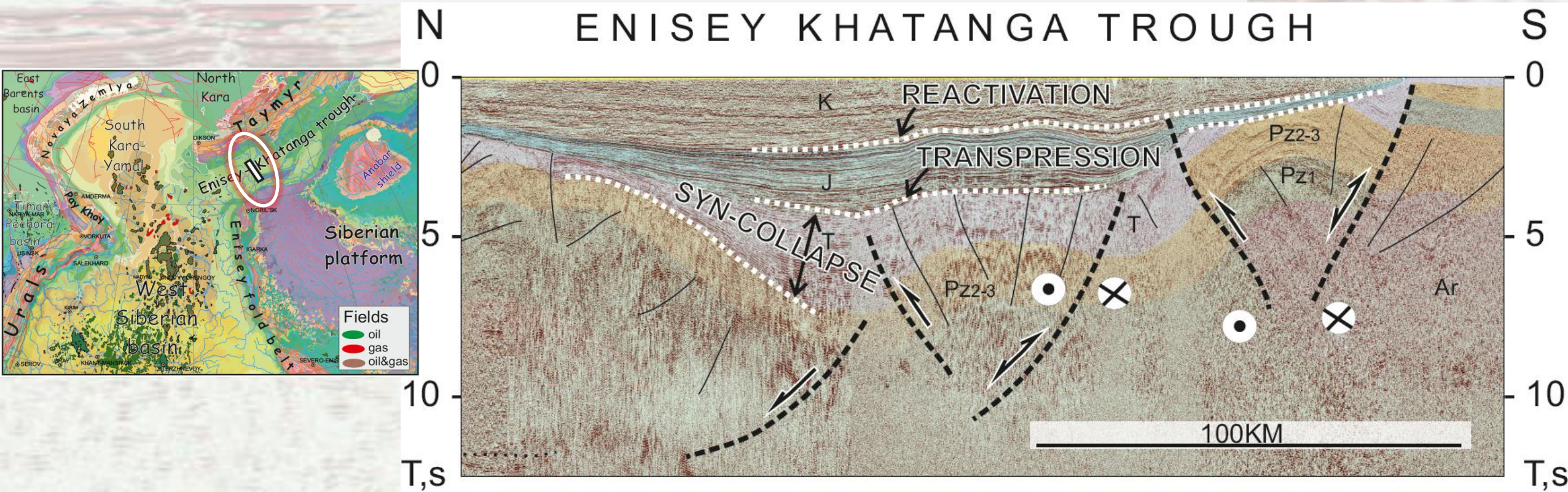




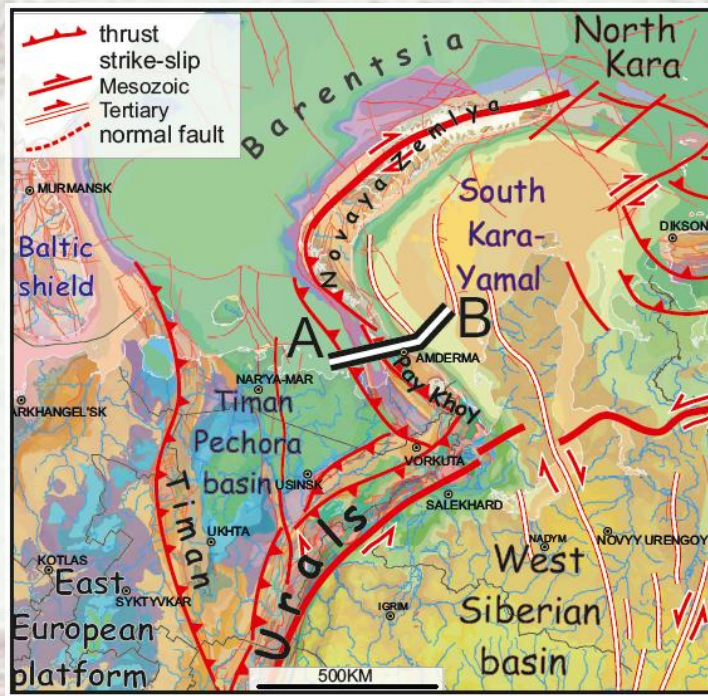
# Triassic-Early Cretaceous structural events

The following sequence of the principal Mesozoic structural events is recognized based on the integrated regional study:

- ✓ T1- post-orogenic collapse
- ✓ **T3- transpression, thrusting**
- ✓ K1- reactivation of the T3 fault systems



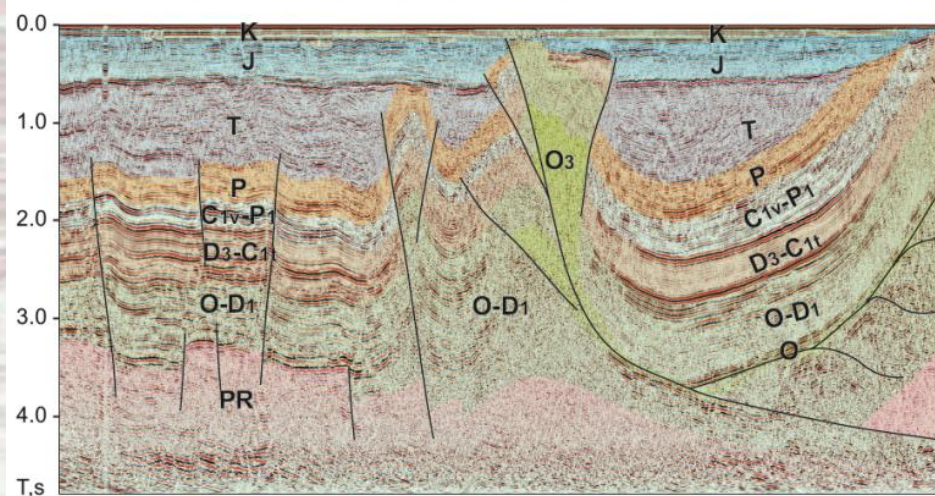




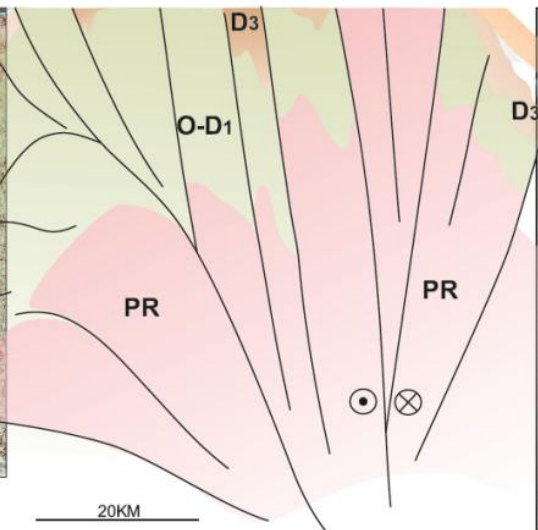
# Post-orogenic collapse, Kara Sea

Post orogenic collapse,  
following the Pangea assembly,  
Early Triassic

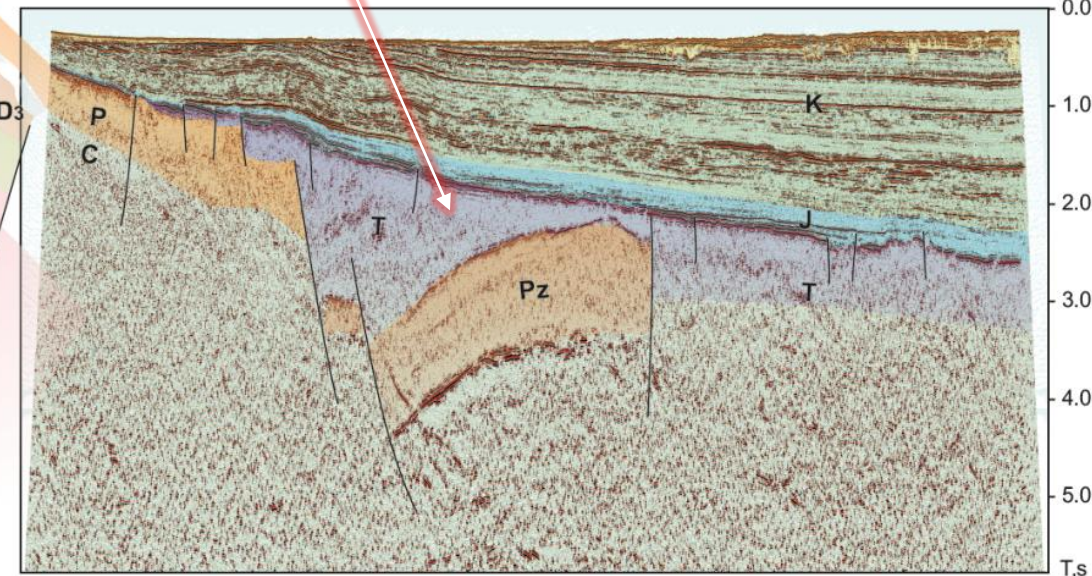
A Timan Pechora Basin



Pay-Khoy Fold Belt



South Kara

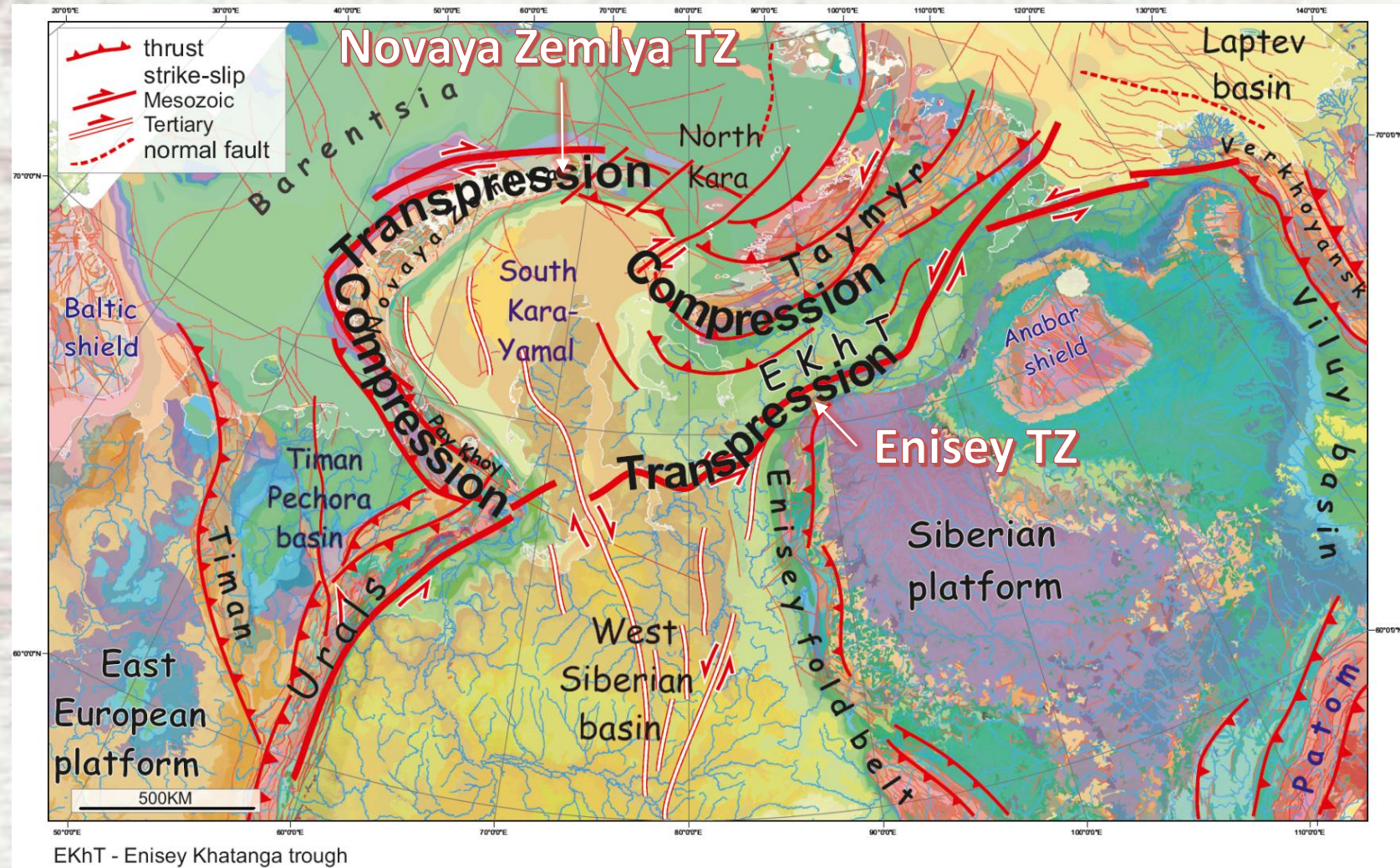


Composite G&G line



# Late Triassic structural setting

Interpreted  
distribution of the  
Late Triassic  
deformation styles,  
based on integrated  
interpretation of the  
G&G data

