[PS]Petroleum Potential of the North Uralian Foredeep, Timan Pechora Basin, Russia*

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Abstract

Historically petroleum exploration in the North Uralian foredeep was focused on easy targets provided by high-relief structures in the western inverted and uplifted flank of the foredeep and the North Uralian foreland thrust belt. The structures were defined mainly by surface mapping, structural drilling, and low-fold 2D seismic. First cycle of exploration has resulted in discoveries of about a dozen of oil and gas deposit,s including the giant Vuktyl gas-condensate field made mainly in 1960–1970s. As the simple plays matured, oil and gas exploration shifted to fresh areas in the northern part of the basin, leaving large areas of the Upper Pechora foredeep virtually unexplored with only a handful of wells drilled there. A reinterpretation of vintage seismic and borehole data, as well as new regional seismic lines, provide important constraints for the regional geology and permit identification of new exploration opportunities. Revisited regional geology shows that the Upper Pechora foredeep may contain a significant yet-to-find potential. The buried Upper Devonian carbonate platform covering as much as 3000 km^2 is seen as a potential focus of a new exploration campaign. It sits over a basement high in the north-central part of the foredeep and rimmed with an extensive system of reefs. These reefs and their drapes are viewed as prime exploration objectives, which are proven to contain prolific oil and gas deposits in better studied analogous areas of the basin. Additional plays include subtle traps as lowstand bypass sands, dolomitized oolitic shoals, reef talus / debris aprons, lagoonal patch reefs, and shoals. Significant opportunities are thought to exist in karstified Silurian-Lower Devonian carbonates truncated by the pre-Frasnian unconformity.

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Incorporating APPEX Regional – Prospect & Property Expo
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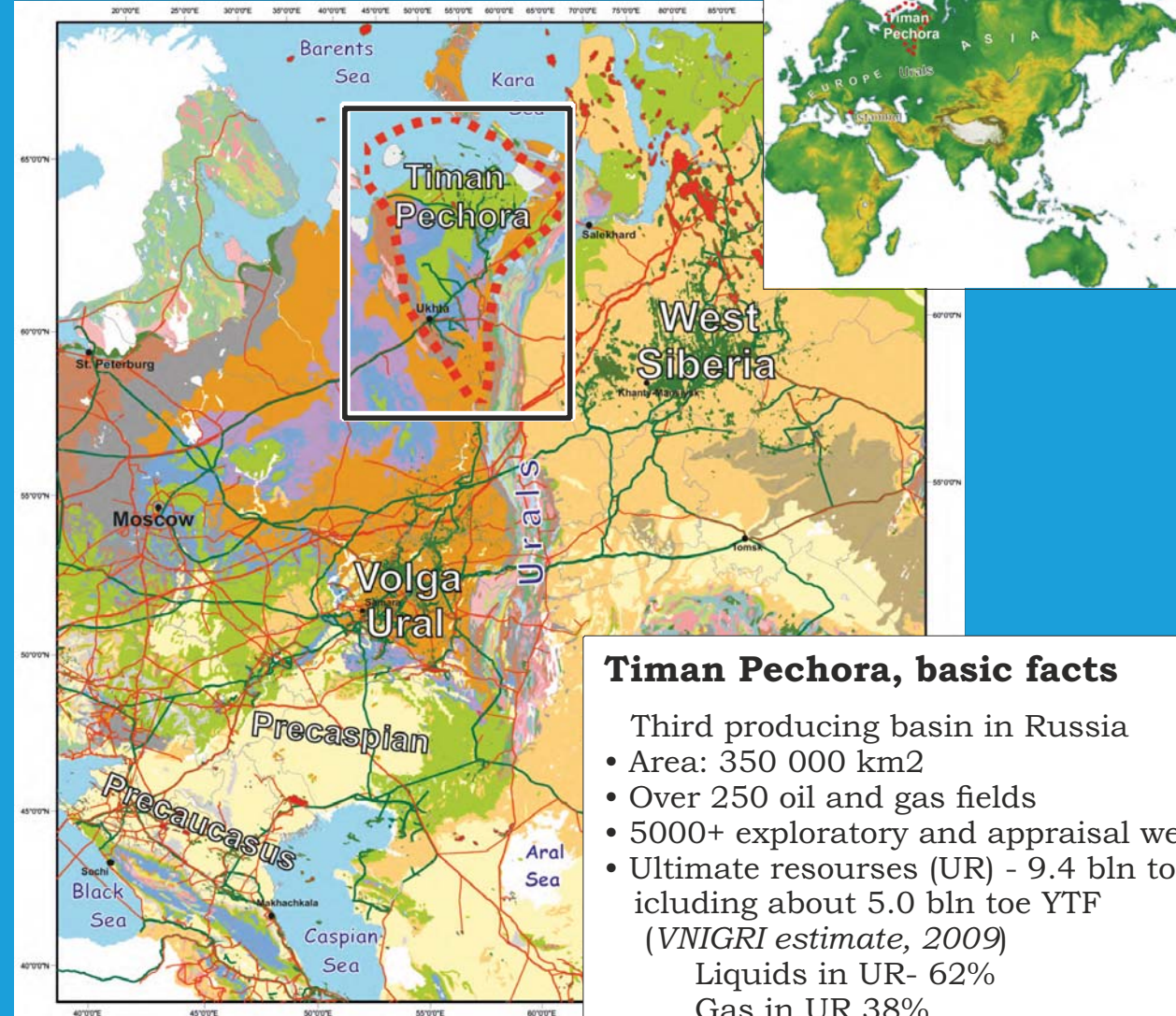Istanbul Congress Center
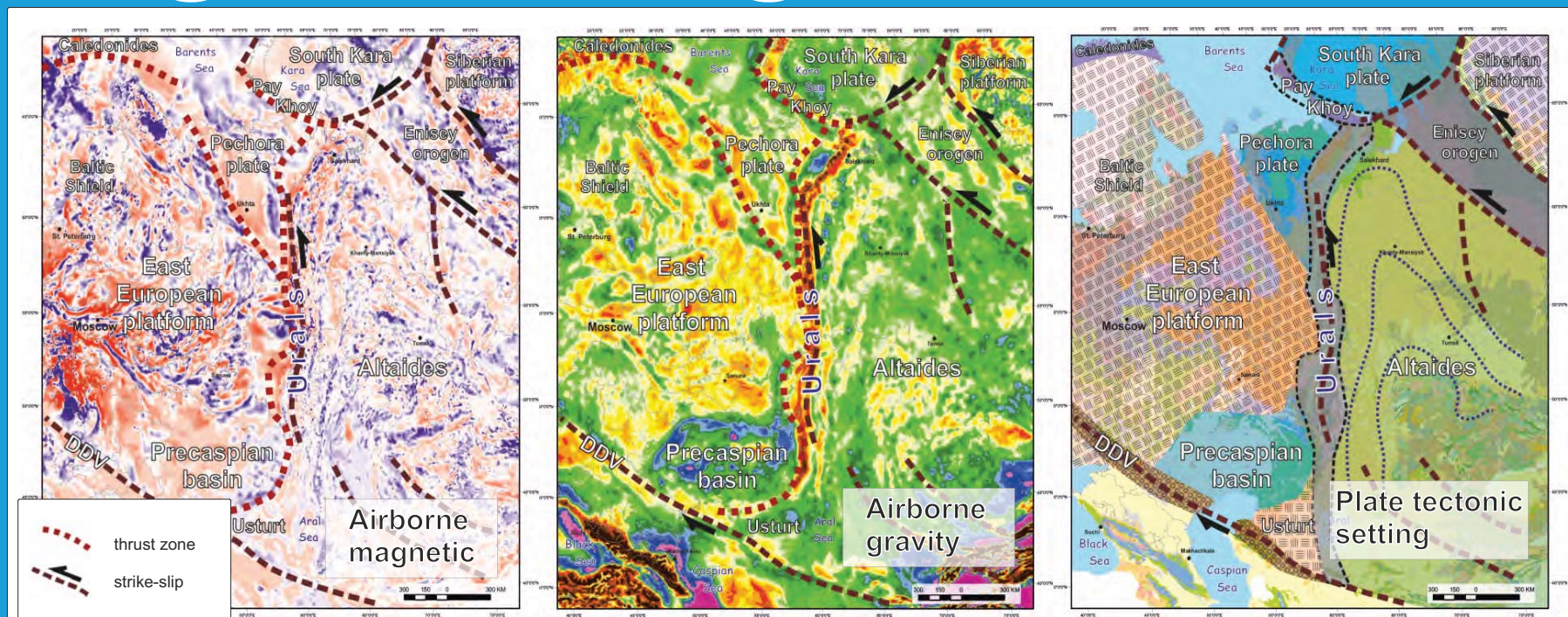Istanbul, Turkey

