Strike-slip Faulting in the Northern Part of the West Siberian Basin and Enisey-Khatanga Trough: Structural Expression, Development and Implication for Petroleum Exploration*

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Abstract

The study area is located in the northern part of the West Siberian basin and Enisey-Khatanga trough. These basins consist of up to 10-km thick Triassic-Tertiary strata overlying disturbed heterogeneous basement terranes and folded sedimentary subbasins amalgamated in the course of the Pangea assembly in the Late Paleozoic. A 1500-km long system of WSW-ENE-trending high-relief swells is recognized in the northern part of the West Siberian basin and Enisey-Khatanga trough. The linked fault segments of this system demonstrate a horsetail pattern, arranging folds in en échelon arrays suggesting considerable strike-slip displacement along this zone. We name it the "Enisey Khatanga strike-slip zone" because it is best developed in the Enisey Khatanga trough. An integrated interpretation combining new regional seismic lines and vintage G&G dataset provides new insight into the structural setting of this zone.

The following succession of events is distinguished in its structural development in the Mesozoic-Tertiary:

1 Post-orogenic collapse and rapid subsidence in the Early Triassic;
2 Sinistral transpression and inversion in the Late Triassic-Early Jurassic;
3 Pulses of compressional reactivation in the Early Cretaceous and Tertiary.

The proposed post-orogenic collapse phase is justified by the presence of up to 5-km-thick tilted wedge-shaped Triassic sedimentary packages interpreted on seismic lines. Accommodating space probably was produced by a combination of crustal-scale, north-dipping extensional detachment faulting and formation of pull-apart subbasins related to plausible strike-slip displacement. The proposed Triassic post-orogenic collapse overprinted the Late Paleozoic fold belt. It is possible that the extensional faults recycled the preexisting thrust faults. It is noteworthy that the Early Triassic extension was accompanied by the prominent Triassic flood basalt volcanism. Overall seismic expression of the Triassic half-grabens has common features with zones of outer marginal collapse (Pindell et al., 2014). The Neogene post-orogenic Vienna basin (Picha, 2011) may provide a viable structural analogue for the interpreted Triassic grabens.

The following onset of compression in the Late Triassic-Early Jurassic resulted in inversion of the Triassic half-grabens. The major deformation occurred in the zone of crustal weakness created by the Early Triassic post-orogenic extension. The compressional inversion most likely was caused by the oblique convergence of the North Kara plate and East Siberian platform, producing massive sinistral transpressional displacment in the study area. The oblique sense of the plate convergence is attributed mainly to the clockwise rotation of the East Siberian platform documented by paleomagnetic studies (e.g., Smethurst et al., 1998, Metelkin et al., 2010).

It seems likely that the Enisey-Khatanga and Novaya Zemlya structural elements are transpressional zones along the northern and south boundaries of the South Kara – Yamal plate; this allowed its southwestward "escape" from the collision zone to the southwest (Sobornov, 2013). According to paleomagnetic study, the southwesterly movement of this plate was accompanied by its counterclockwise rotation (Iosifidi and Khramov, 2010). The "escape" of the South Kara –Yamal plate led to the large-scale thrust faulting in front of it in the Late Triassic-Early Jurassic, resulting in the development of the Pay-Khoy fold belt.

A period of tectonic quiescence and epi-platformal sedimentation in the Jurassic was followed by an outbreak of intraplate compression induced by tectonic stress transferred from the Verkhoyansk fold belt and compressional deformations in the southern part of the East Siberian platform in the Early Cretaceous. The corresponding intraplate deformation led to a reactivation of transpressional swells in the study area. The corresponding uplift of the Siberian craton formed a source of clastic material for the Neocomian clinoformal complexes which host large amount of oil and gas deposits in West Siberia. The significant high-relief structuring, produced by the strike-slip faulting in the study area, was eventually leveled off by the Neocomian clinoformal complex. A new episode of intraplate compressional reactivation of the strike-slip system occurred in the Tertiary. It was likely related to rifting in the Eurasia basin and Alpine orogeny.

The majority of oil and gas deposits are hosted in shallow structural closures in the crestal parts of the swells. Poor qualities of Cretaceous reservoirs, as well as breaching of top seals related to the Tertiary fault reactivation, are regarded as key factors limiting volume of known reserves. The principal plays that can be predicted in this environment include lowstand sands onlapping flanks of the swells, pinch-out zones as well as deeper structural closures including the folded pre-Jurassic deposits. It is noteworthy that swells related to inversion of the listric faults, coupled with transpression, may have significant offsets of crestal zones with depths. This has to be taken into account if exploring for deeper objectives. The key challenges in pursuing deeper prospective plays are identifying traps which are deep enough to escape biodegradation, but at the same time shallow enough to preserve liquids hydrocarbons and porosity.

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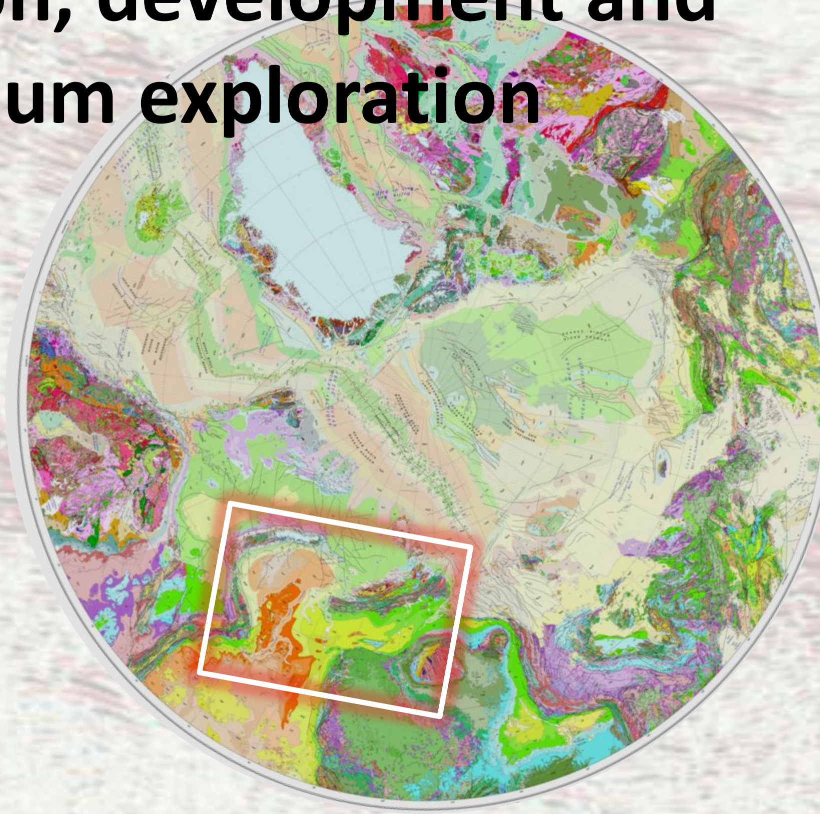

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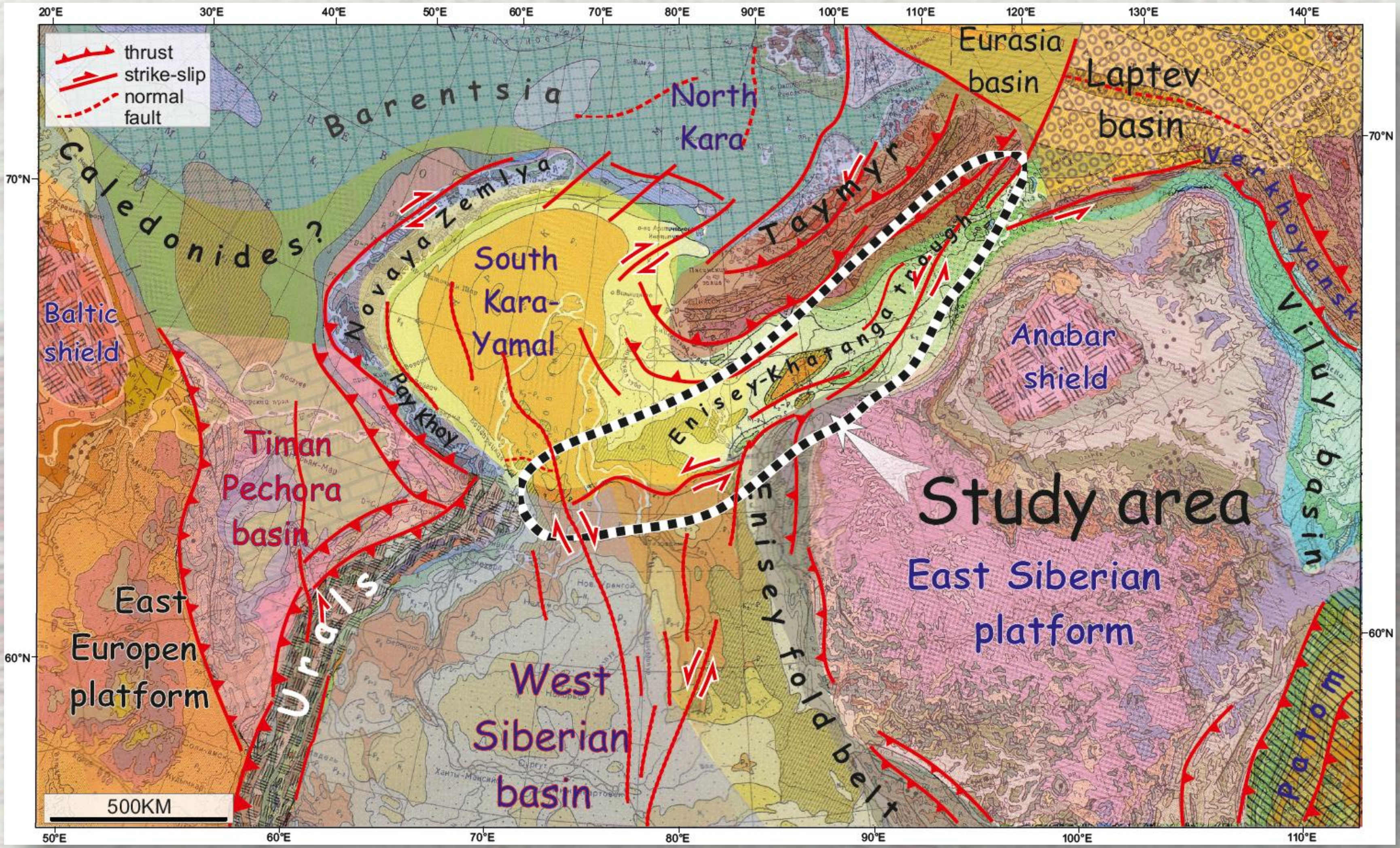
Outline