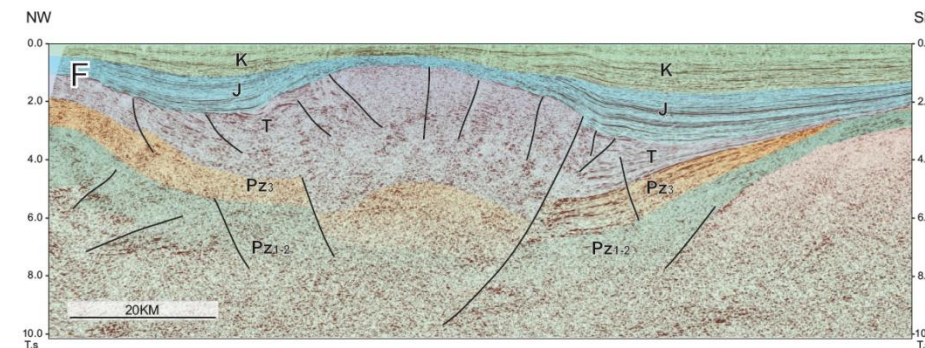
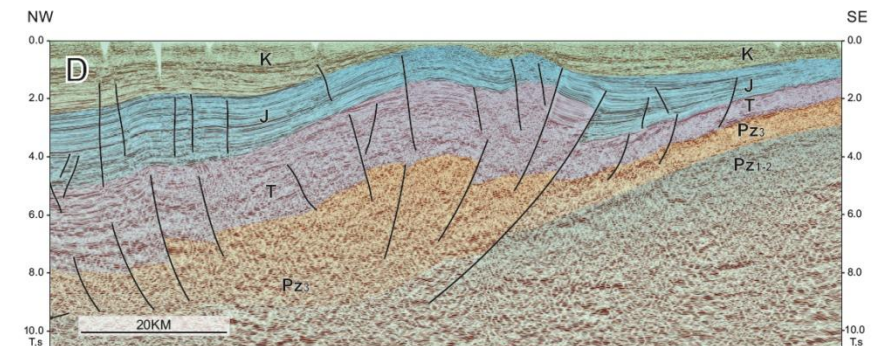
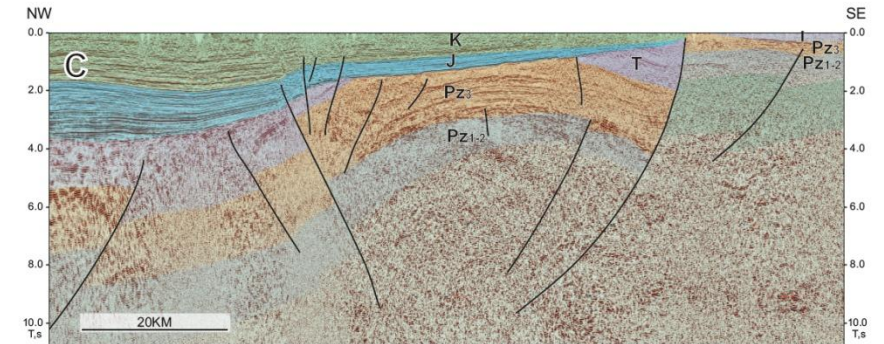
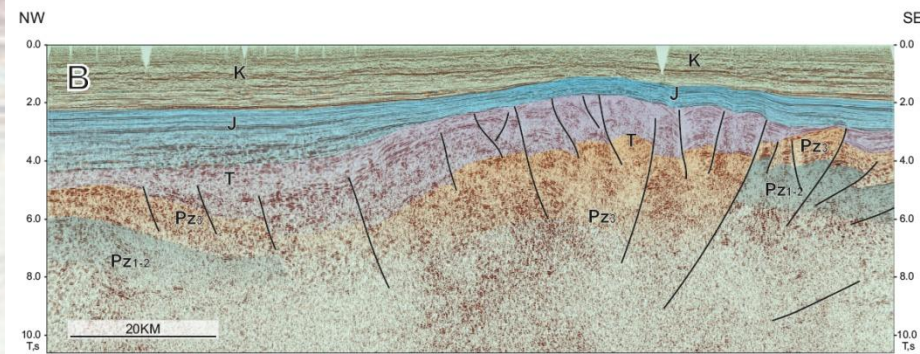
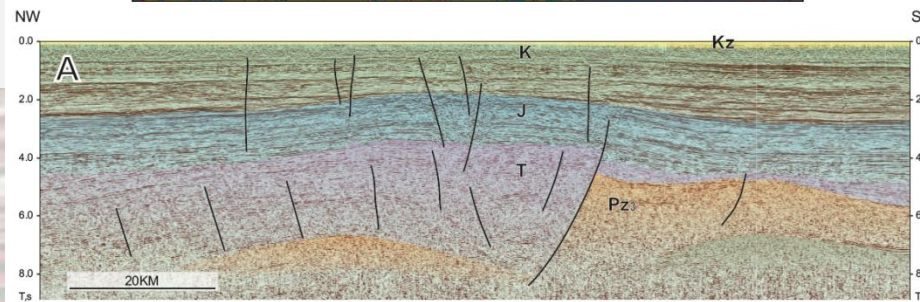
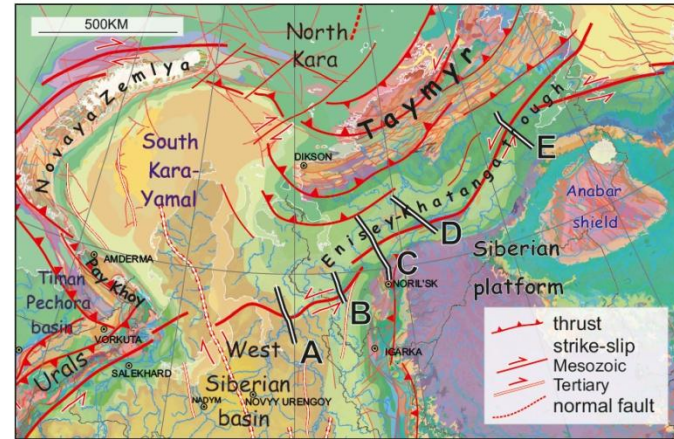


TZ- transpression zone



# Enisey (southern) transpression zone

Interpreted seismic lines across different segments of the 1500+ km-long Enisey transpression zone (ETZ)



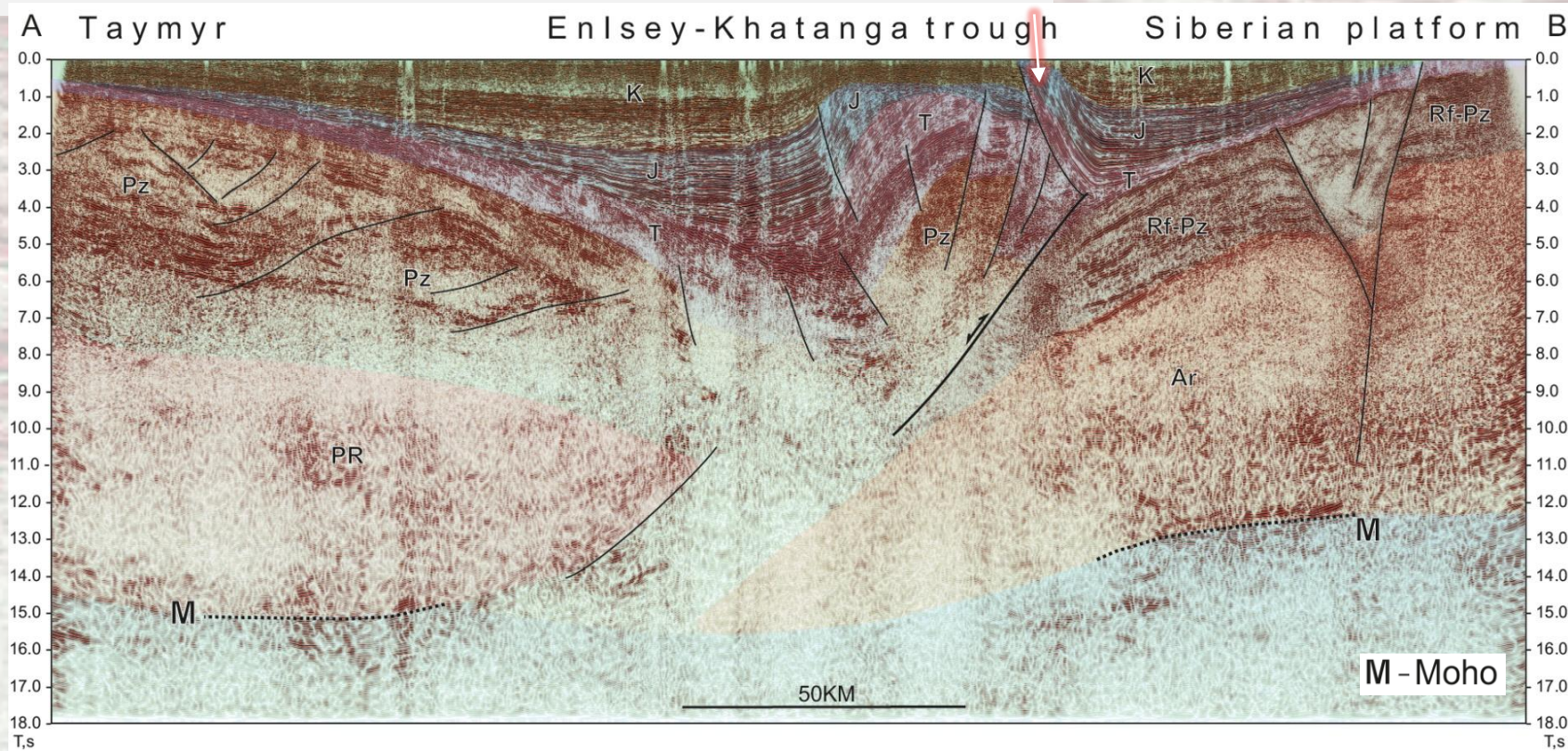
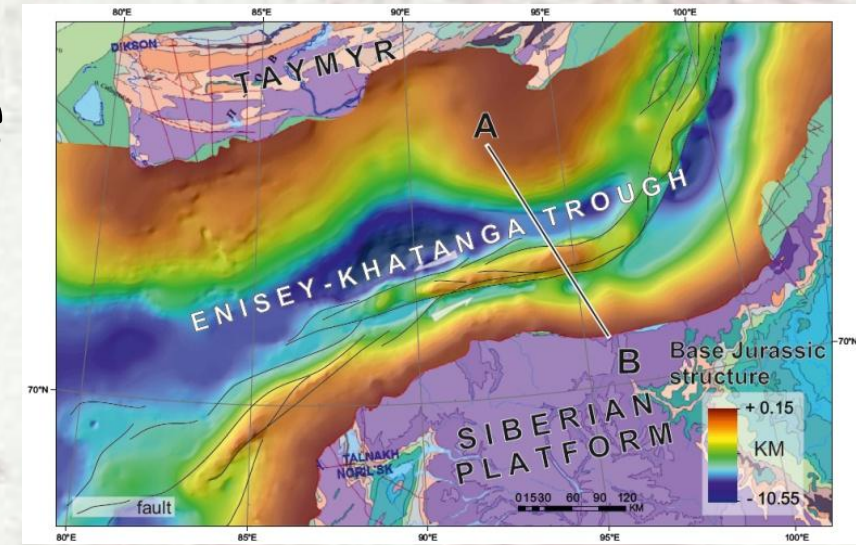


# Enisey (southern) transpression zone

Enisey transpression zone:

✓ en echelon array of restraining bends developed in the suture zone separating the Taymyr fold belt and Siberian craton