Summary

Historically petroleum exploration in the North Uralian foredeep was focused on easy targets provided by high-relief structures. They were defined mainly with surface mapping, structural drilling and low-fold 2D seismic. First cycle in of exploration 1960-1970s resulted in significant discoveries oil and gas deposits including the giant Vuktyl gas-condensate field. As the simple plays matured, oil and gas exploration shifted to fresh areas in the northern part of the basin, leaving large areas of the North Uralian foredeep underexplored.

Recently a large amount of legacy data was digitized, vectorized and georeferenced. Coupled with study of new regional seismic lines this big dataset allows revisit of geology of the North Uralian foreland. A reinterpretation of vintage and new G&G data with use of new geological concepts permitted the identification of new high-impact conventional exploration opportunities. These include thrust-related 4-dip closures, large buried carbonate platforms, subtle traps related to unconformities and pinching-outs. An inventory of vintage data showed the presence of significant bypassed oil and gas pools which may add a considerable upside potential. Integration of the new play concepts and modern technologies may result in a new generation of large oil and gas finds in the North Uralian foredeep.

Location, oil

Timan Pechora, basic facts

Third producing basin in Russia
• Area: 350 000 km2
• Over 250 oil and gas fields
• 5000+ exploratory and appraisal wells
• Ultimate resourses (UR) - 9.4 bln toe, icluding about 5.0 bln toe YTF (*VNIGRI estimate, 2009*)
   Liquids in UR- 62%
   Gas in UR 38%

Regional setting

The principal tectonic elements within the Uralian region are shown above. The Uralian fold belt is essentially a west-vergent thrust belt. It is flanked on the west by the East European platform and the West Siberian basin on the east. The present day structure of the Uralian foreland was mainly controlled by the closure of the Uralian Ocean in the Late Paleozoic followed by the oblique collision of structural domains of the East European affinity with the Altaide collage involving terranes of island arc origin and microcontinents (Şengör et al., 2003). The post-oroganic collapse gave way to the development of the West Siberian basin.

Tectonics

Timan Pechora tectonic scheme
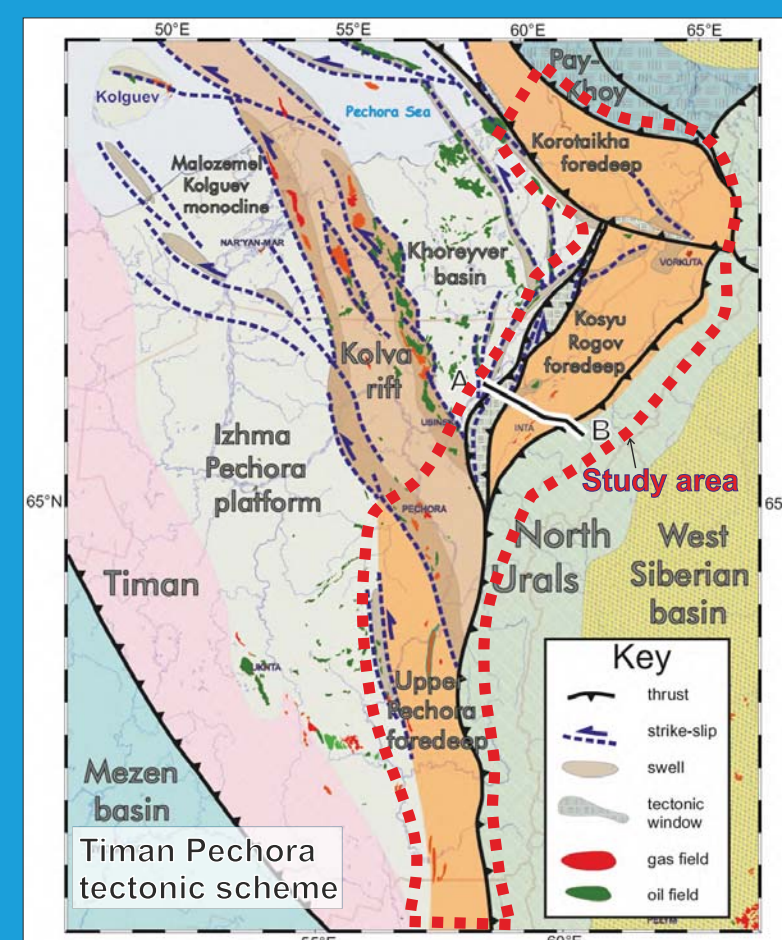
The North Uralian foredeep consists of a chain of asymmetrical subbasins situated between the Urals and Pechora plate. It comprises an Upper Proterozoic basement overlain by Paleozoic-Cenozoic sedimentary cover. Thickness of the sedimentary section is increasing to the east reaching up to 12 km. The pre-Uralian part of the study area exhibits a classical foreland fold and thrust belt with an extensive development of thrust imbrications involving the Proterozoic basement and Paleozoic-Triassic shelf and bathyal deposits. The principal tectonostratigraphic elements of the basin and major unconformities are shown below.