- Regional setting
- Structural geology
- Tectonic development
- Prospectivity

Ordovician deposits, Taymyr

Regional setting



SW- trending trough separating the Taymyr fold belt and East Siberian platform

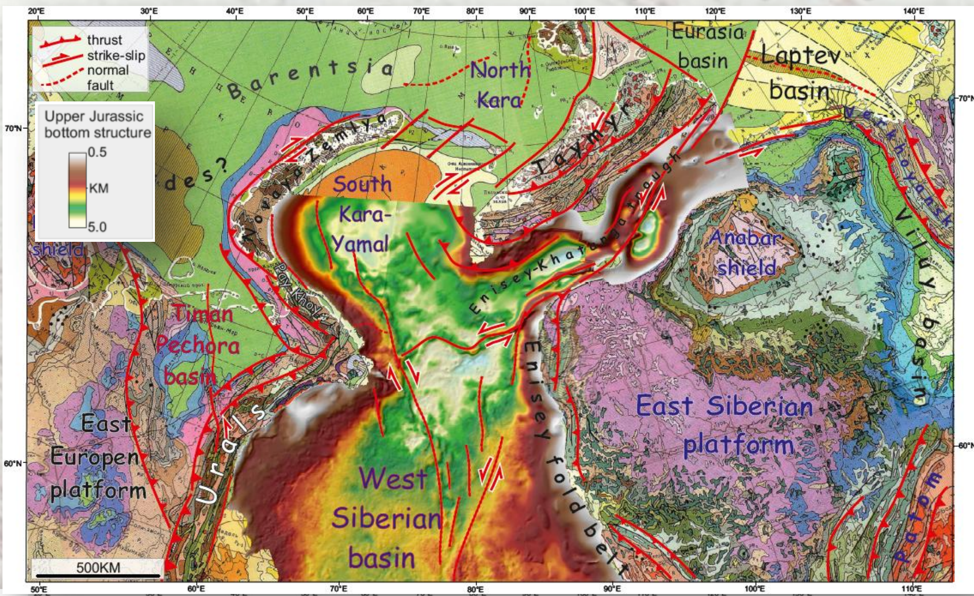
Data

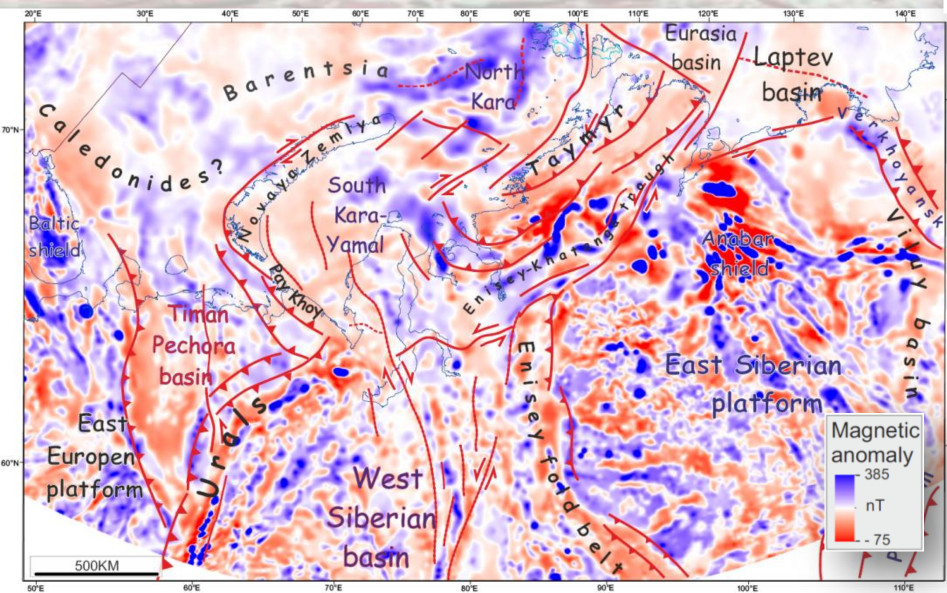
This study is a part of a regional project involving reinterpretation of G&G data and updating structural model of the northern part of the Siberian platform and adjacent areas.

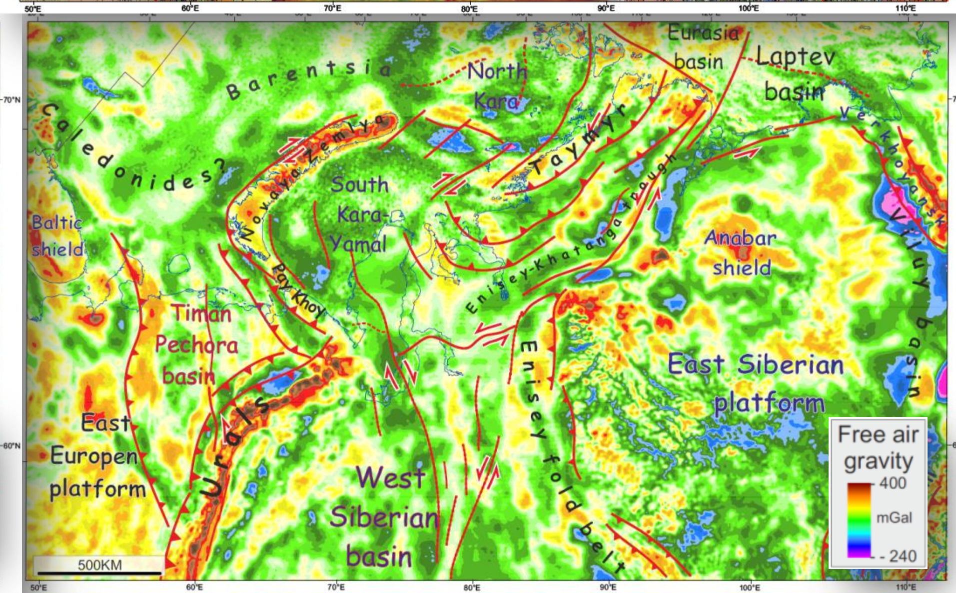
Database

Vintage and new seismic surveys
Data from potential fields
Drilling data
Geological maps
Public-domain information
etc.

Base Upper Jurassic structural map of the West Siberia basin and Enisey-Khatanga trough