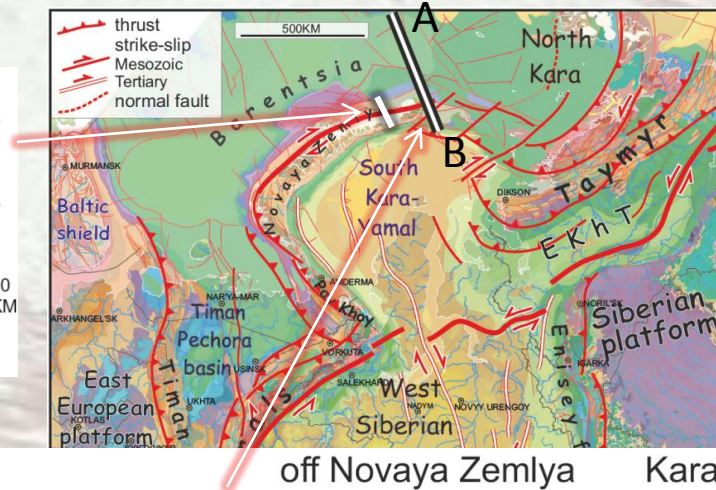
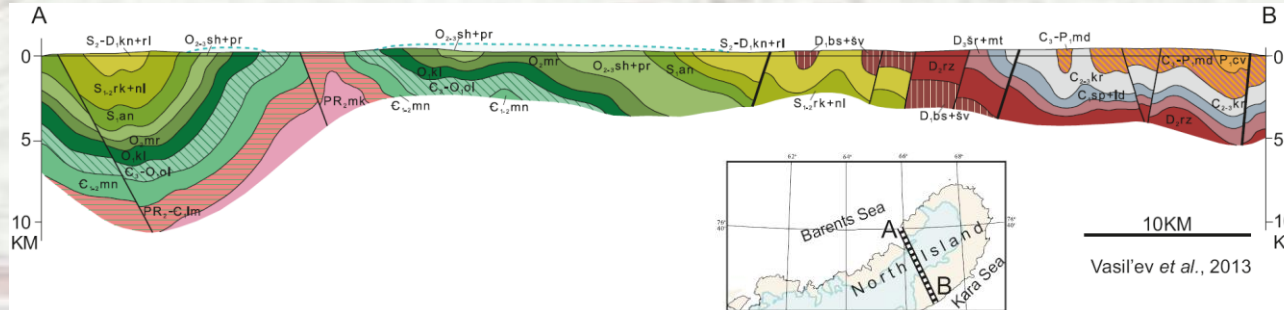
Backthrust





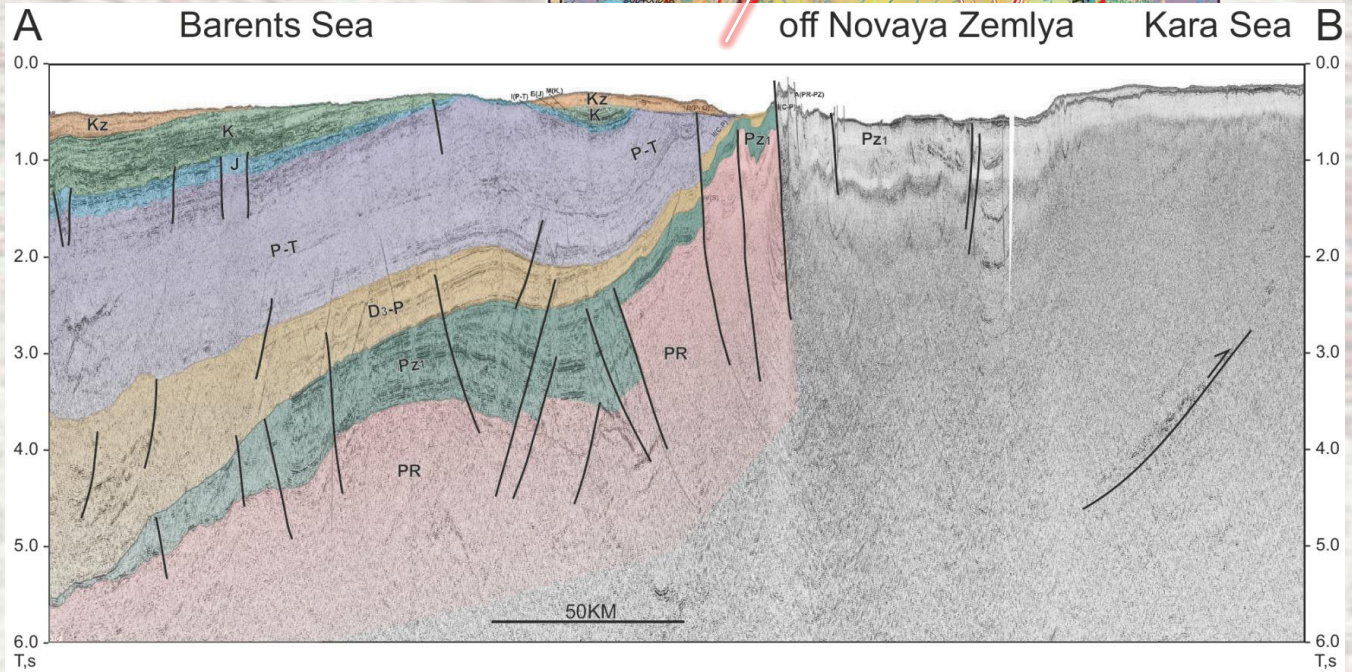
# Novaya Zemlya (northern) transpression zone

# Geological section across Novaya Zemlya



NZTZ:

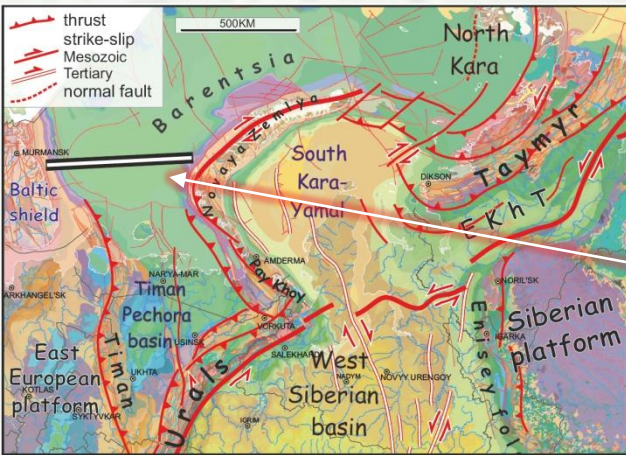
- ✓ high-relief uplift
- ✓ limited shortening
- ✓ bivergent high-angle faulting





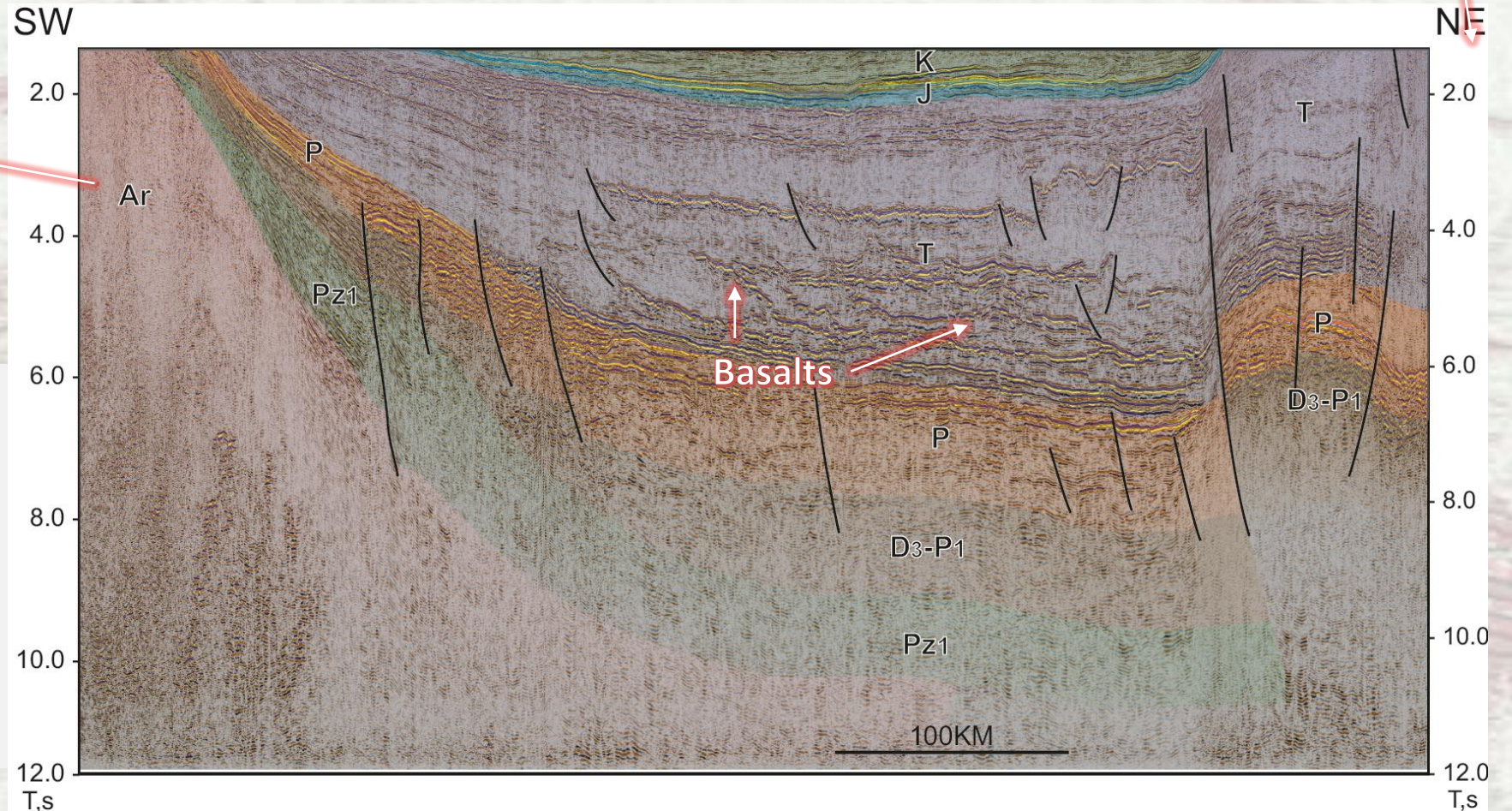
# Novaya Zemlya (northern) transpression zone