Structural geology
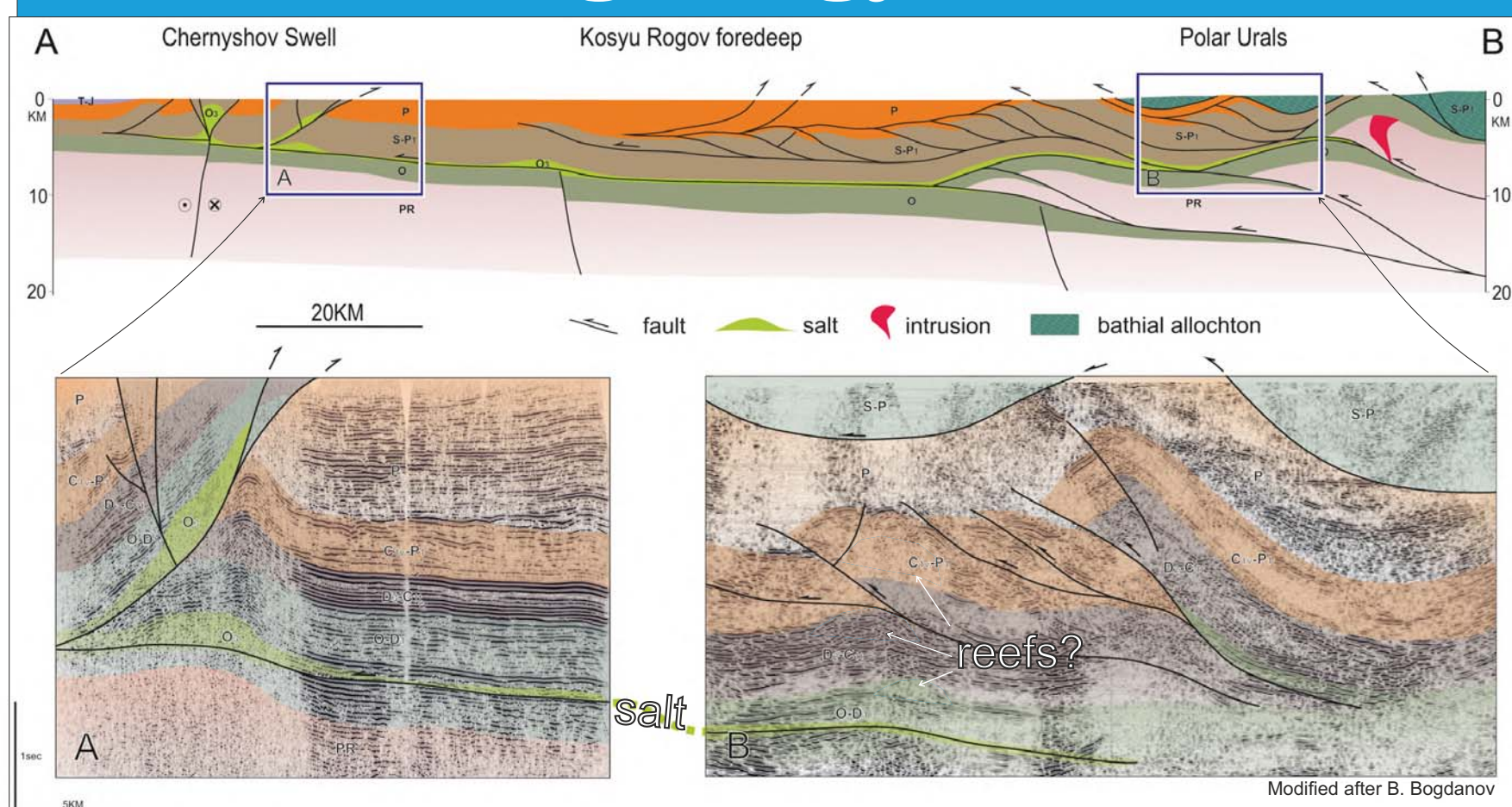
Top: regional geological section across the Polar Urals - Kosyu-Rogov foredeep-Chernyshev swell.
Bottom: interpreted seismic lines illustrating the structural styles, corresponding to boxes on the geological section. The main detachment level is interpreted to correspond to the Upper Ordovician evaporite unit. Line location is shown in the tectonic map (middle-right).

Tectonostratigraphy

Tectonostratigraphic chart of the Kosyu Rogov foredeep and the Polar Urals thrust belt


Timing of structuring
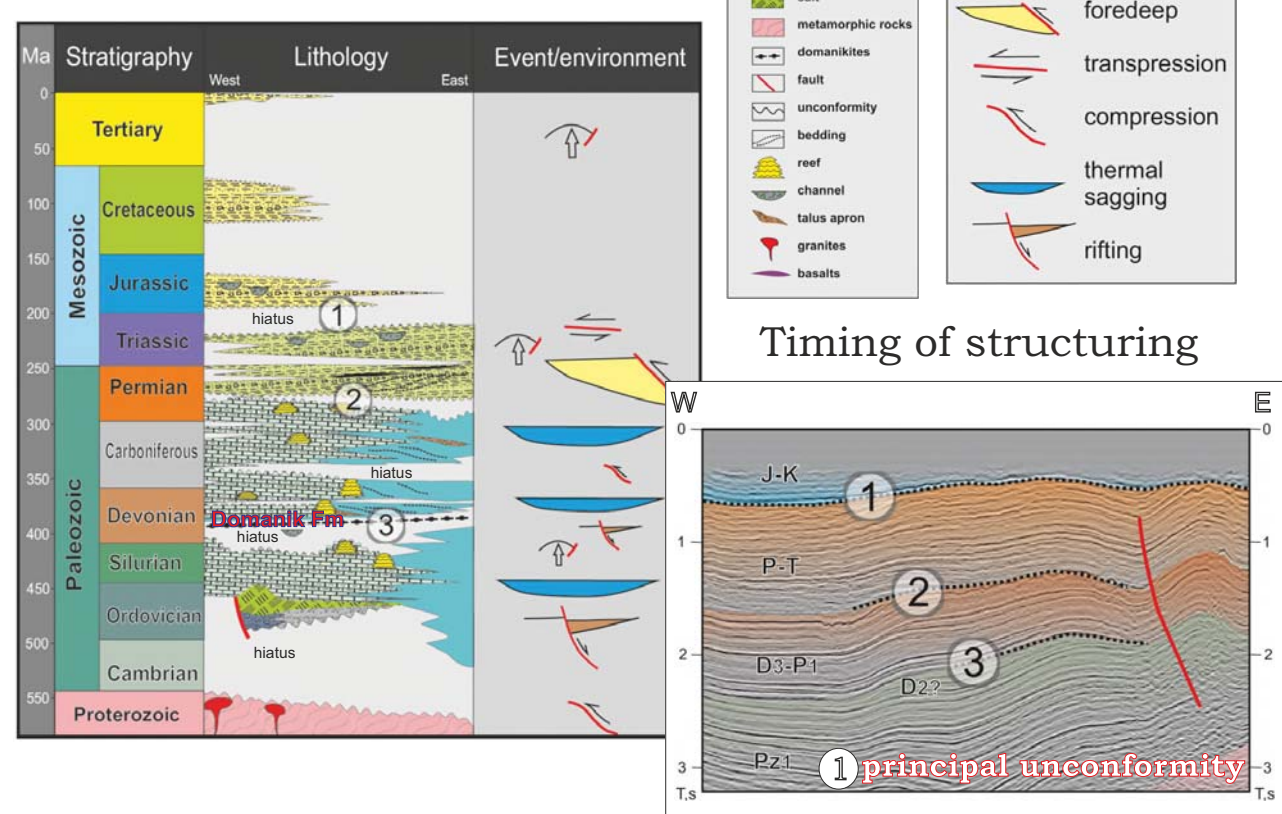
# Past exploration, petroleum systems