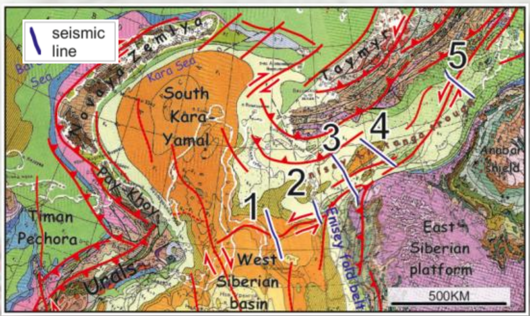






Seismic expression

Location map of lines

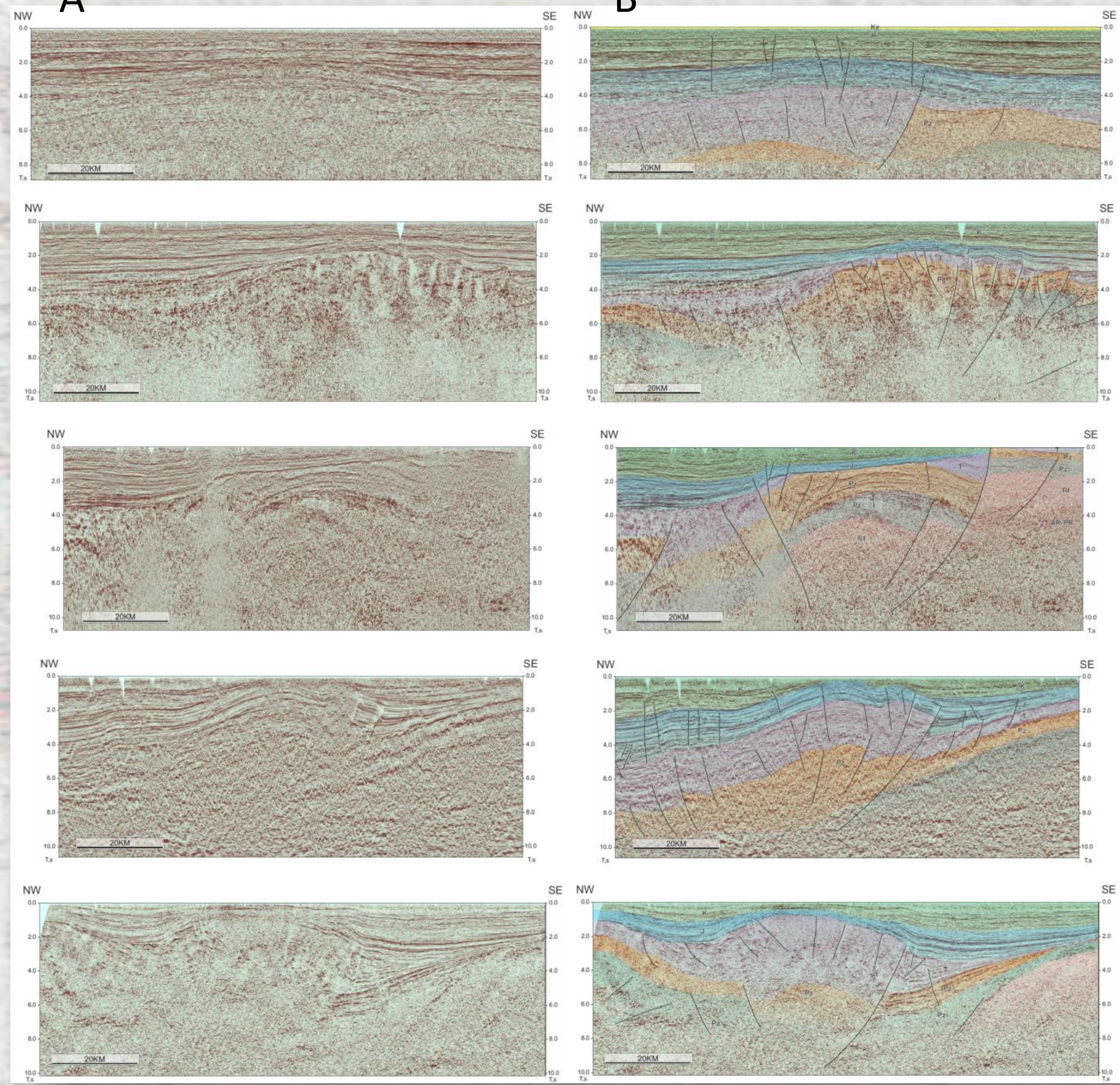


Seismic lines across the Enisey-Khatanga strike-slip zones:
A- uninterpreted
B- interpreted

Pre-Jurassic stratigraphy is poorly calibrated

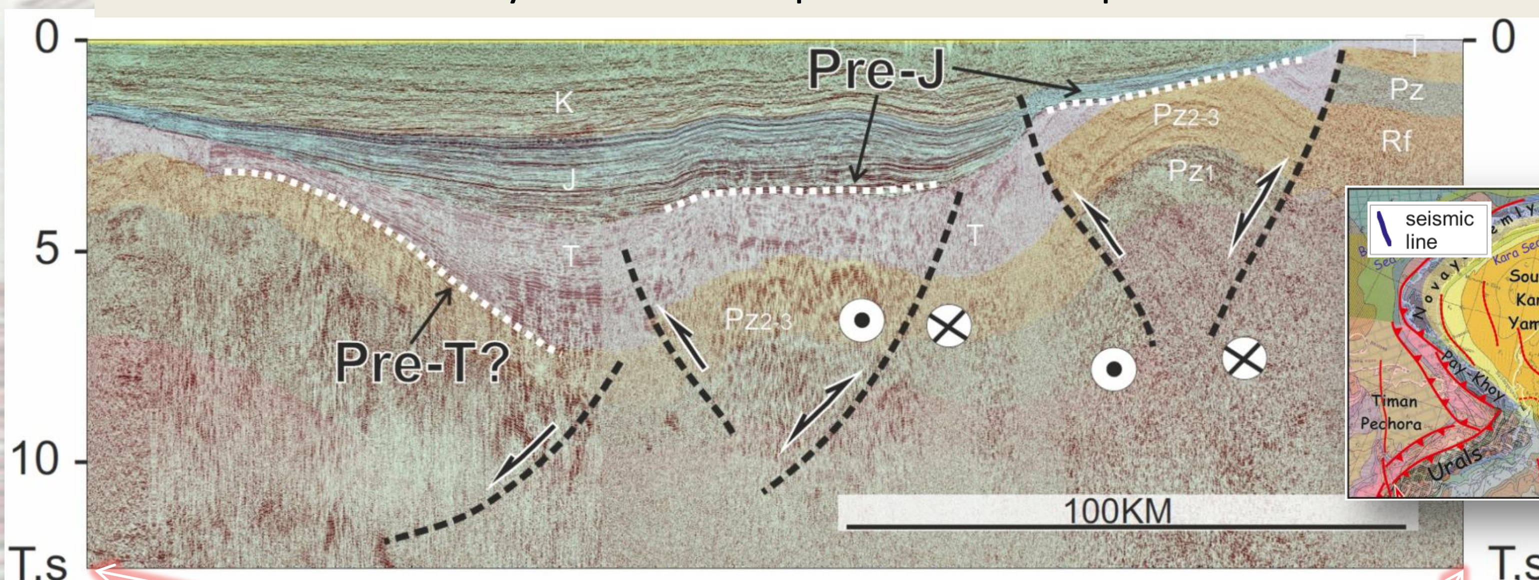
A B

1
2
3
4
5

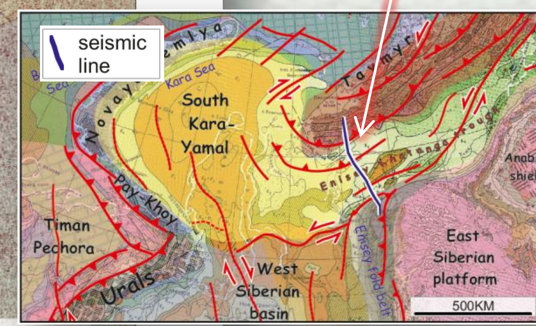


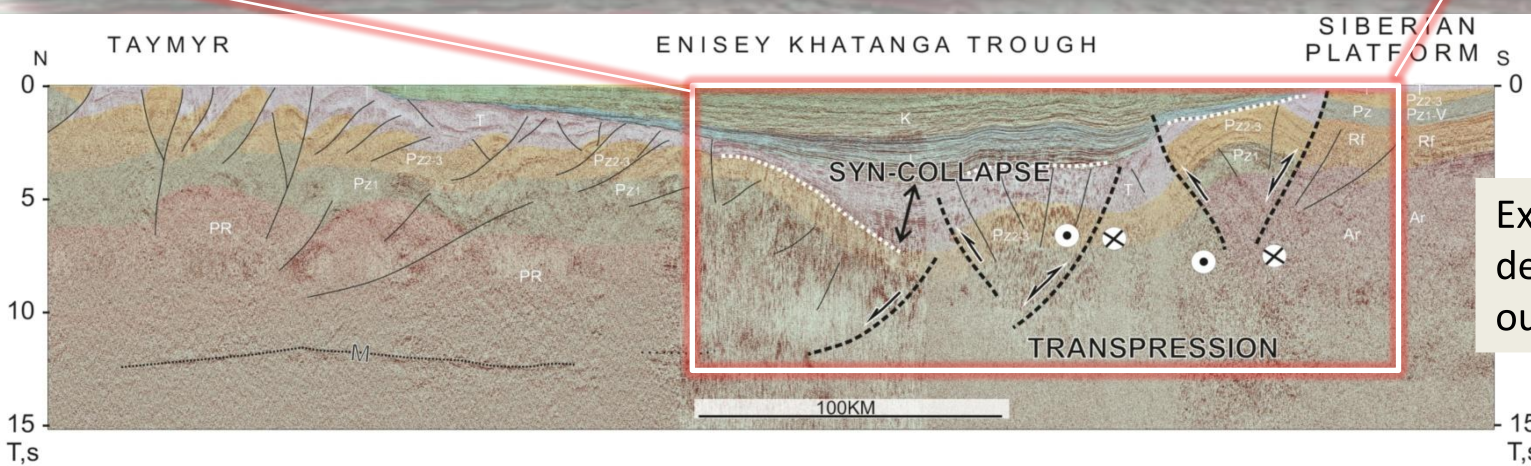
Early Mesozoic events: key observations

- ✔ Early Triassic collapse of the Paleozoic fold belt flanking the Siberian craton
- ✔ Late Triassic- Early Jurassic transpression developed in the zone of weakness