Novaya  
Zemlya



Kola monocline

East Barents basin

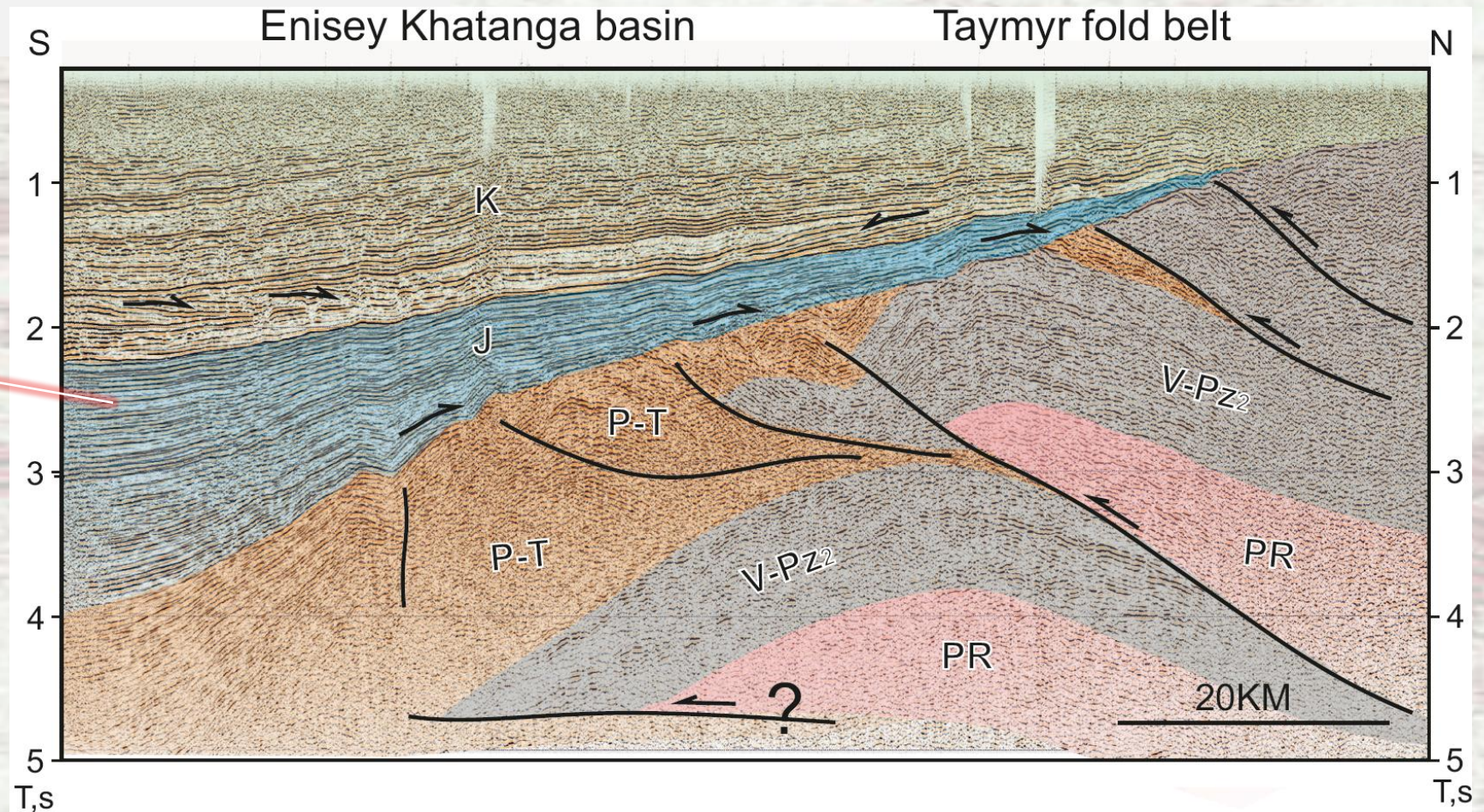
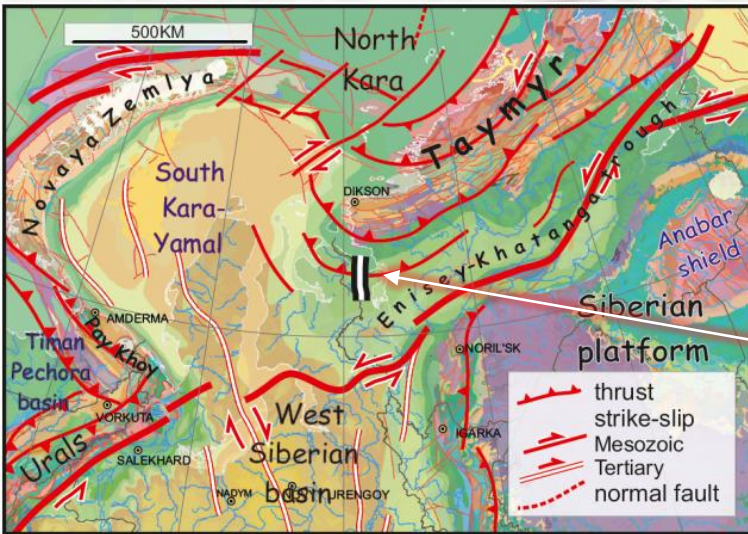


- ✓ high-relief inversional/transpressional swells along Novaya Zemlya,
- ✓ little shortening



# Compression, South Taymyr

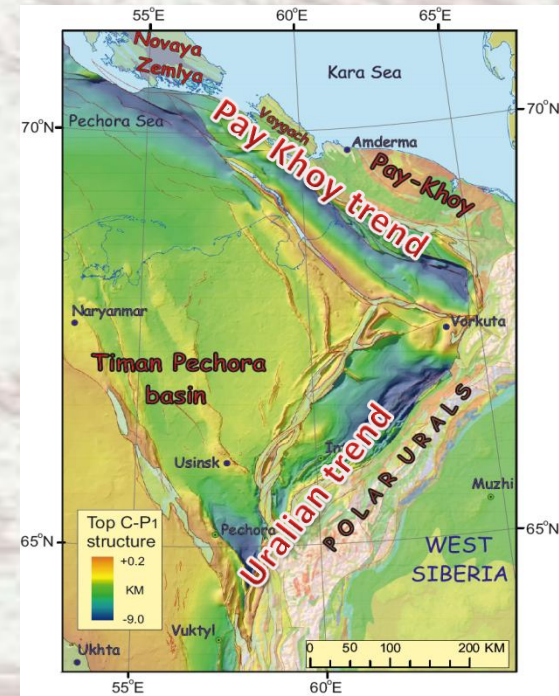
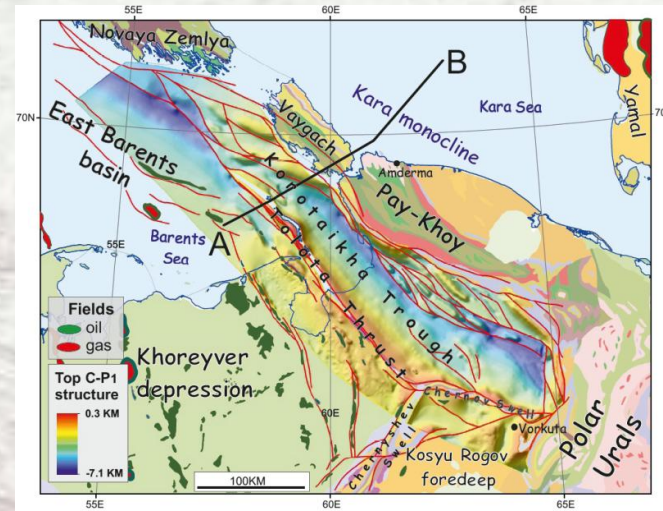
- ✓ major shortening in the Late Triassic
- ✓ buried fold belt is sealed by the basal Jurassic unconformity



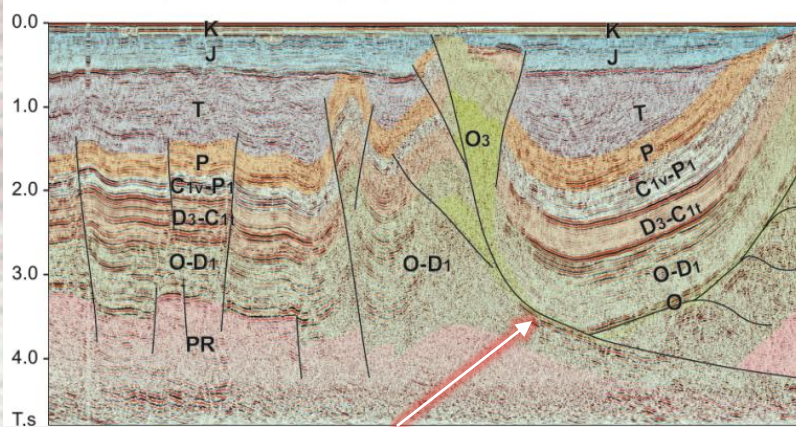


# Compression, Pay Khoy

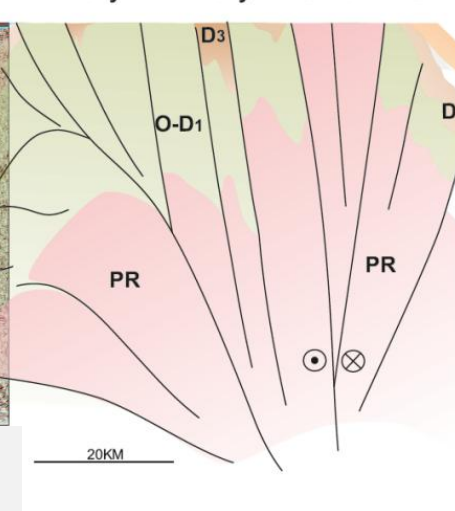
- ✓ major Late Triassic compressional folding
- ✓ the Pay Khoy fold belt strikes perpendicular to the Polar Urals, cross-cutting and overprinting the older Uralian structural trends



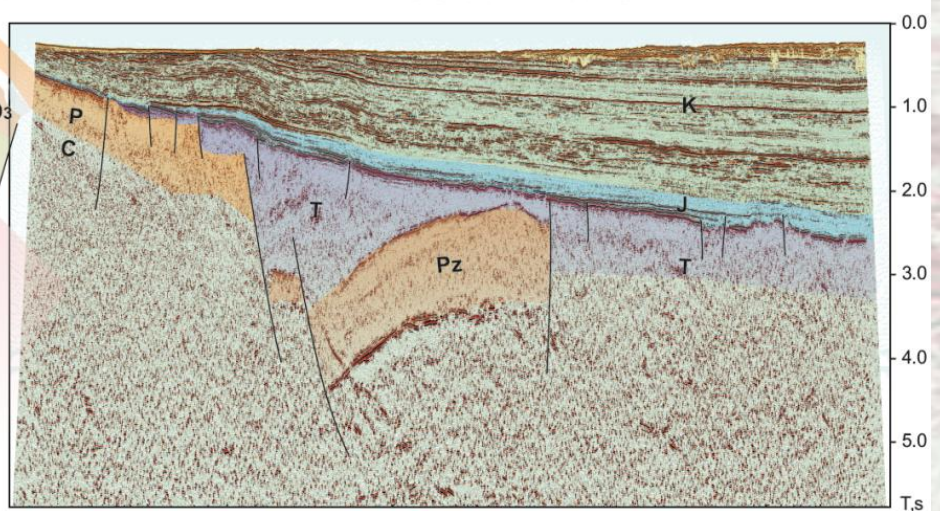
A Timan Pechora Basin



Pay-Khoy Fold Belt



South Kara



Delamination of the sedimentary cover at the Upper Ordovician evaporite level

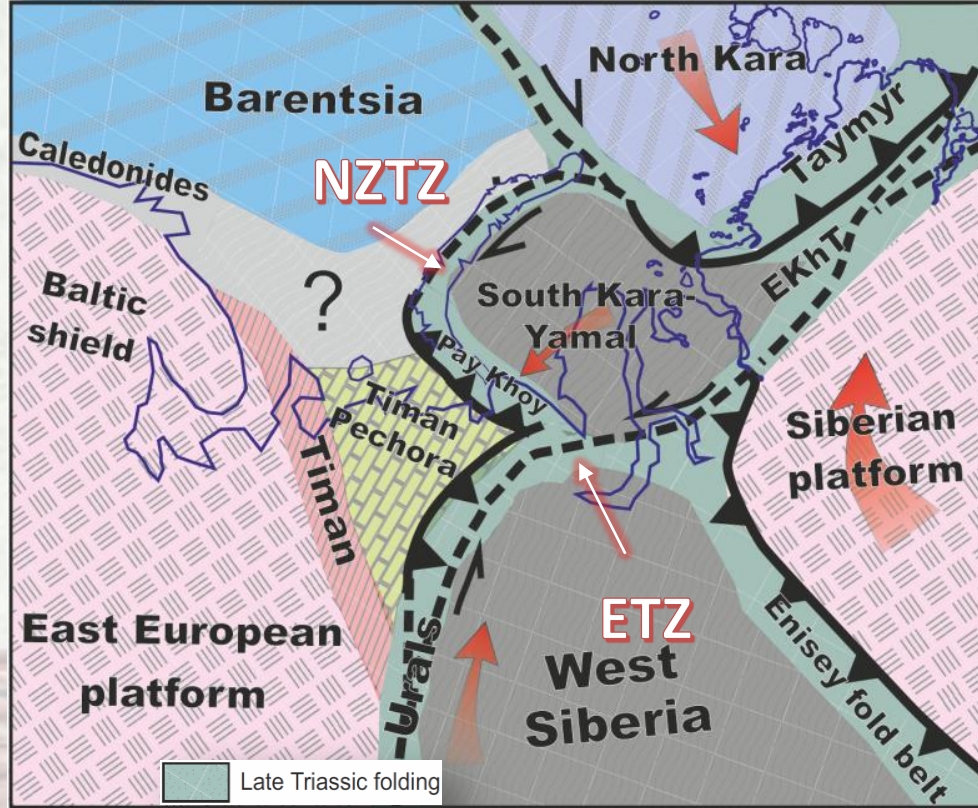


# General structural setting, Late Triassic

- ✓ Convergence of the Siberian craton and North Kara
- ✓ Lateral escape of the South Kara – Yamal plate

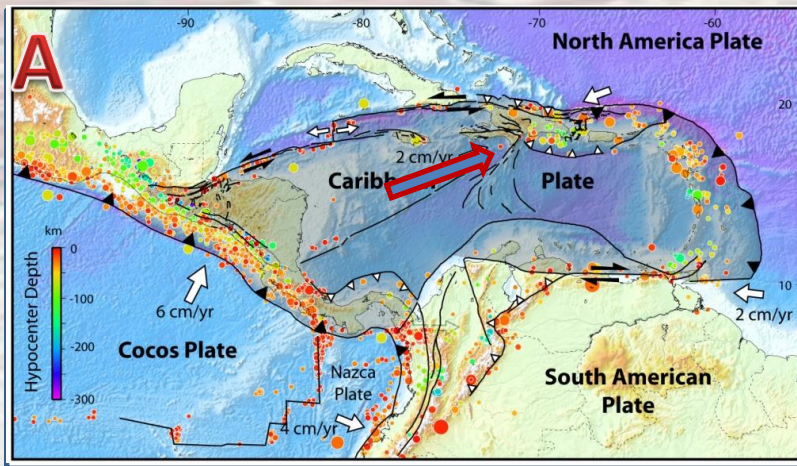
## Analogs

- A** – The Caribbean plate, Lesser Antilles
- B** – The Anatolian plate, Pannonian basin- Carpathians