NORD WEST

Past exploration

The first commercial oil deposits in the Timan Pechora basin were found in the Ukhta area in the 1930ies. During the following decades exploration in the area was focused on the western uplifted flanks of the foredeep and large structures in the thrust belt. The drilling campaign carried out in the 1960-70ies was targeting high-relief structural closures defined by the surface mapping, shallow structural drilling and low-fold seismic. It resulted in a number of small and middle sized fields in the platformal part of the foredeep. In the fold and thrust belt exploration led to the discovery of giant Vuktyl gas-condensate field and several small deposits. As the simple plays matured, oil and gas exploration shifted to areas in the northern part of the basin, leaving large areas of the North Uralian foredeep poorly explored.
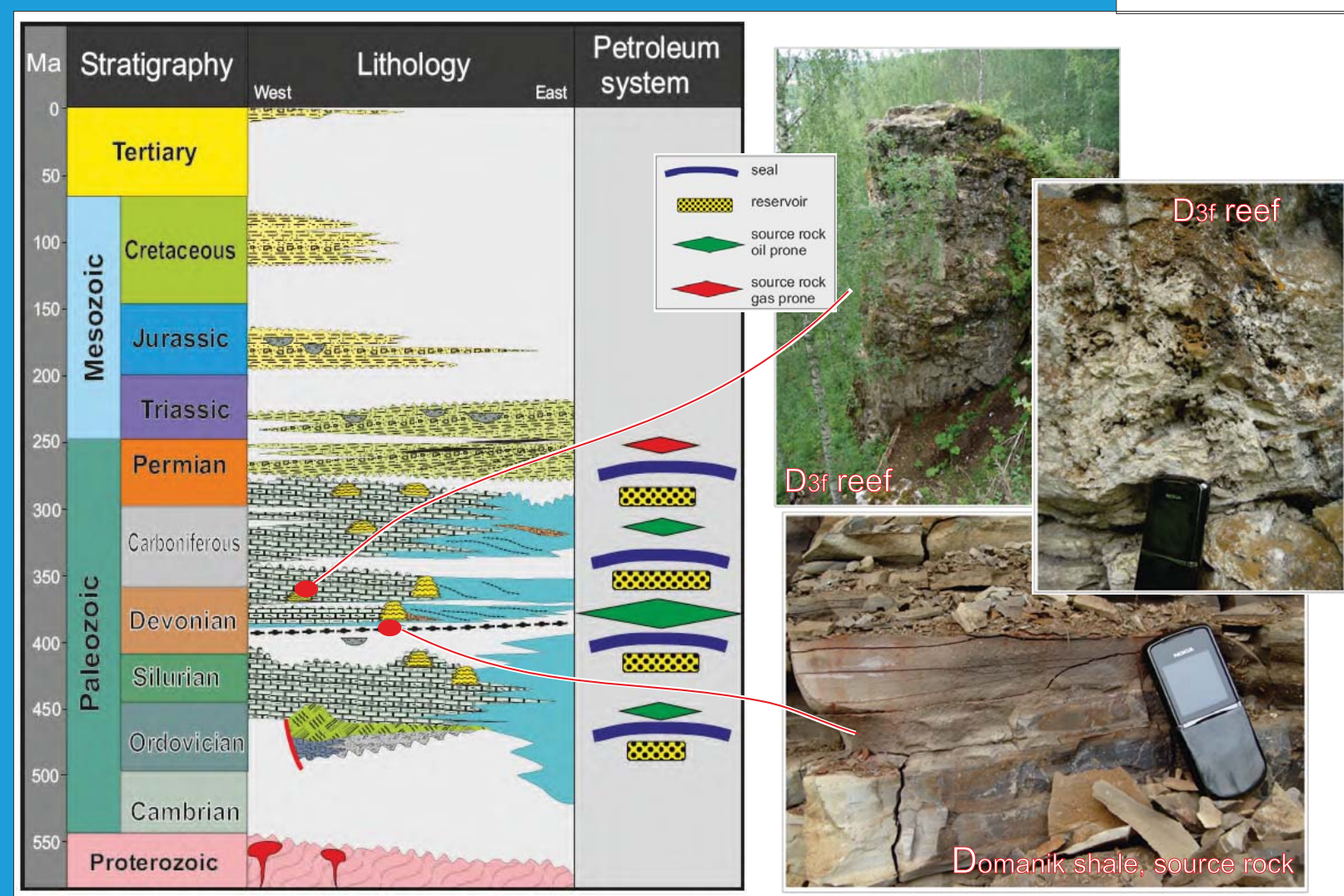

Oil and gas fields
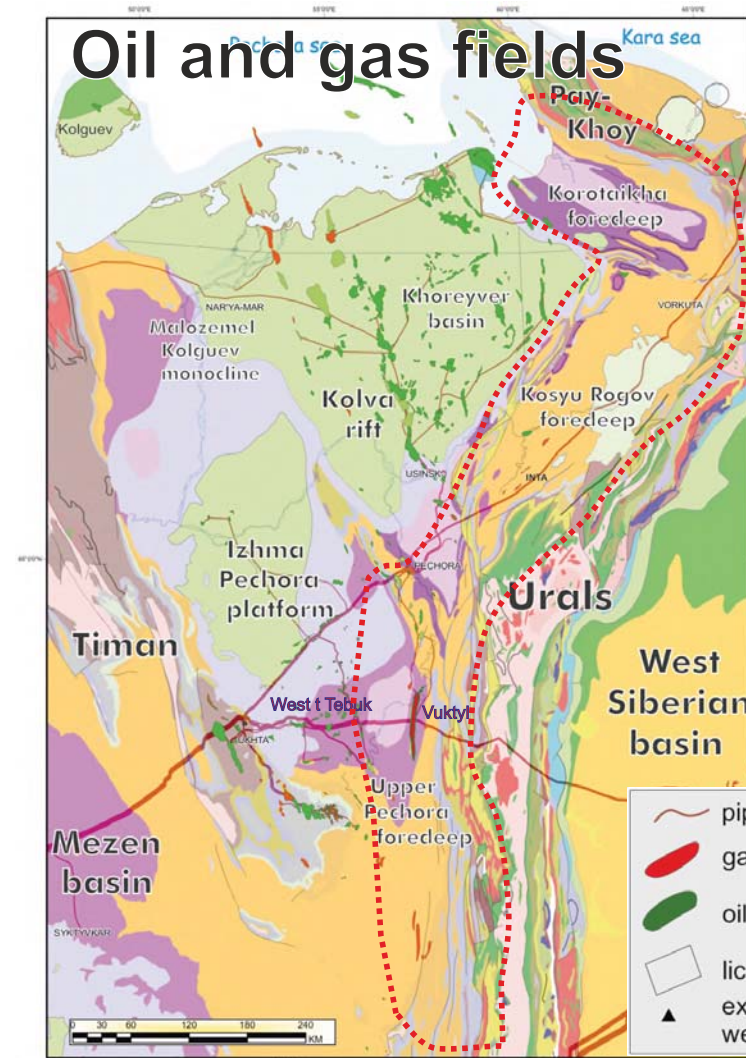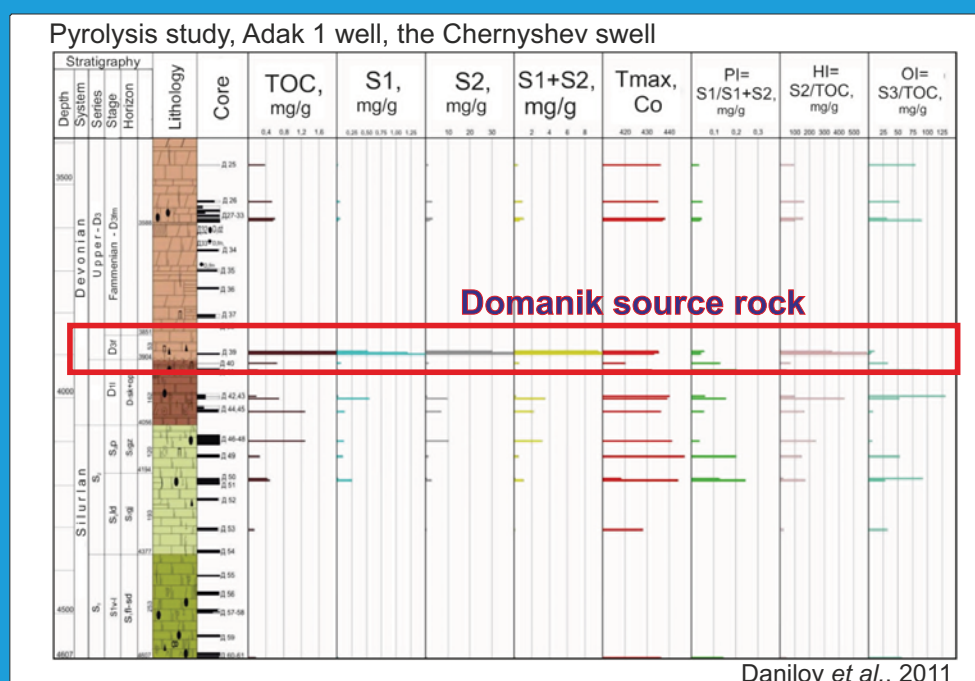