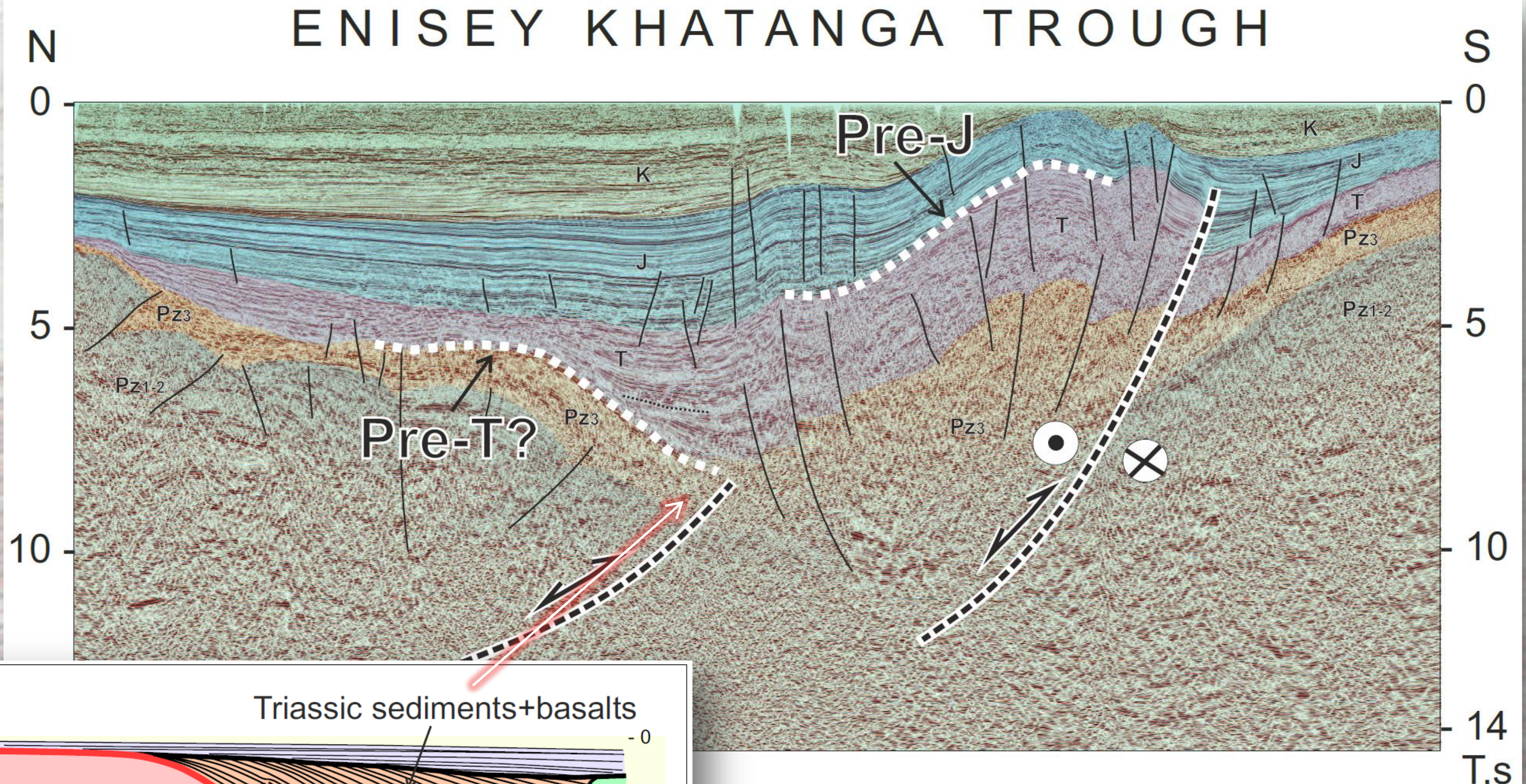
Line location

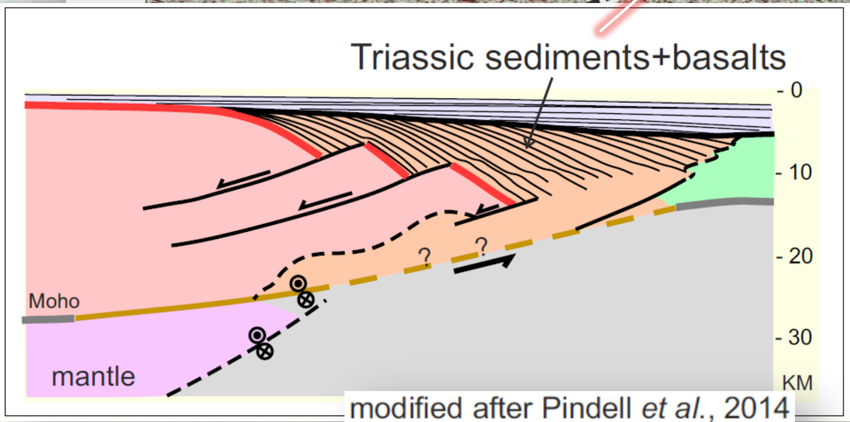




Extensional detachments soles out at the Moho?

Early Triassic collapse

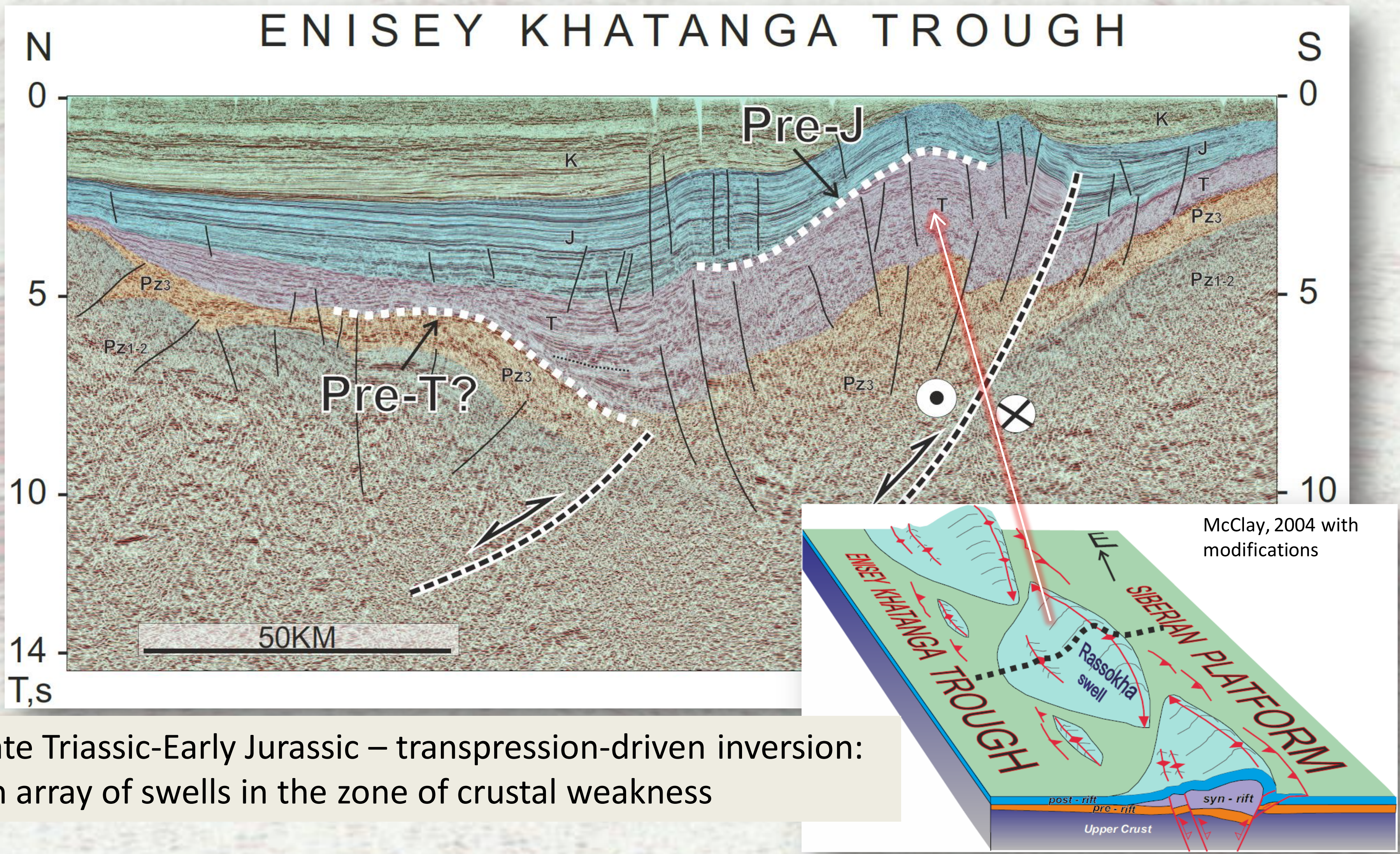




Late Permian-Early Triassic post-orogenic collapse:

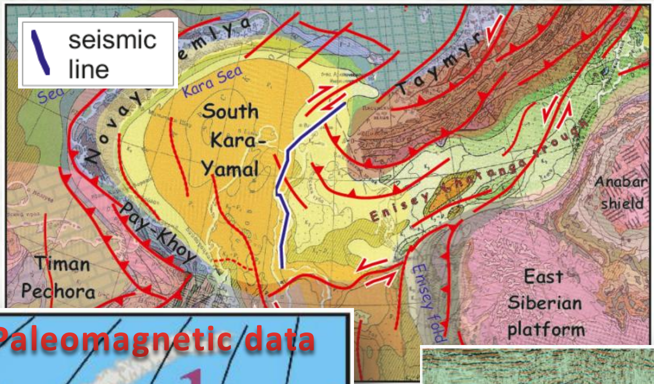
- ✔ extensional detachment faulting
- ✔ asymmetrical pull-apart subbasins
- ✔ rapid volcaniclastic deposition
- ✔ structural analog – the Vienna basin (Picha, 2011)