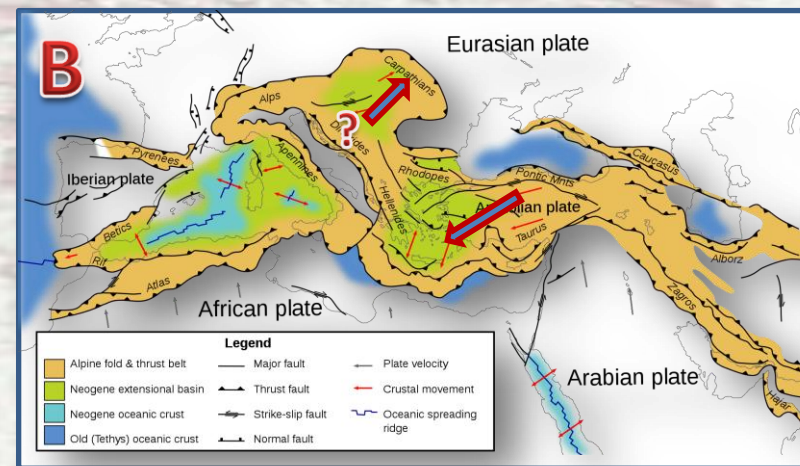


EKhT- Enisey Khatanga trough

Sobornov, 2013 with modifications



<http://web.ics.purdue.edu/~ecalais/haiti/context/>

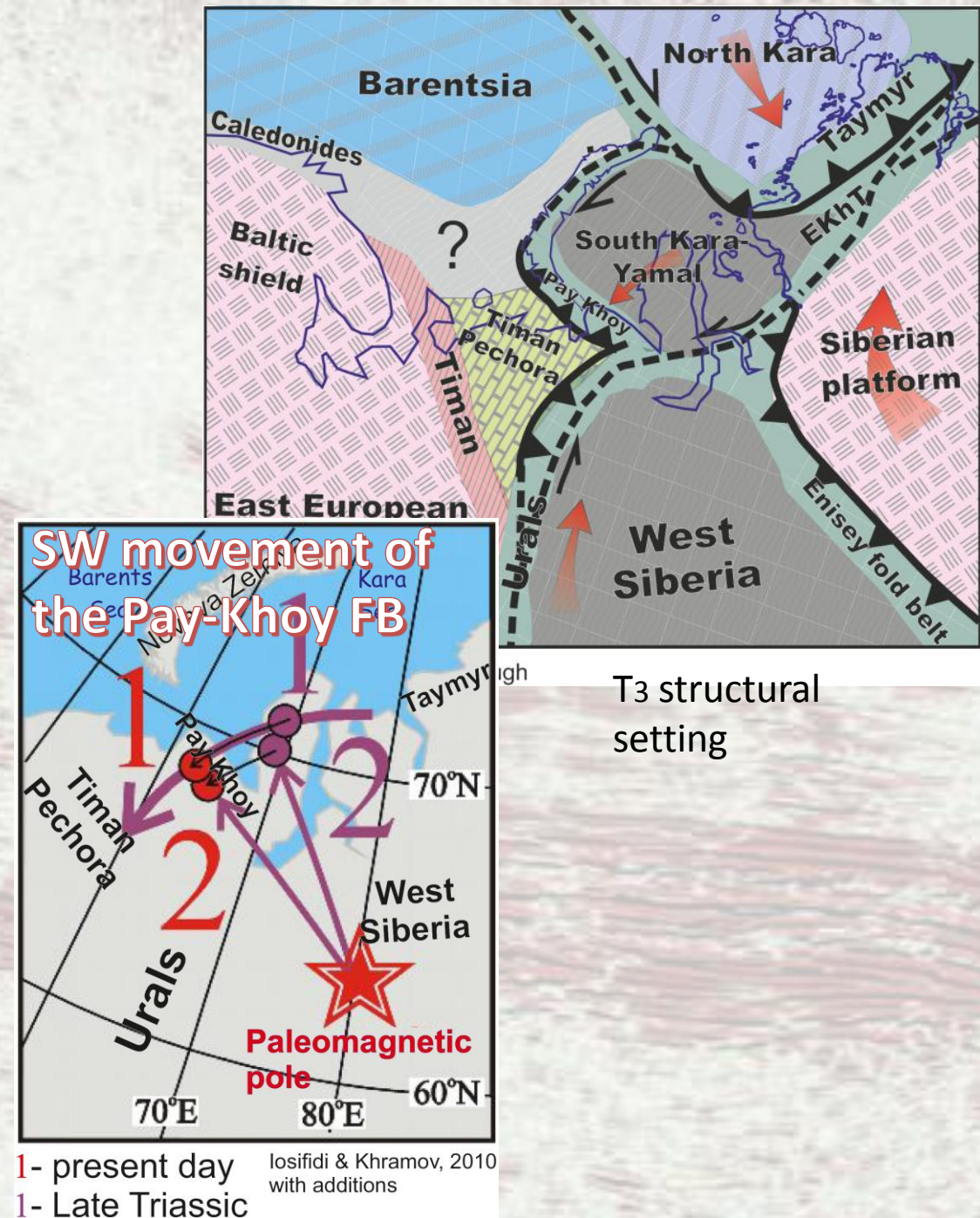
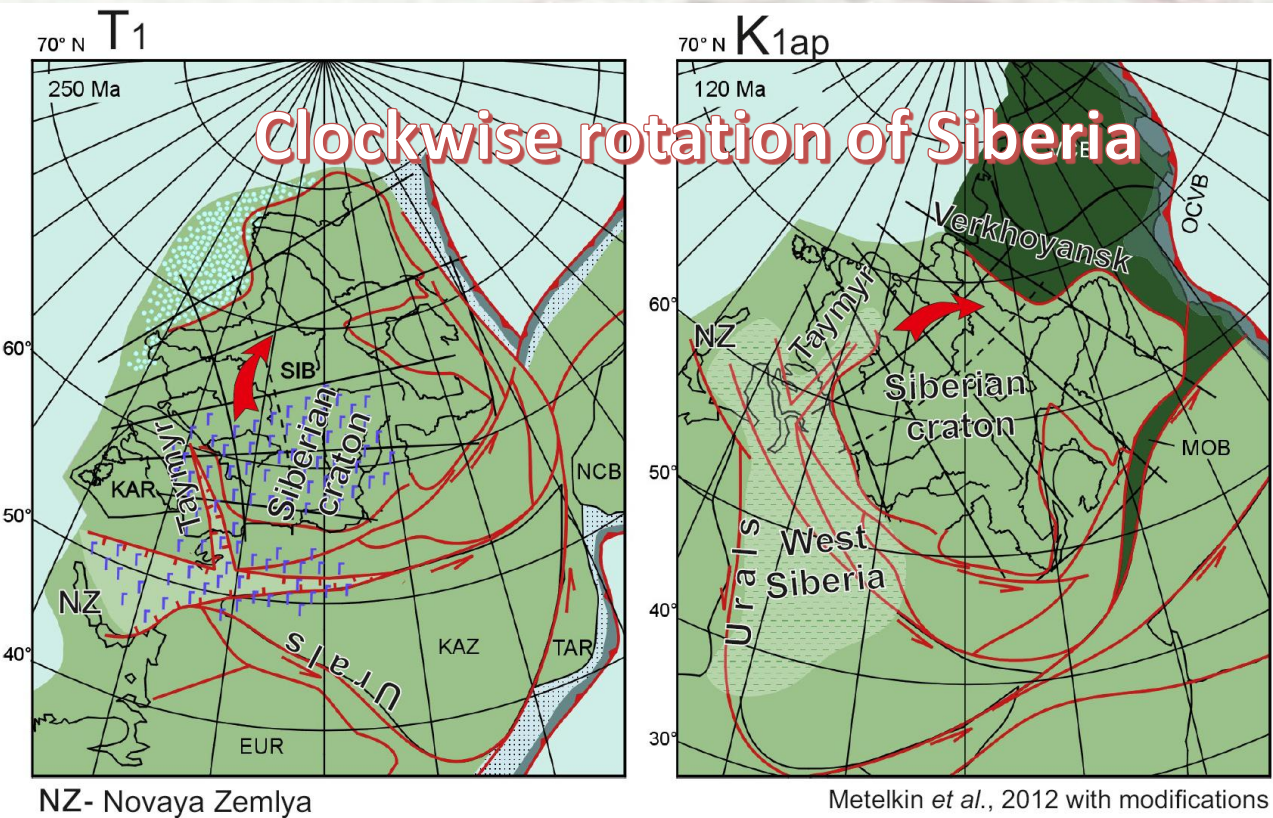


<http://retosterricolas.blogspot.com/2014/10/cuando-y-como-se-formo-el-mediterraneo.html>



# Plate tectonic context

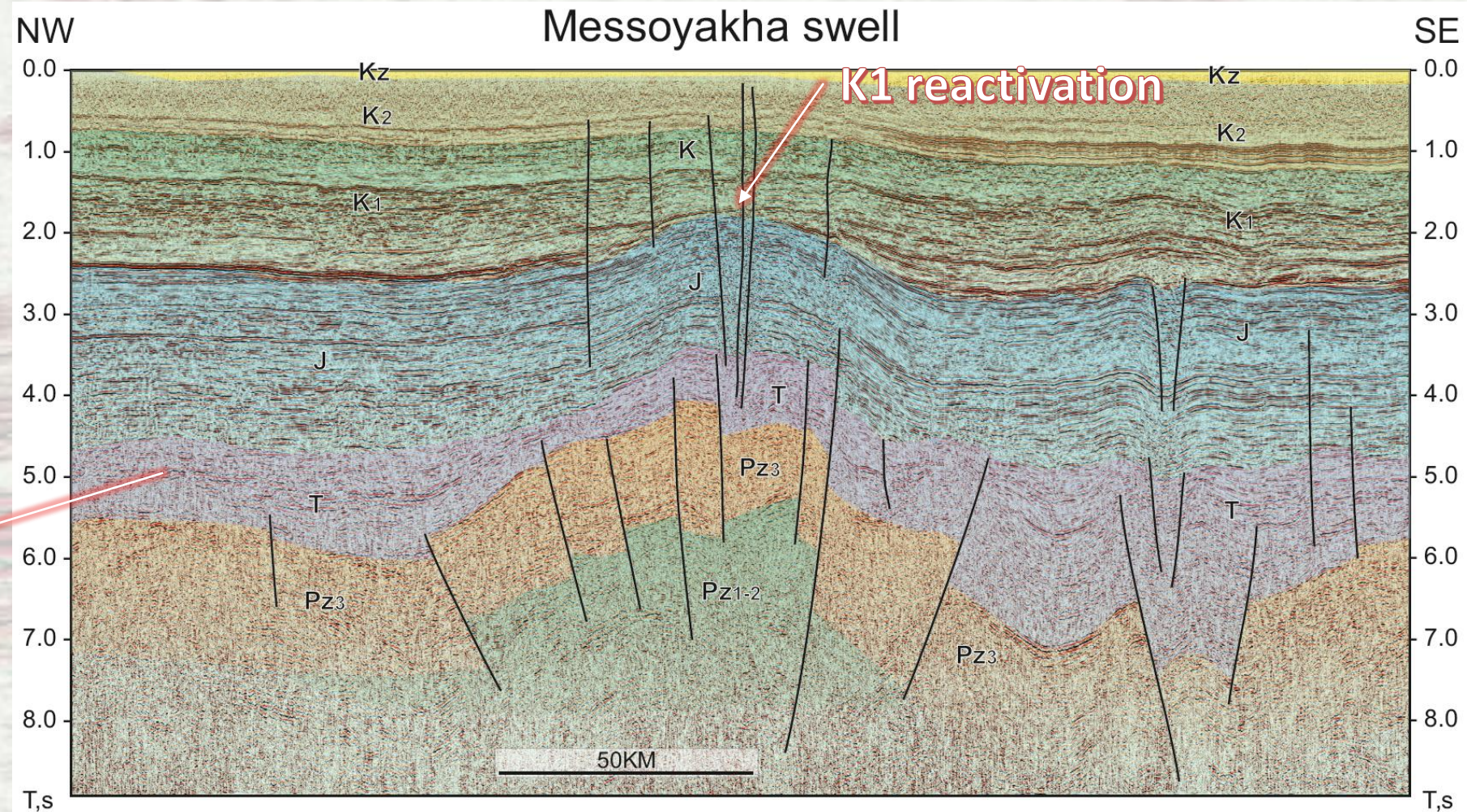
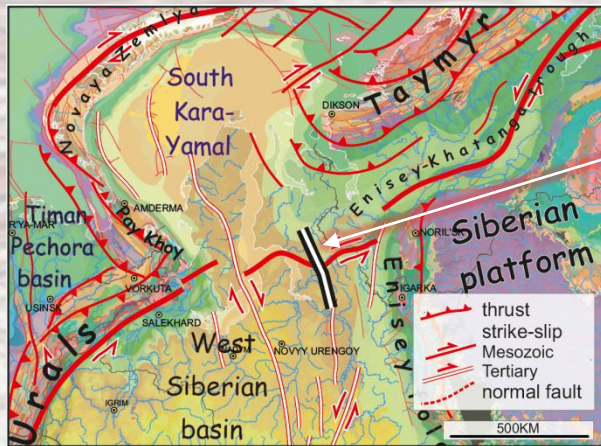
Reconstructions for the Mesozoic based on paleomagnetic data