Driling maturity
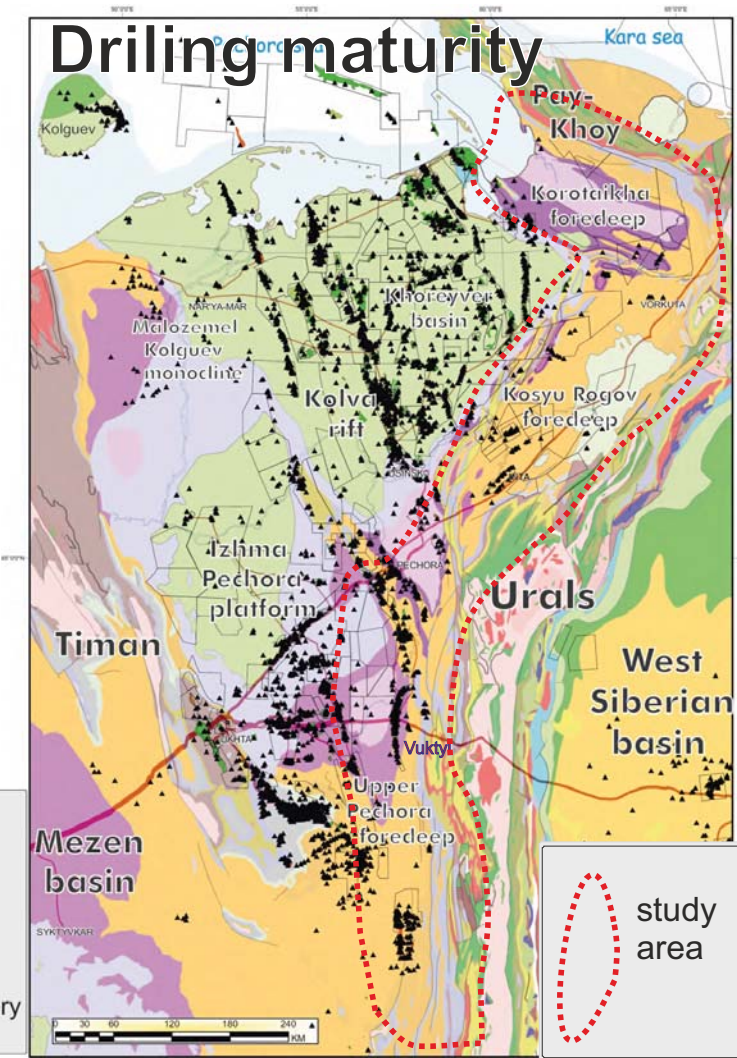
Petroleum systems

Tectonostratigrapthic column with identification of the major elements of the petroleum systems of the North Uralian foredeep.

Domanik source rock

Pyrolysis study, Adak 1 well, the Chernyshev swell

Domanik source rock

Danilov et al., 2011

The large petroleum potential of the North Uralian foreland was essentially provided by the presence of favorable conditions for petroleum generation and accumulation including the wide development of the world-class mature Domanik (Upper Frasnian) source rocks.
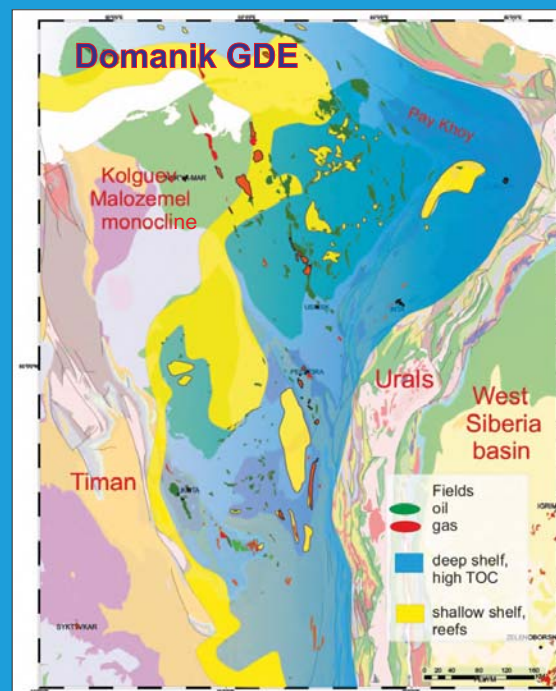
Reinterpretation

Reinterpretation of vintage and new G&G data provided new constraints on structural geology of the North Uralian foredeep allowing revision of traditional and definition of new explorationl plays.