Late Triassic inversion

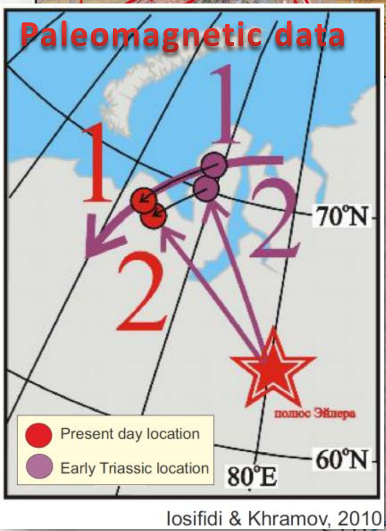


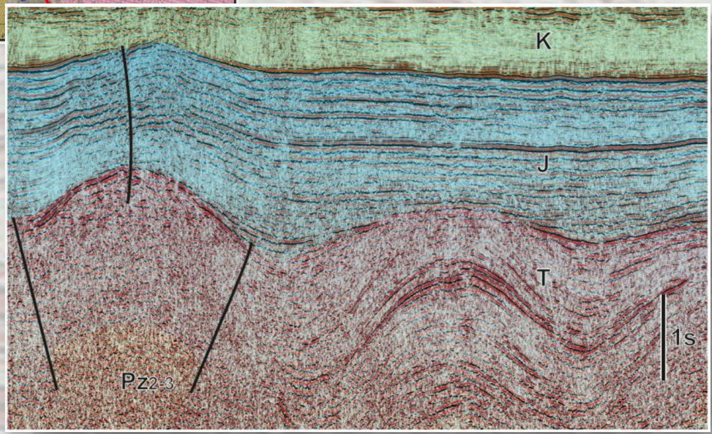
Late Triassic-Early Jurassic – transpression-driven inversion: an array of swells in the zone of crustal weakness

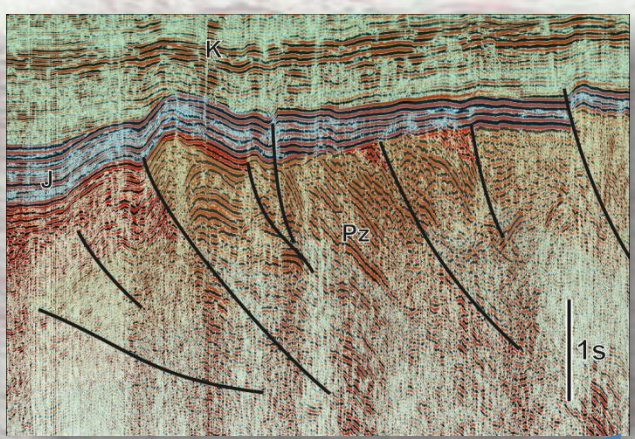
Late Triassic compression

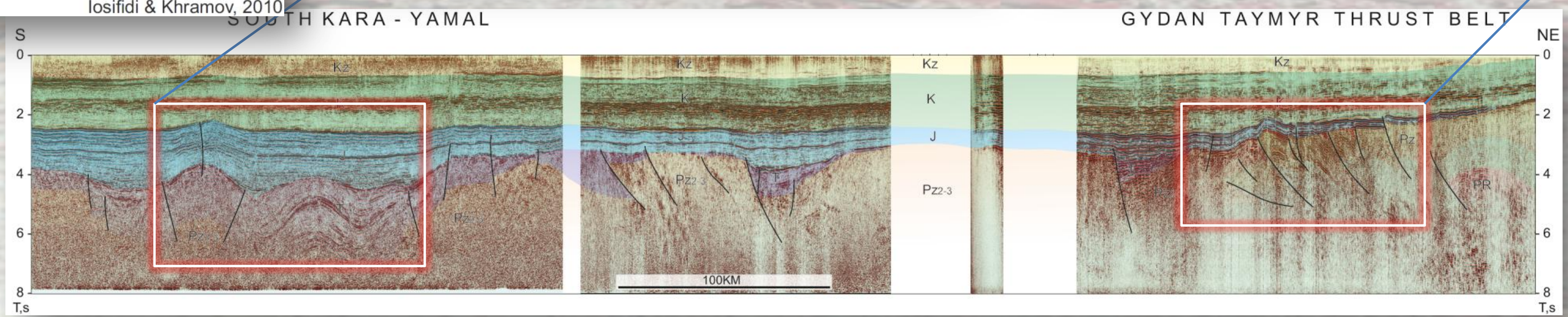


✔ SW-vergent compressional deformation in the South Kara –Yamal sealed by the Jurassic unconformity
✔ paleomagnetic evidence of the South Kara – Yamal counterclockwise rotation and SW movement



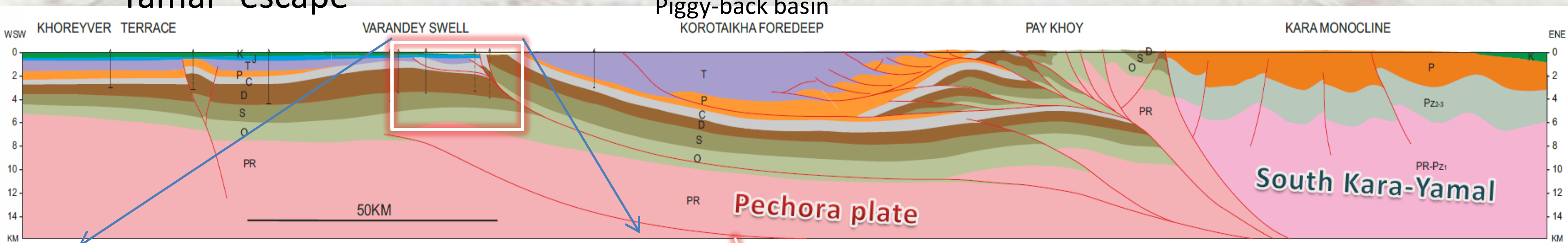


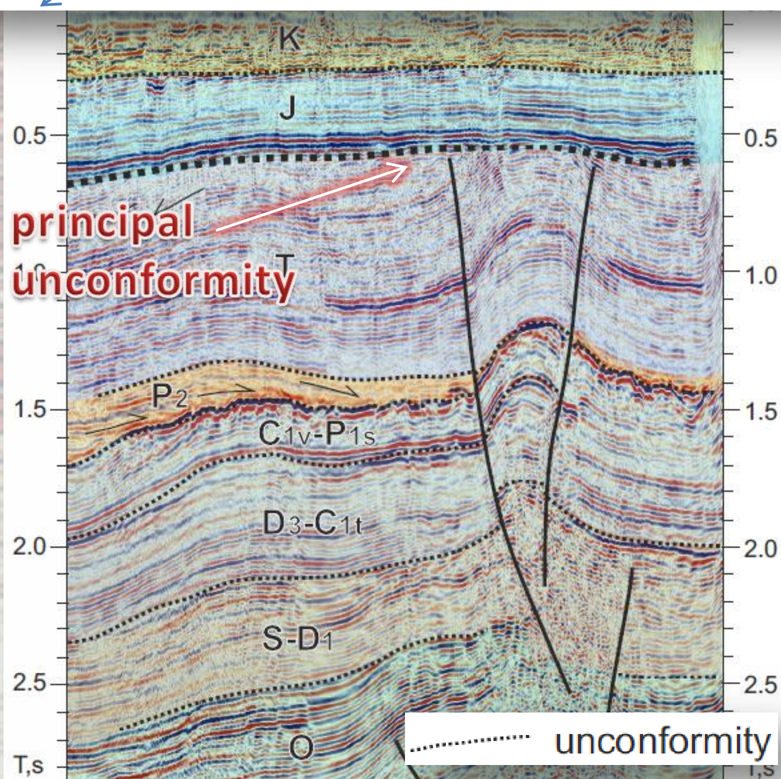




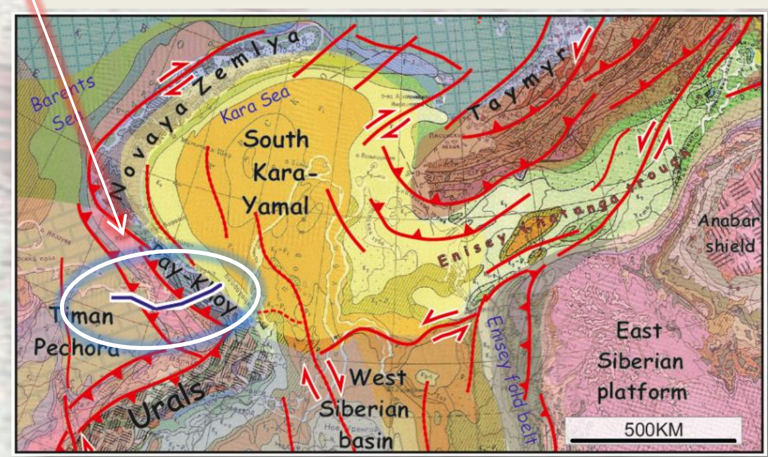
Pay-Khoy thrust belt development

Large-scale thrusting in the Late Triassic-Early Jurassic produced by the South Kara Yamal "escape"