# Early Cretaceous reactivation

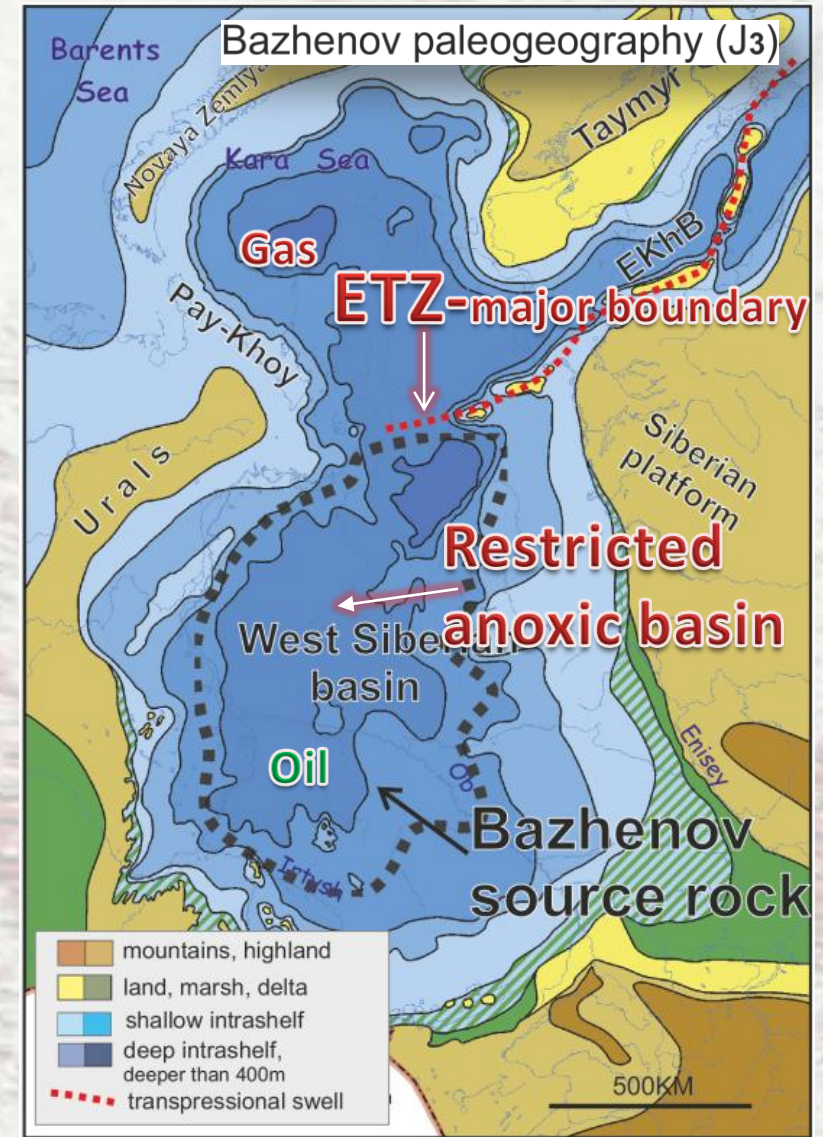
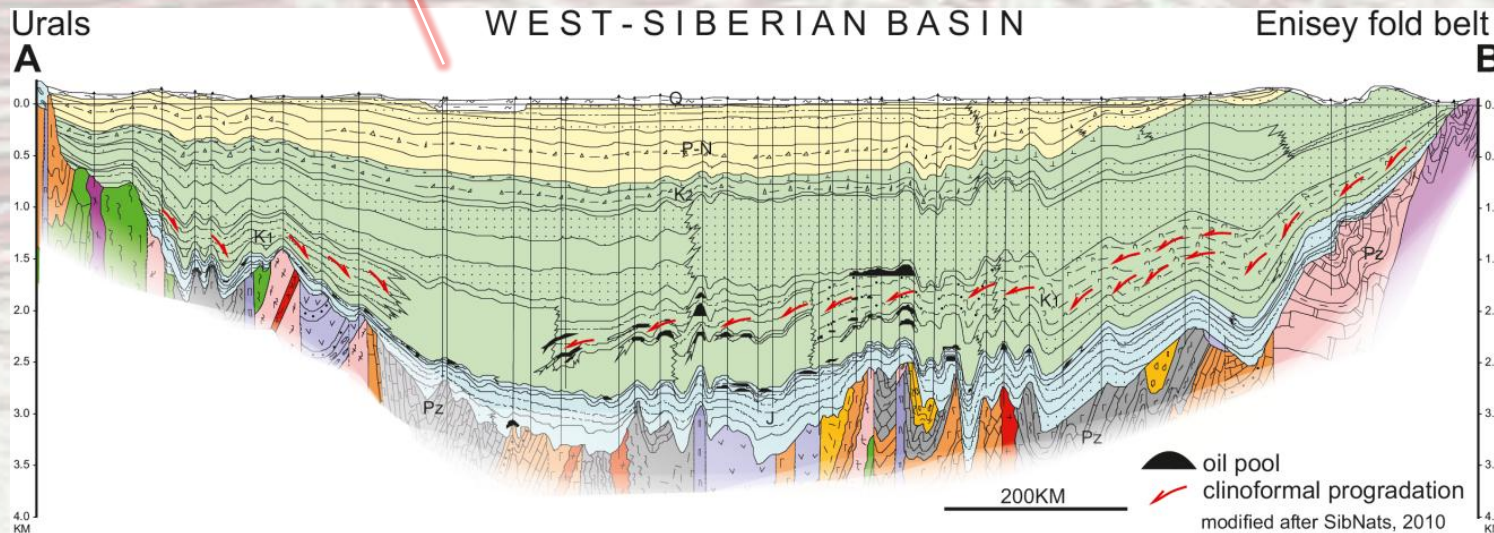
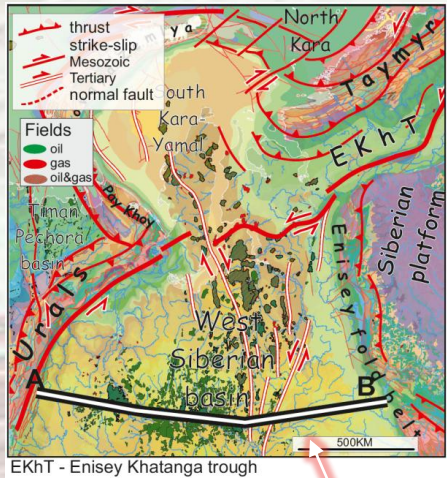
Reactivation and uplift in the Early Cretaceous along the ETZ





# Petroleum systems: the ETZ control

- ✓ The ETZ limits the areal extent of the of the Bazhenov Fm.
- ✓ TOC of its stratigraphic equivalents to the north of the ETZ is much lower

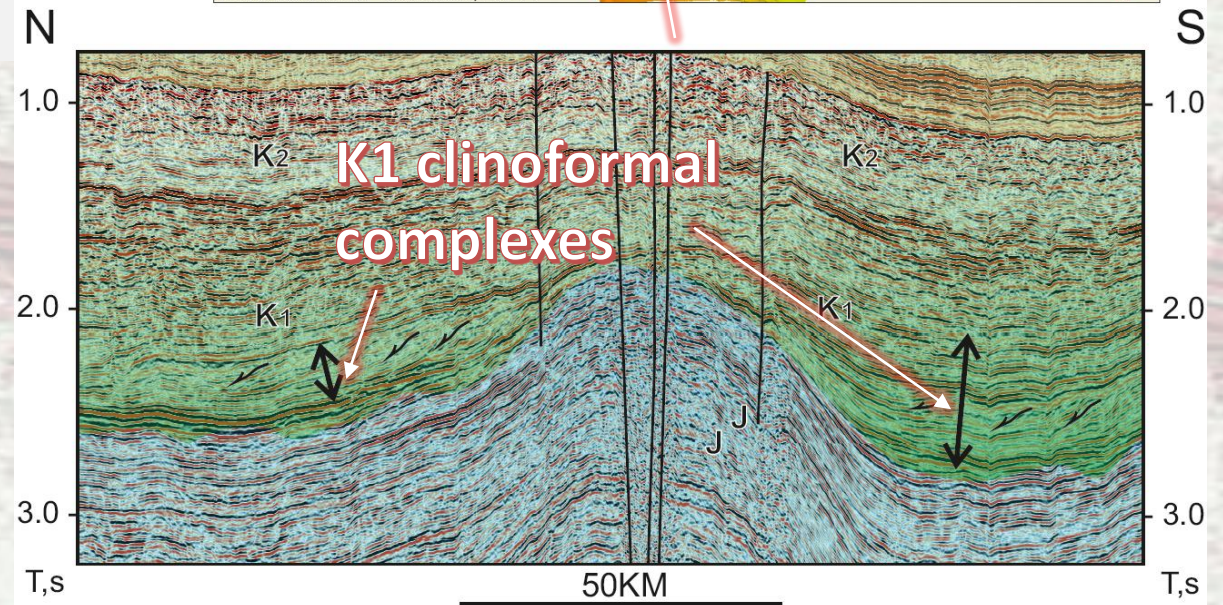
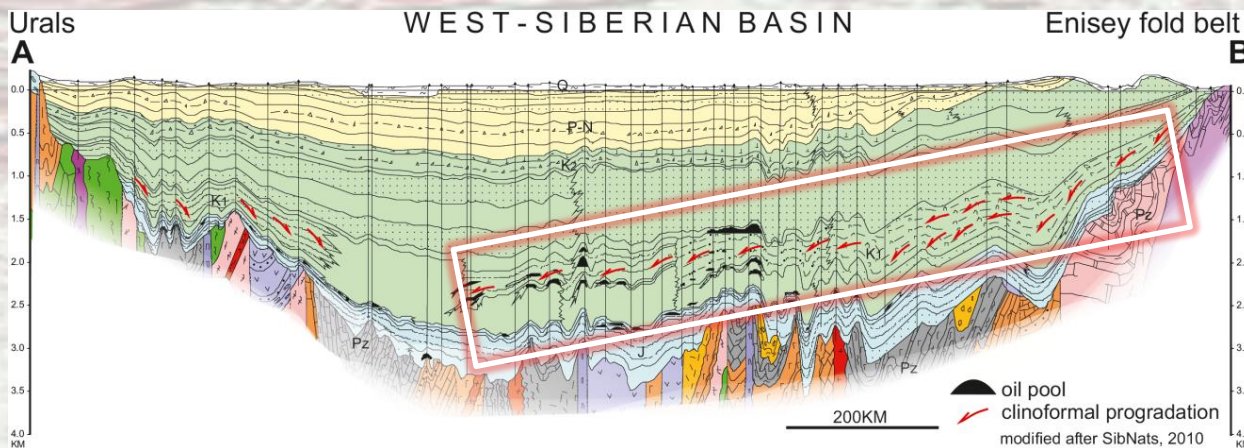
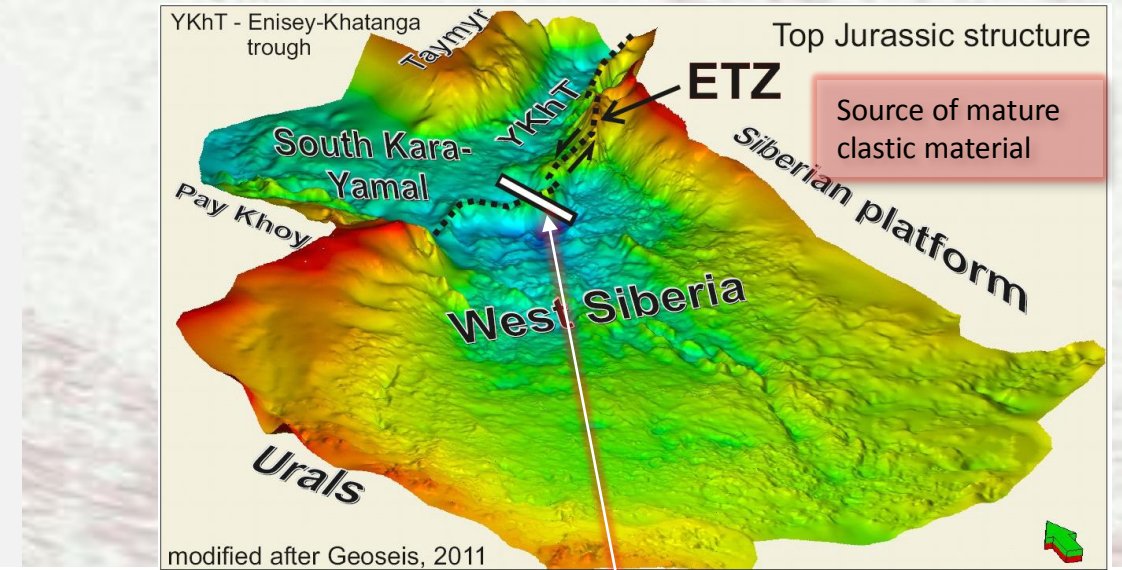