Interpretation of 1980-ies

New interpretation

Domanik GDE

Fields

West Tebuk

Vuktyl
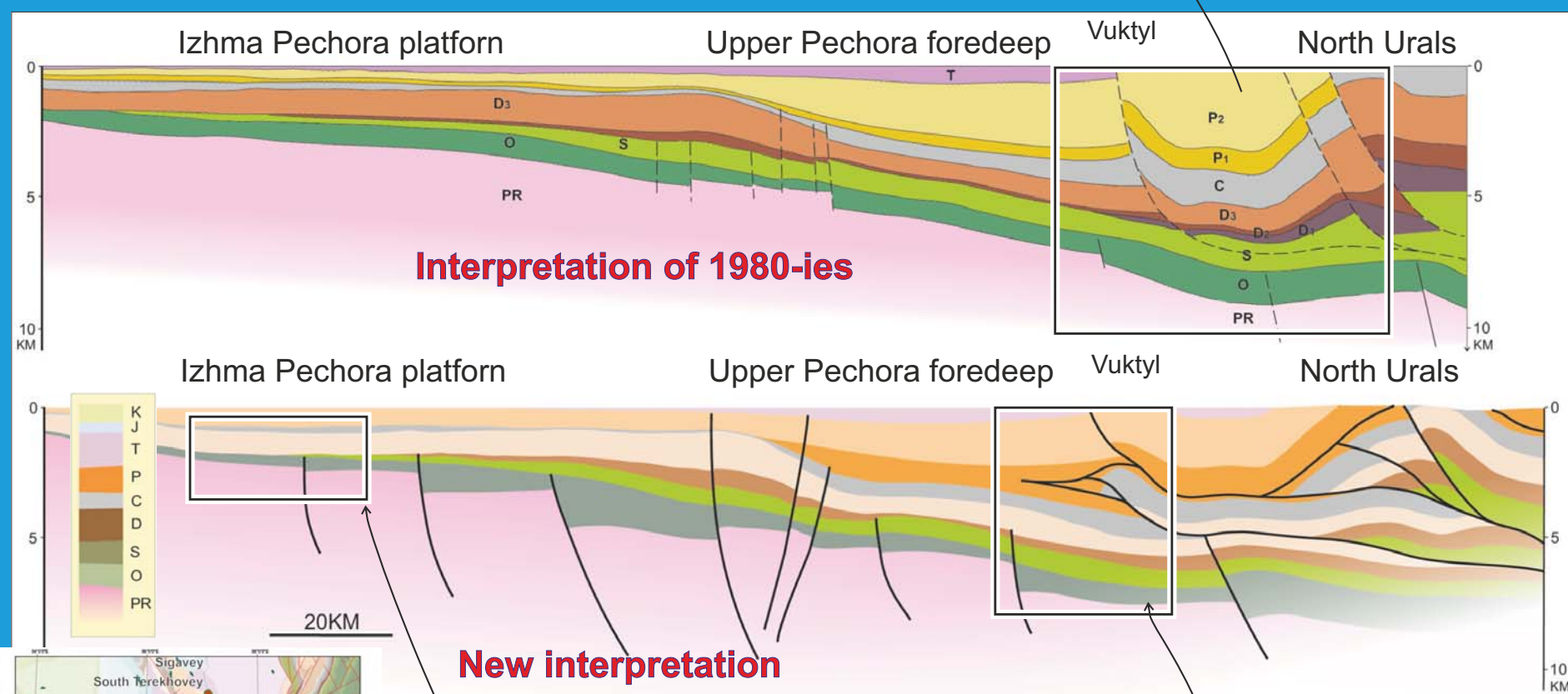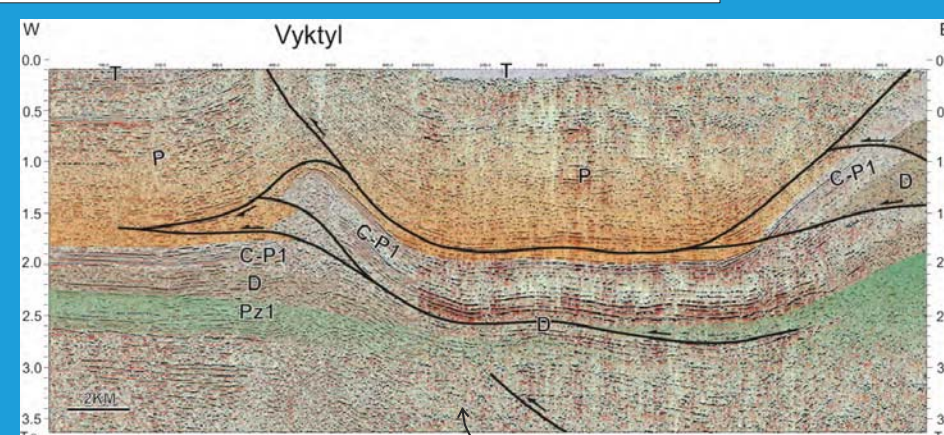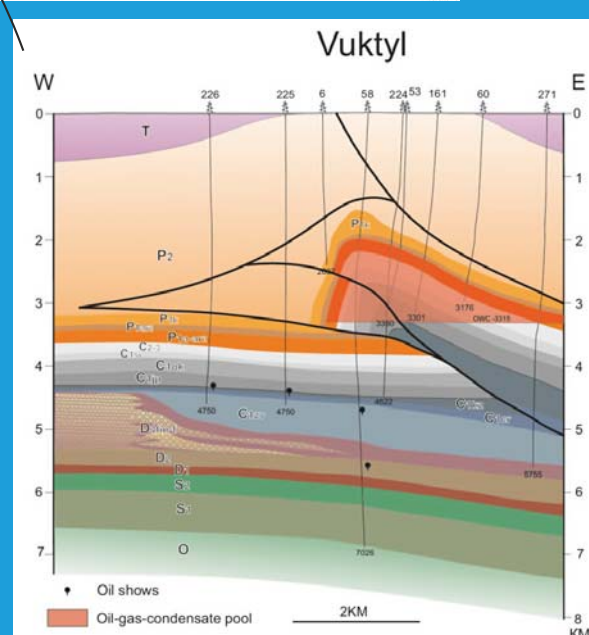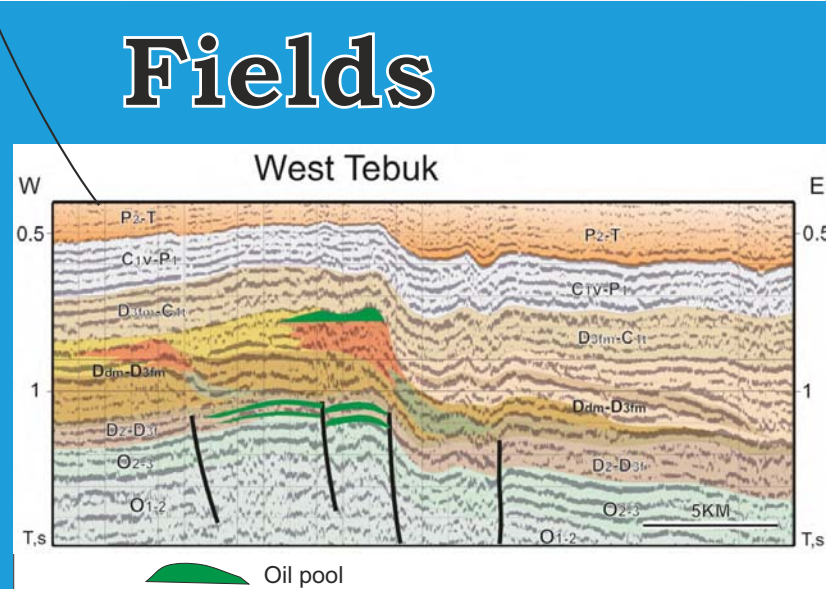
Cross-sections of selected fields in the study area.

Petroleun Geology

In the central platformal part of the Timan Pechora basin majority of deposits are found in Middle Devonian sands and Upper Devonian – Lower Carboniferous carbonates. Of secondary importance are Silurian-Lower Devonian and Upper-Carboniferous-Lower Permian carbonates. Seals are provided by shale units originated from transgressions and sea-level high-stands.

Structures are mainly related to strike-slip and normal faulting and inversion of extensional faults. It the thrust belt the known pools occur in the allochthonous section within anticlinal structures expressed at the surface. The depth of the pays ranges from 1.5 to 4.5 km. Most of the discovered hydrocarbons are hosted in Visean sandstone and fractured Carboniferous-Lower Permian carbonates, sealed by Artinskian marine shales and Kungurian evaporites.

Throughout much of the basin the Domanik shale (Upper Frasnian) provides mature prolific source rock. Additional source rocks are locally developed in the Silurian-Lower Devonian, Lower Carboniferous and Lower Permian deposits.
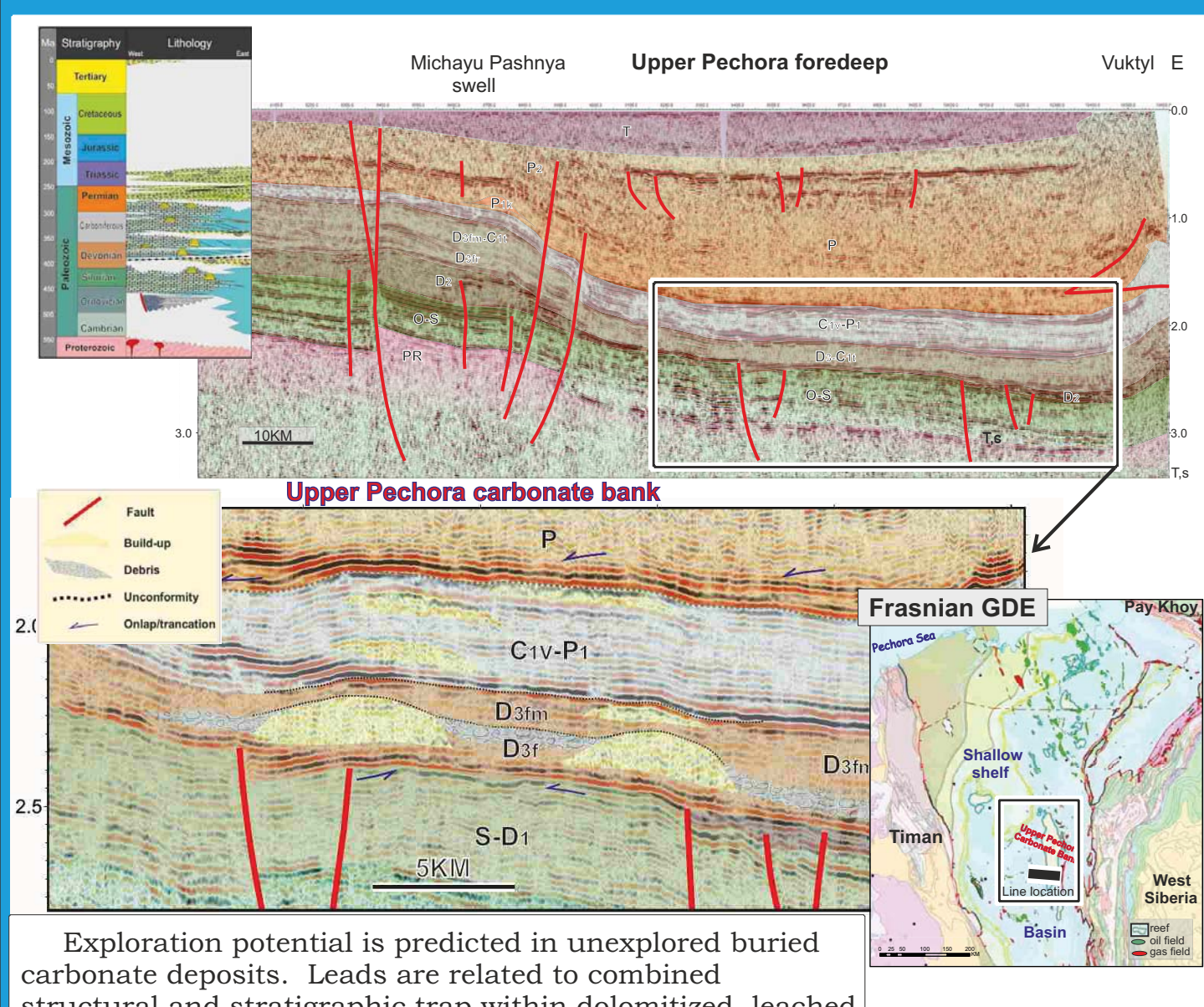
New exploration opportunities