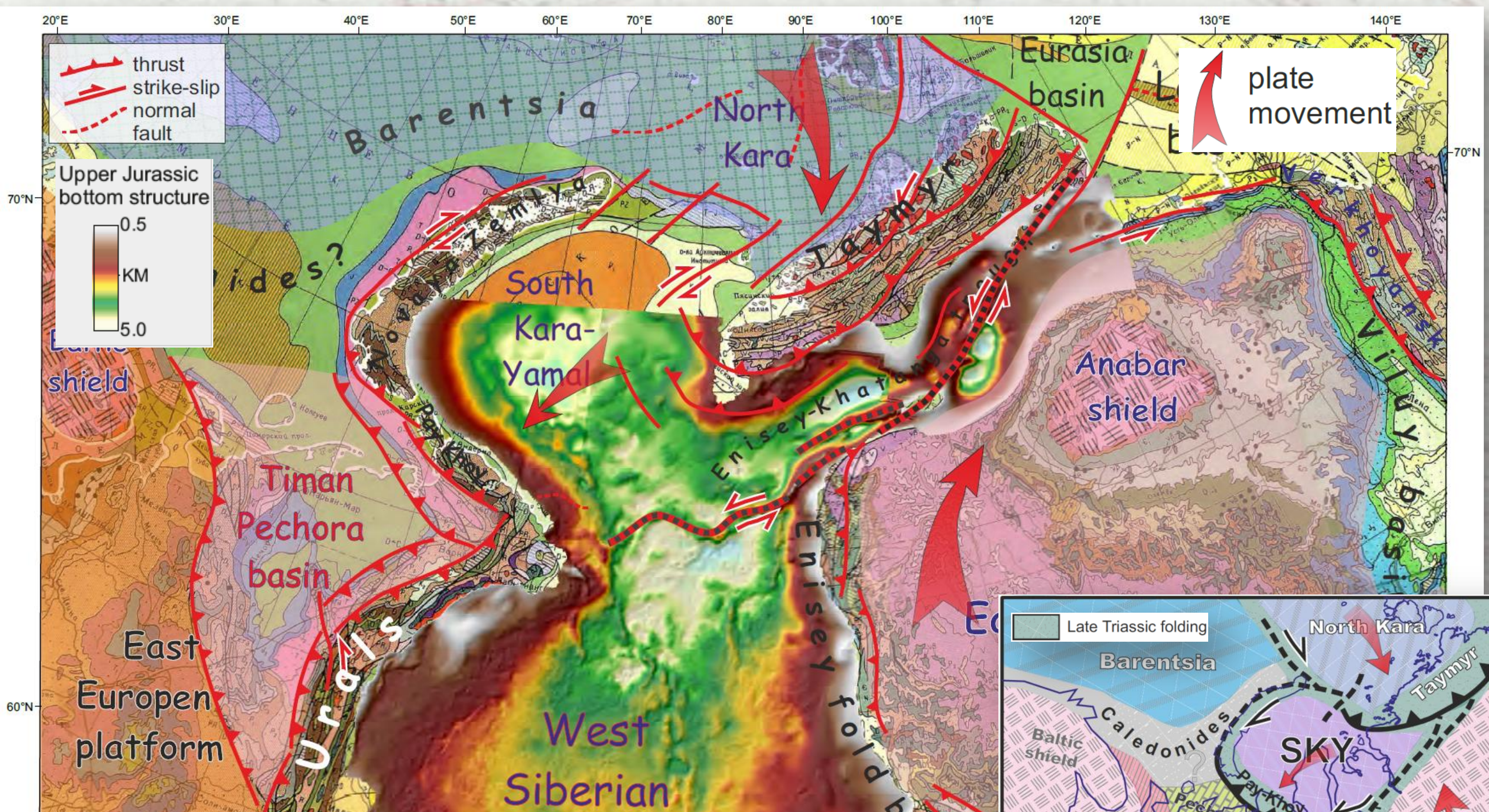


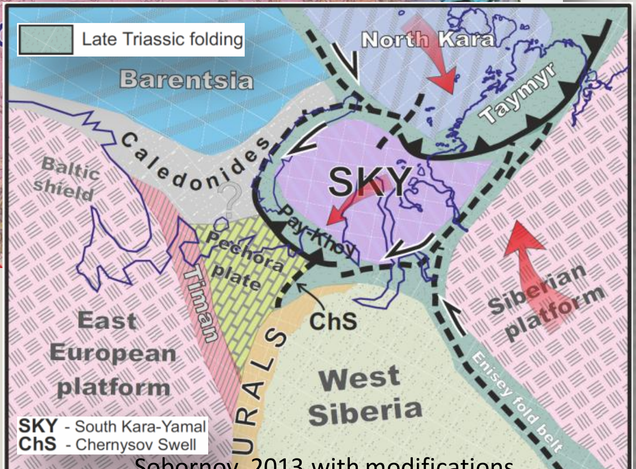


- ✔ Late Triassic – Early Jurassic folding in the Pay-Khoy foreland
- ✔ Folding is sealed by the Jurassic unconformity



Late Triassic transpression



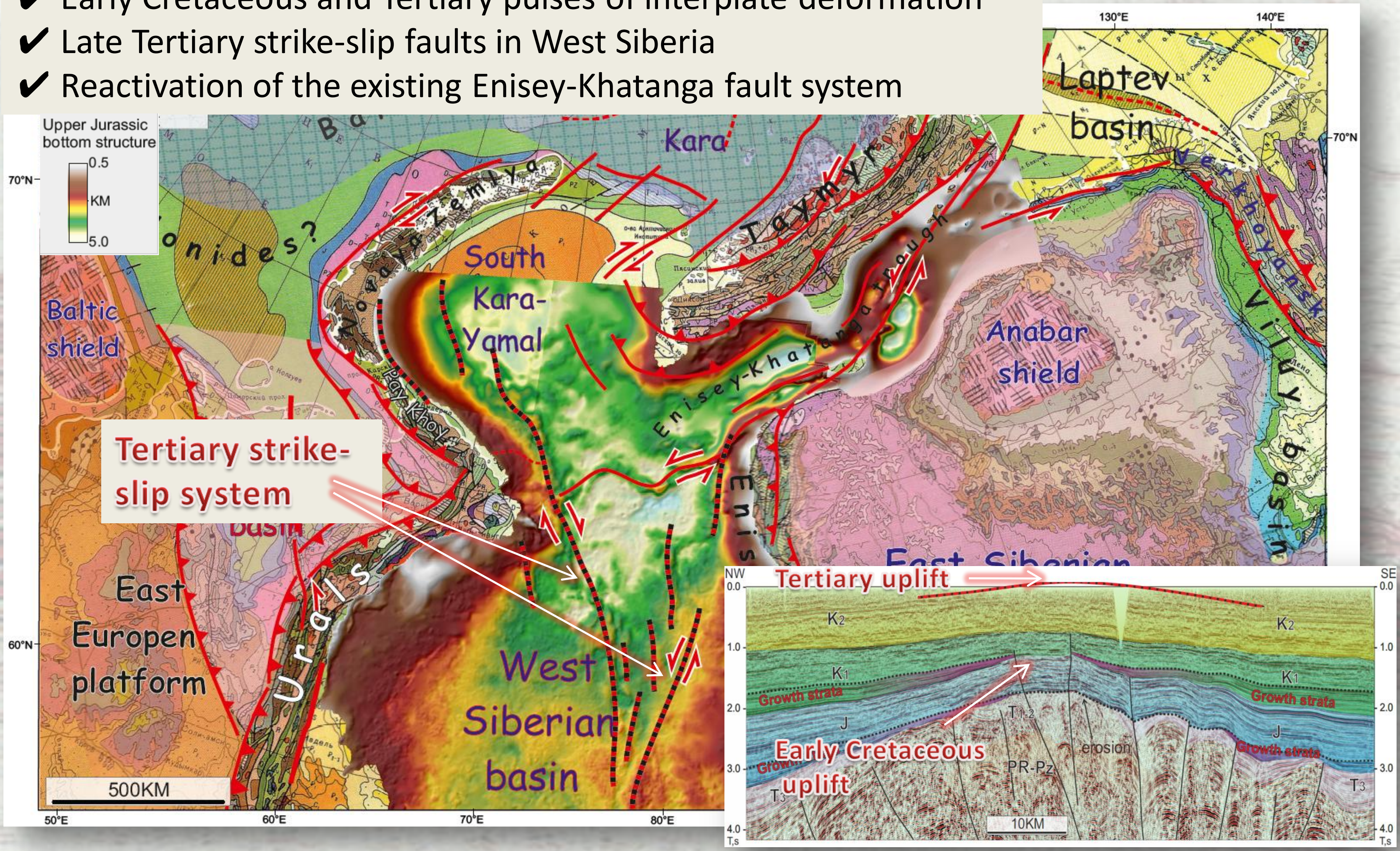


Sobornov, 2013 with modifications

- ✔ Clockwise rotation of the Siberian platform (e.g., Metelkin *et al.,* 2010)
- ✔ Oblique convergence of the North Kara and Siberia
- ✔ Sinistral transpression in the Enisy-Khatanga trough
- ✔ SW lateral "escape" of South Kara - Yamal