modified after Kontorovich *et al.*, 2013



# Petroleum systems: the ETZ control

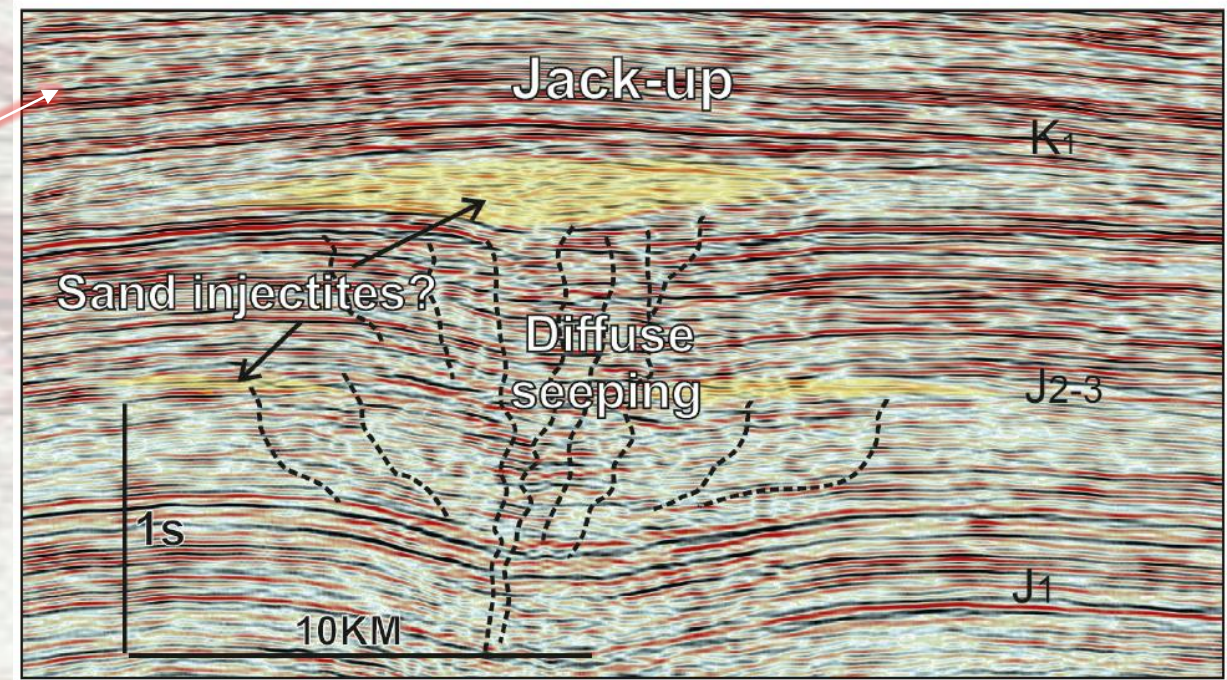
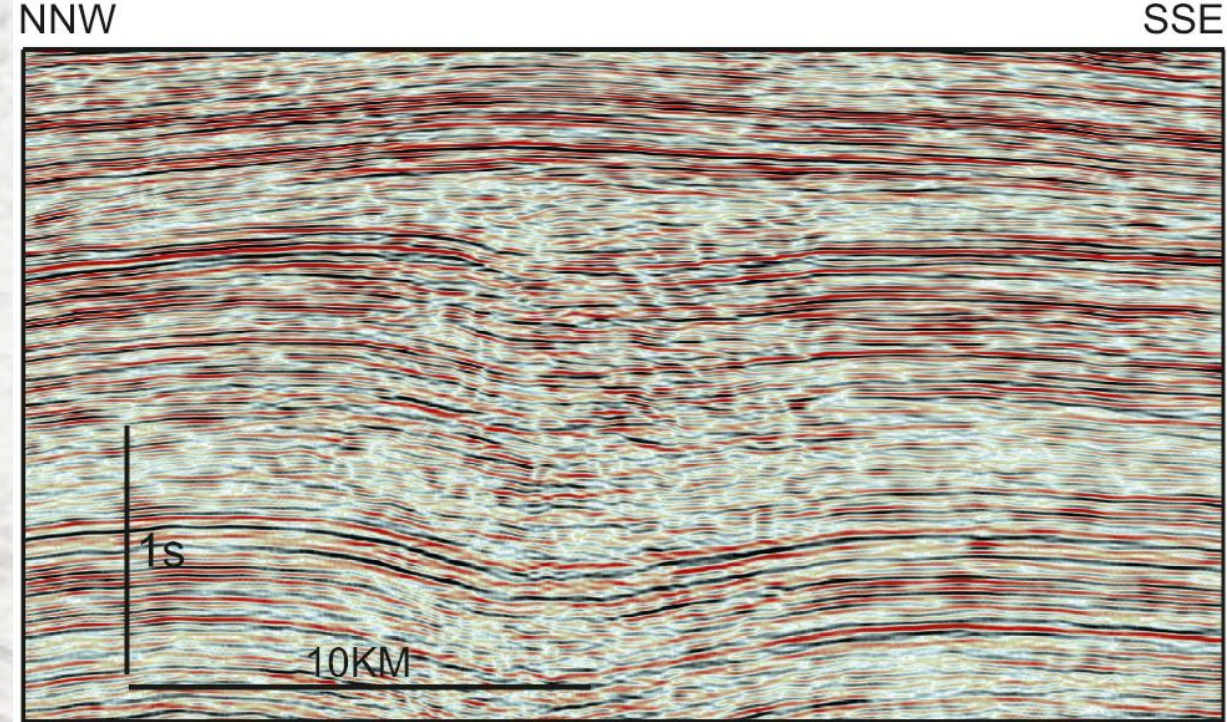
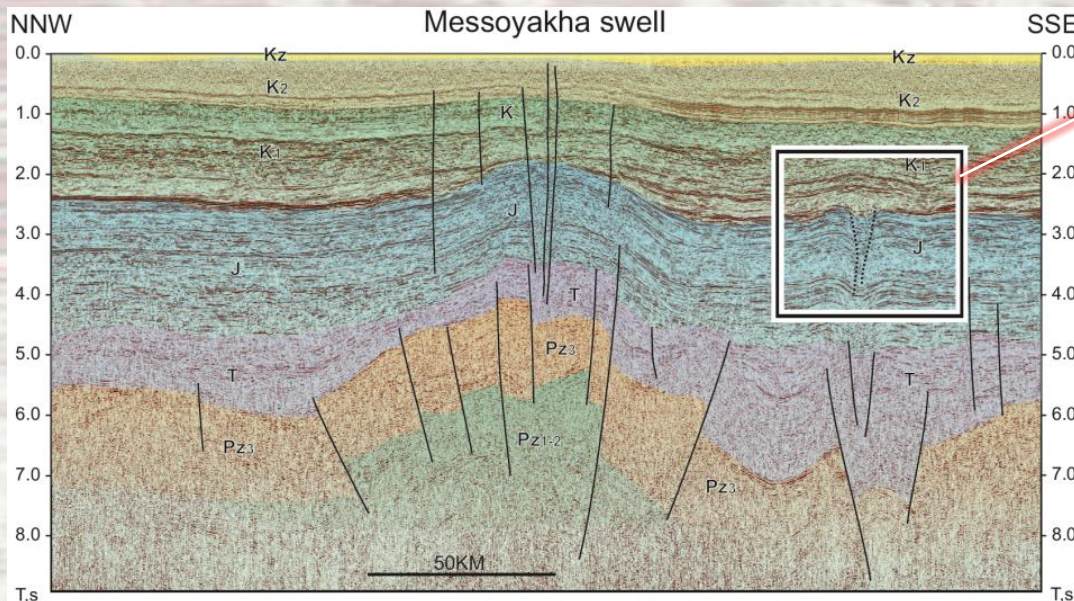
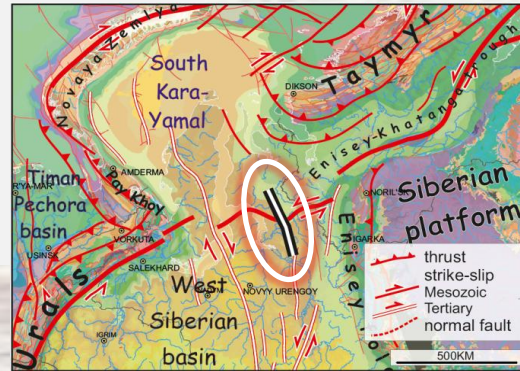
- ✓ The ETZ shaped drainage pattern of the basin
- ✓ The K1 reservoirs, hosting bulk of oil in the West Siberian basin, are primarily of the Siberian craton provenance
- ✓ The best K1 reservoirs are largely developed to the south of the ETZ