Reinterpretation of a large dataset with use of new geological concepts shows that the North Uralian foredeep may contain untested high-impact conventional opportunities. Prospective plays include thrust-related high-relief 4-dip closures, buried reefs and associated traps, and numerous subtle traps. There is an additional upside potential related to bypassed pools. In the past most of them were difficult to find due to inadequate exploration technologies. Some leads are shown below.

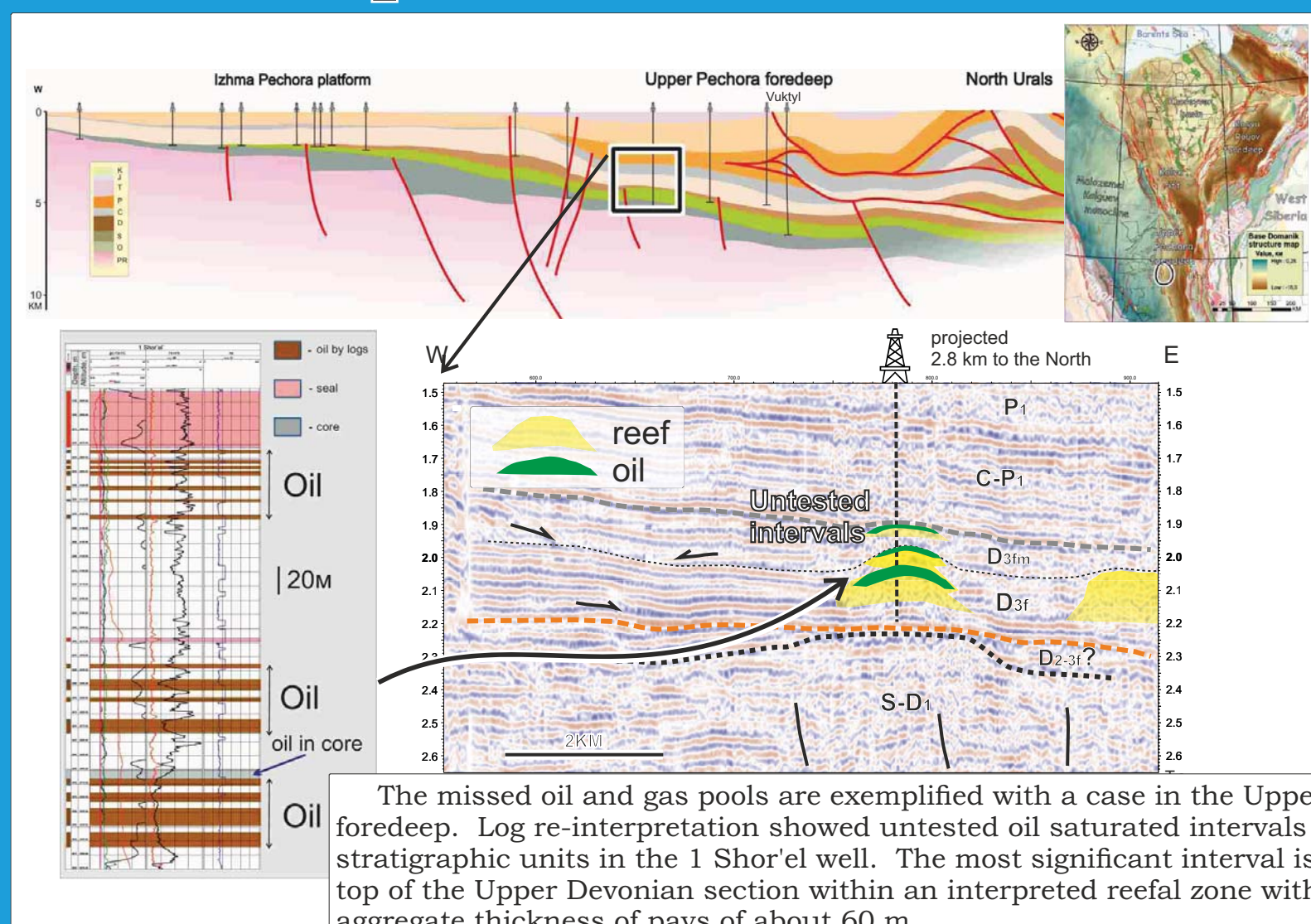### Pay-Khoy foredeep

Play types
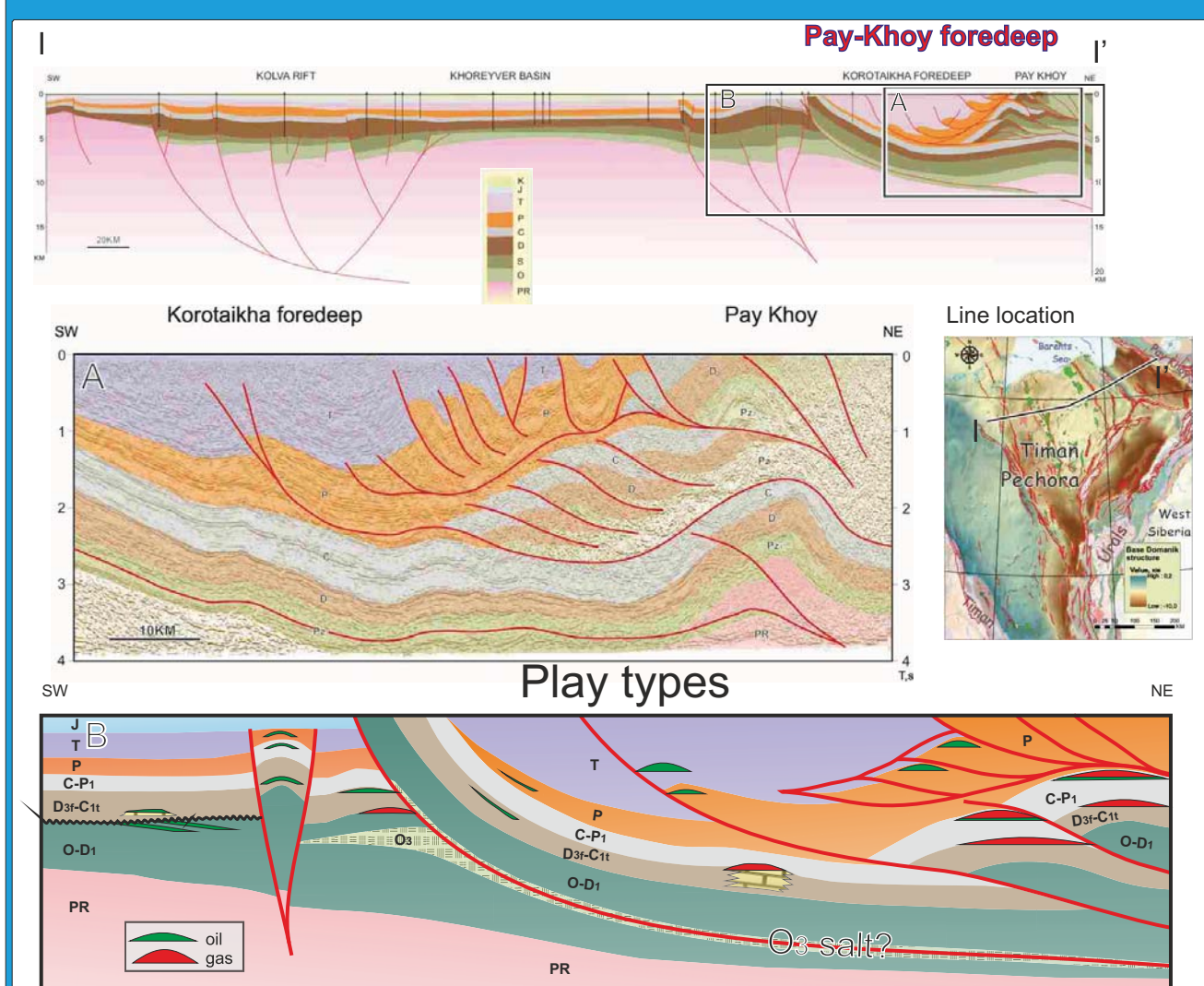
The detachment faulting and structural imbrications of the fold and thrust belt provides diverse types of hydrocarbon traps. Of prime interest are high-relief thrust related 4-dip closures, flower structures, carbonate build-ups, pinch-outs, and karstified carbonates subcropping the pre-Frasnian unconformity.

Thrust-related leads

Polar Urals foredeep