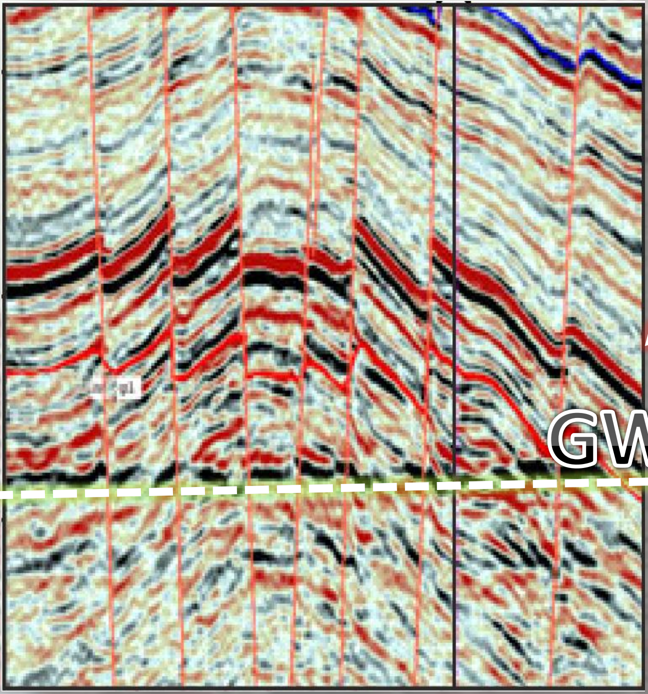
Cretaceous, Tertiary reactivations

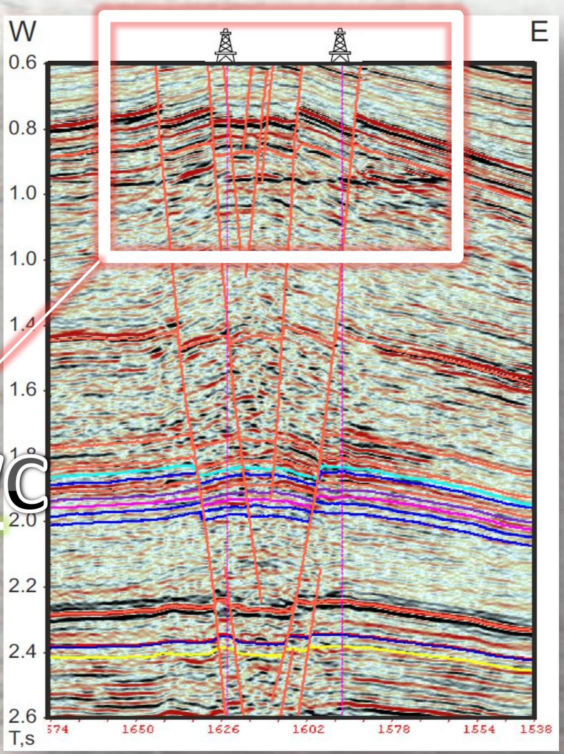
- ✔ Early Cretaceous and Tertiary pulses of interplate deformation
- ✔ Late Tertiary strike-slip faults in West Siberia
- ✔ Reactivation of the existing Enisey-Khatanga fault system

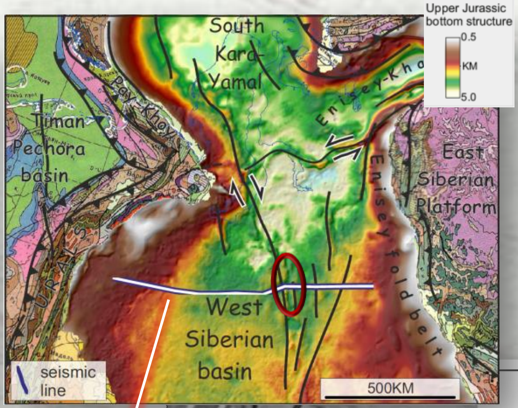


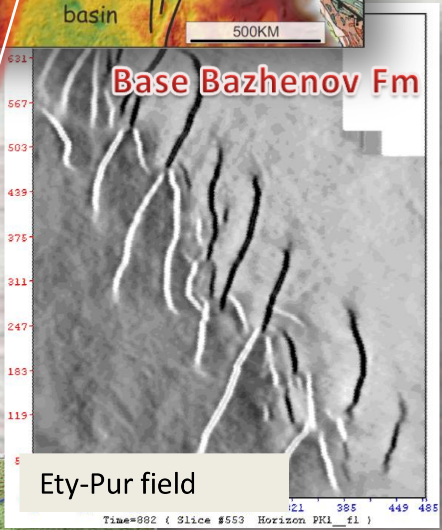
West Siberia: strike-slip faulting, fields

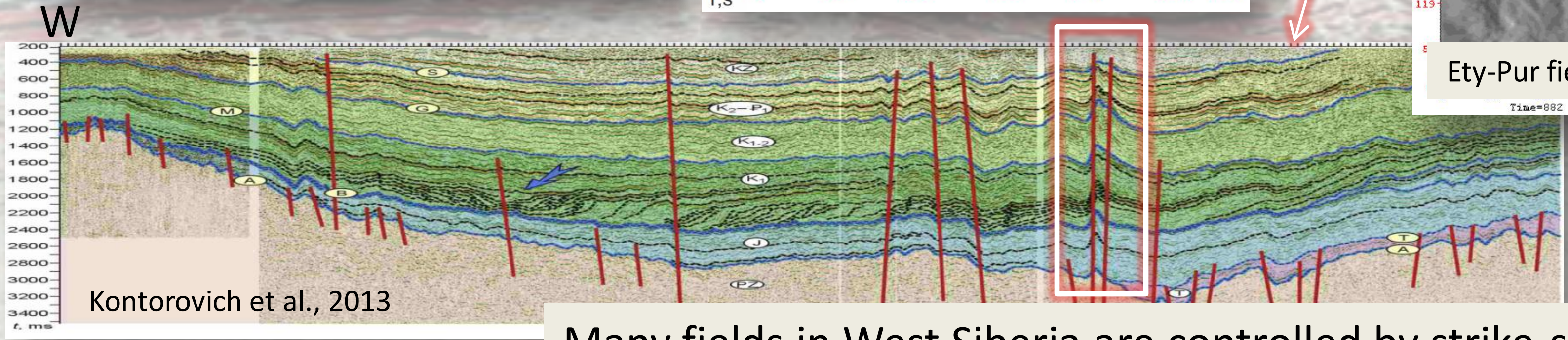
Ety-Pur field











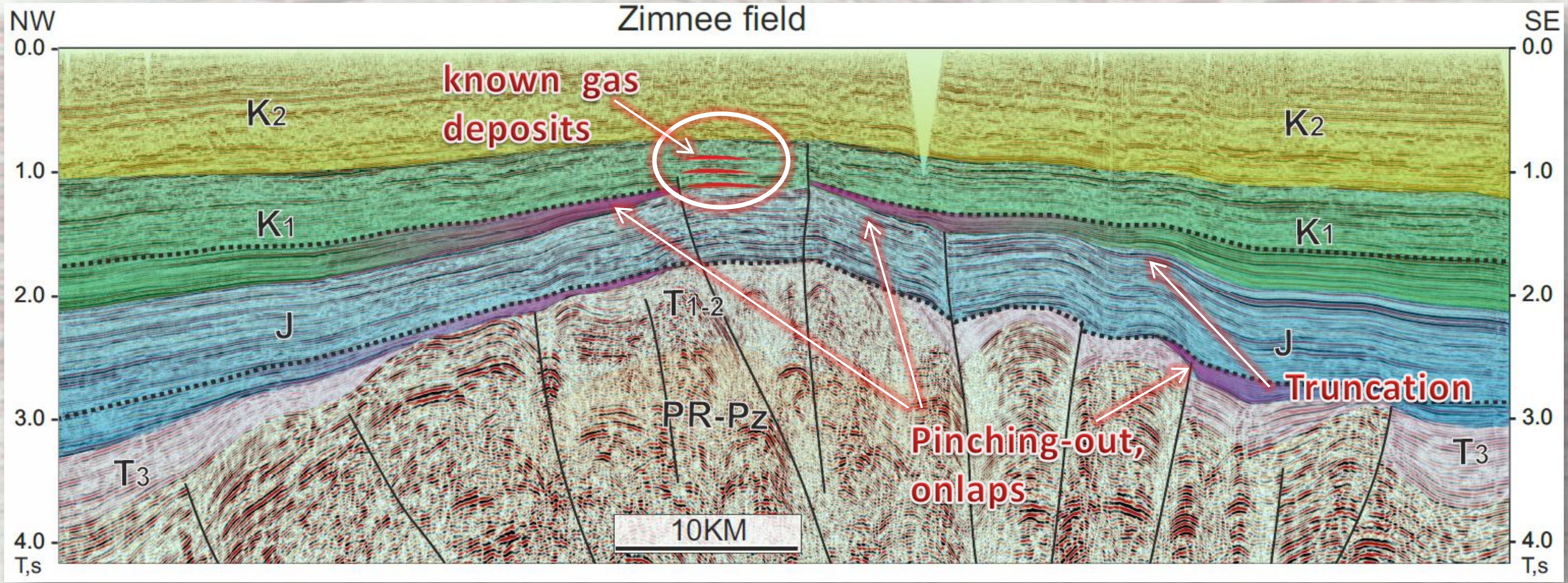
Many fields in West Siberia are controlled by strike-slip faulting