# Sand injectites

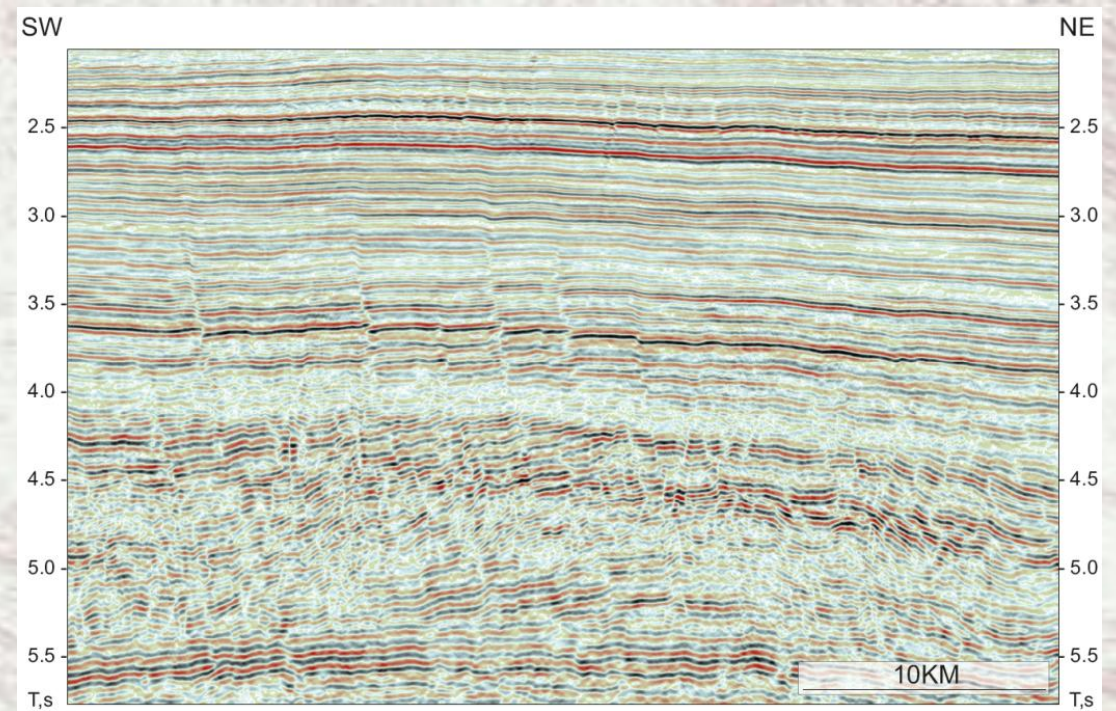
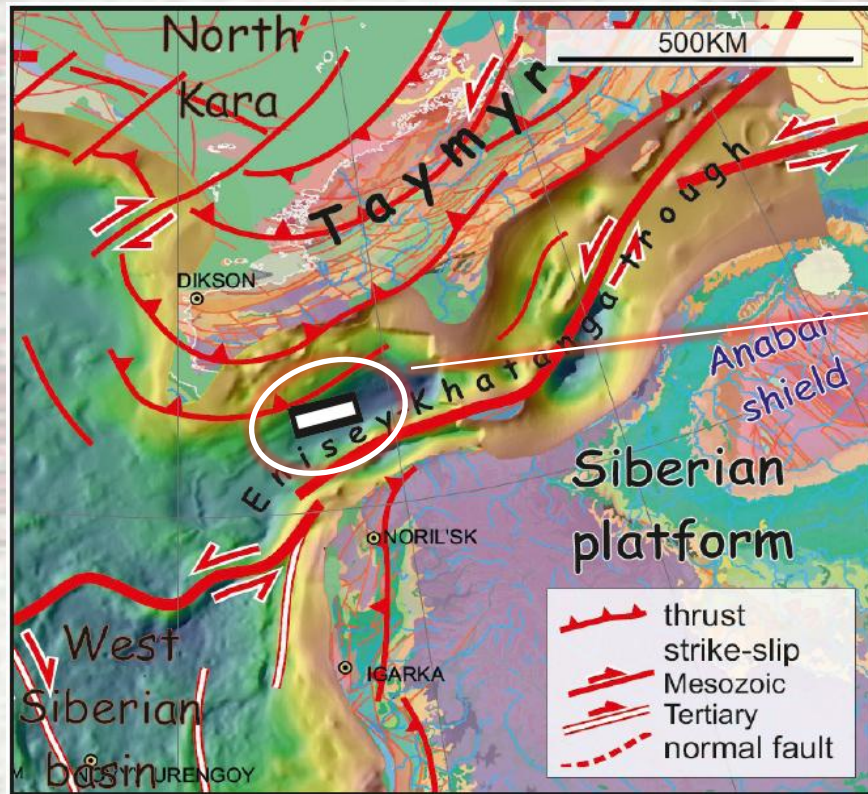
Rapid clastic sedimentation in the Early Mesozoic troughs, related to the post-orogenic collapse and transpression, led to the mobilization of sands and development of large-scale sand intrusions





# Polygonal faulting

- ✓ Small offset polygonal faulting systems in the Early Mesozoic troughs
- ✓ Multiple HC migration conduits

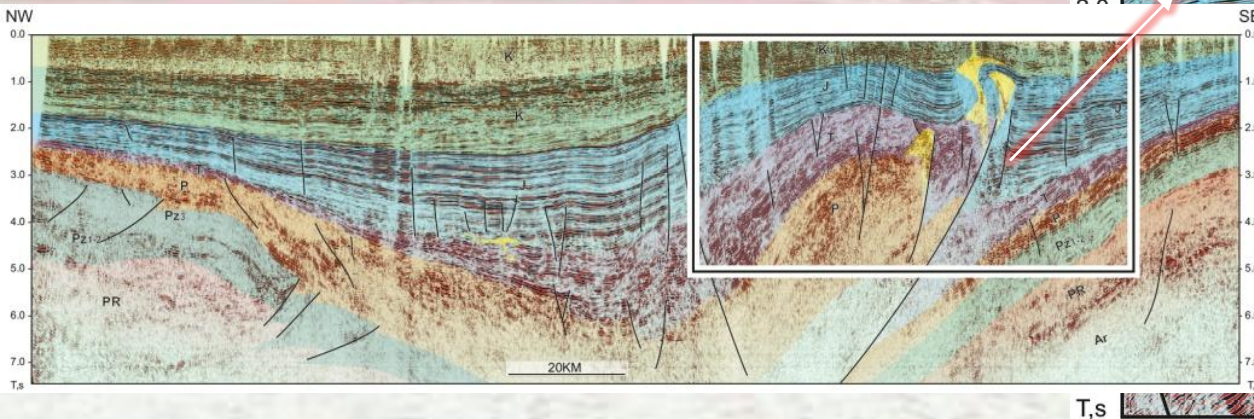
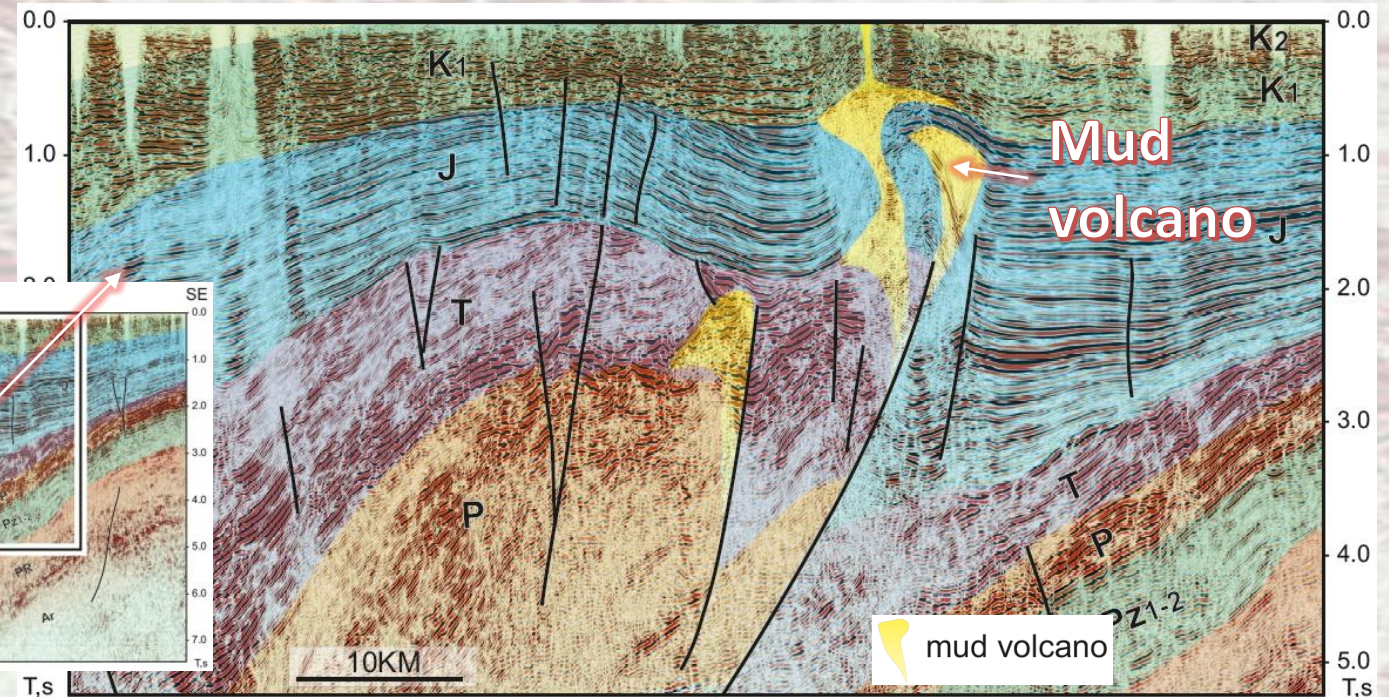
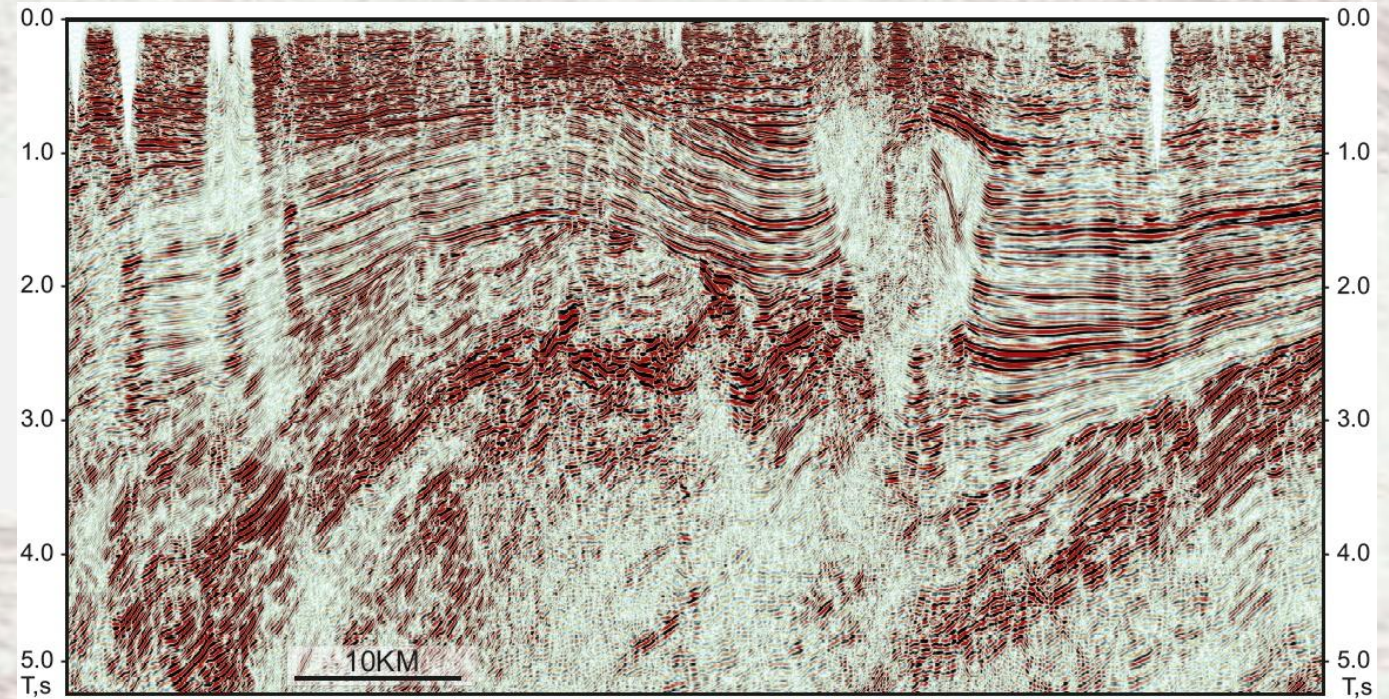
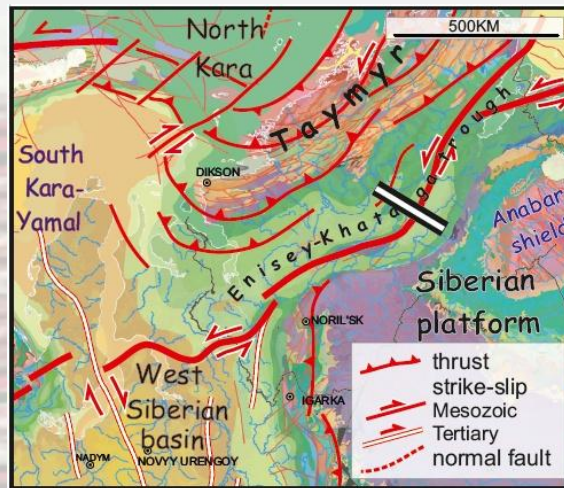




# Mud volcanos

Mud volcanoes are interpreted in the inversion/transpression zones.

They are likely produced by deeply buried Triassic and Jurassic overpressured shale packages in compressional settings.





# Conclusions

✓ The Early Mesozoic development of the central part of the Northern Eurasia includes:

- T<sub>1</sub>- post-orogenic collapse
- **T<sub>3</sub>- transpression, thrusting**
- K<sub>1</sub>- reactivation of the T<sub>3</sub> fault systems

✓ The South Kara –Yamal plate escaped from the collision zone of the Siberian craton and North Kara to the SW, producing thrusting in the Pay-Khoy

✓ The Early Mesozoic structural development provided control on depositional environments and petroleum habitat



# Thank You!

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