Prospectivity

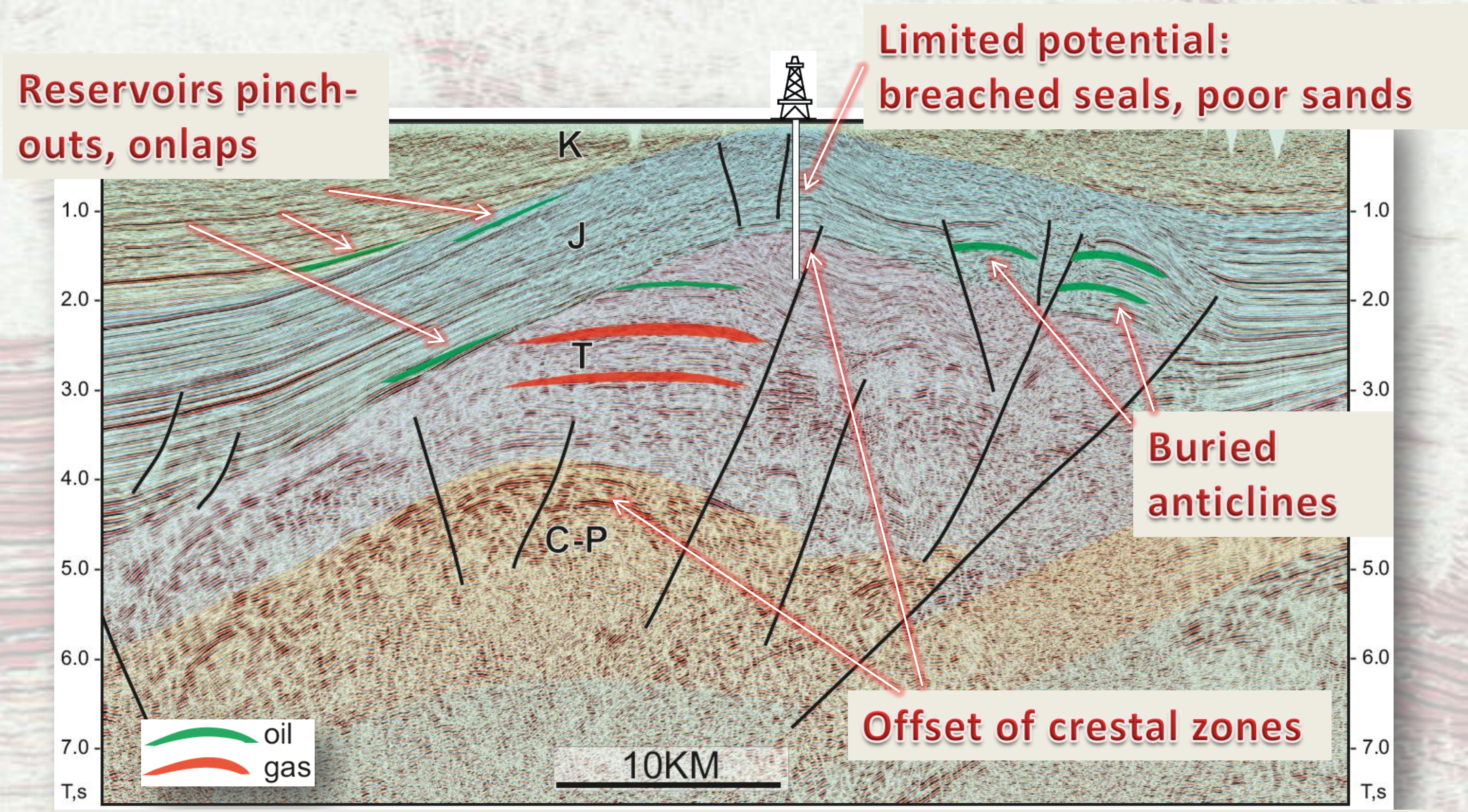
Existing deposits: shallow closures, small and middle-sized pools in the Lower Cretaceous sands.

Leads

- ✔ Deeper Jurassic, faulted pre-Jurassic section
- ✔ Pinch-out intervals, lowstand sands
- ✔ Zones of truncation
- ✔ Stratigraphic traps - Neocomian clinoforms, etc.

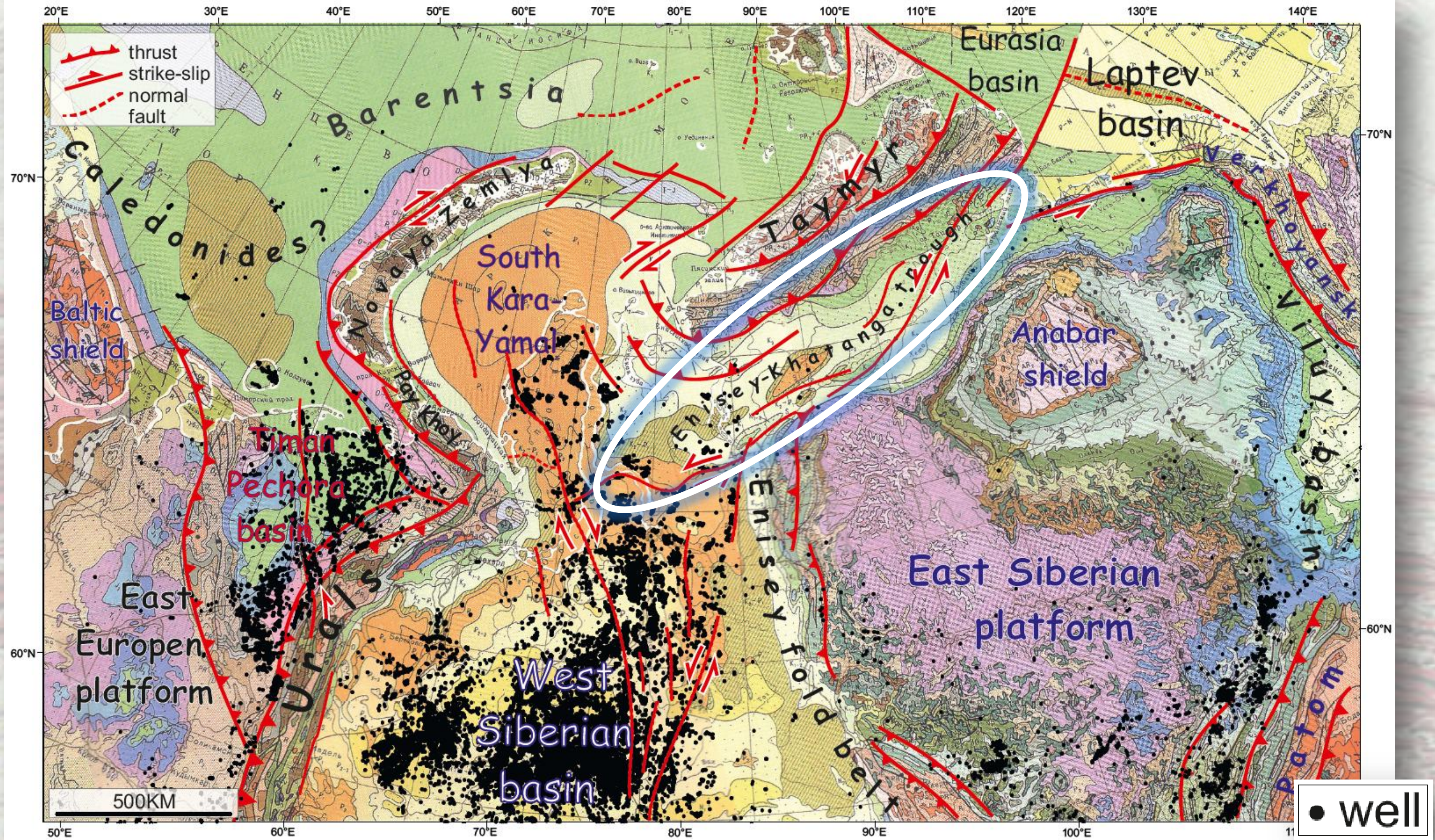


Conventional conceptual plays



✔ pinch-outs, onlapping sands at several levels – multiphase inversion
✔ offset of crestal zones due to listric inversion and transpression

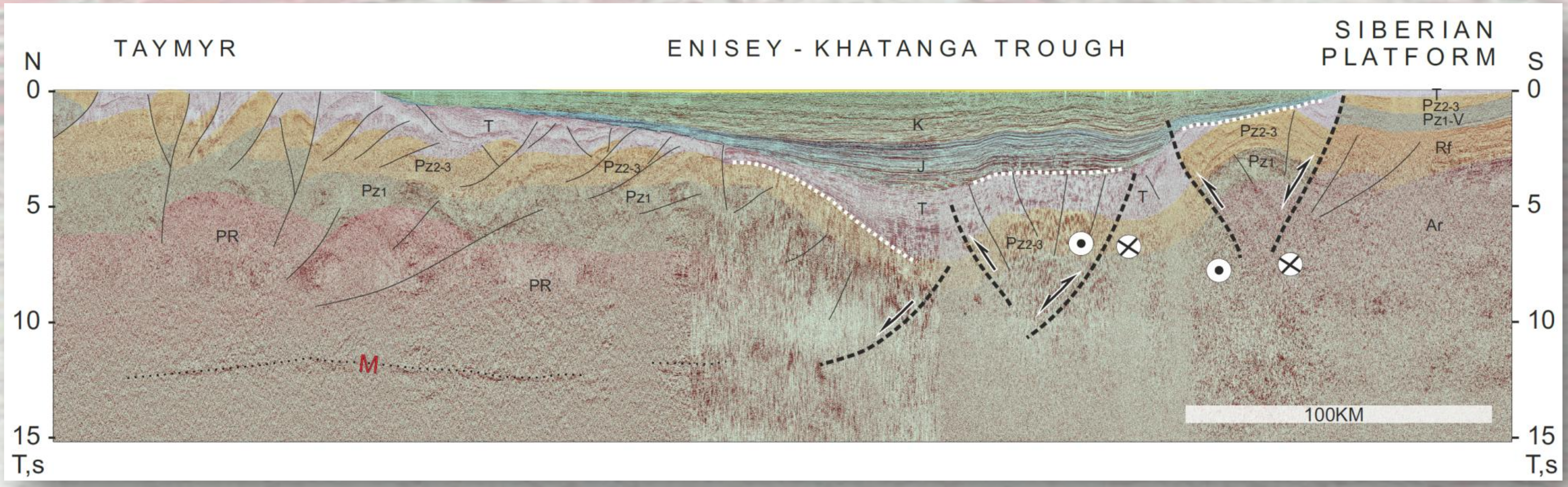
Exploration maturity



Large exploration upside of the underexplored Yenisey-Khatanga trough

Conclusions

- 1500-km long Enisey-Khatanga strike-slip system
- Utilization of zone of weakness produced by collapse of the Late Paleozoic orogen
- Transpression in the Late Triassic-Early Jurassic
- Early Cretaceous, Tertiary reactivations
- Significant hydrocarbon potential



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Thank you!