In the Chernyshev swell area trapping mechanism is provided by a regional high (structural nose) involving prospective Silurian-Permian deposits being juxtaposed against a system of backthrust sheets with the Upper Ordovician salt in the base, forming a high-relief trap. This structure provided focus of migration throughout much of the Permian and Triassic during the most significant period of oil migration from the foredeep to the east.

Buried reefs

Upper Pechora foredeep

Upper Pechora carbonate bank
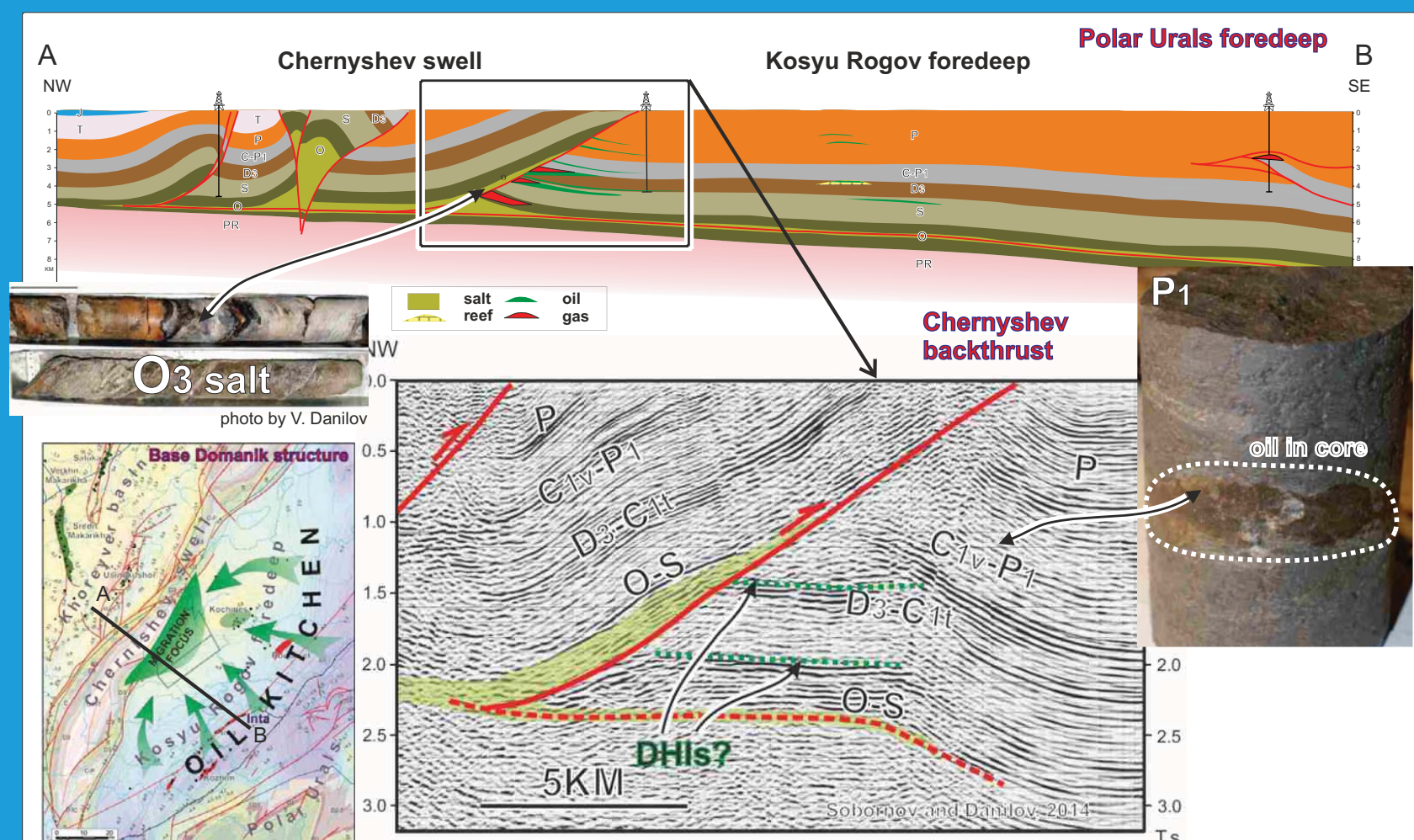
Frasnian GDE

Exploration potential is predicted in unexplored buried carbonate deposits. Leads are related to combined structural and stratigraphic trap within dolomitized, leached and fractured reef margin and reef foreslope facies in Upper Devonian and probably Silurian units. Good reservoirs are predicted in lowstand by-pass sands, dolomitized oolitic shoals, reef talus/debris aprons, and backreef patch reefs.

Stratigraphic traps

Study of vintage and new seismic data supported by well log interpretation showed the widespread development of subtle stratigraphic traps related to truncation and pinching-out of prospective intervals. Of significant interest are zones of dolomitization and karstification sealed by shale units.
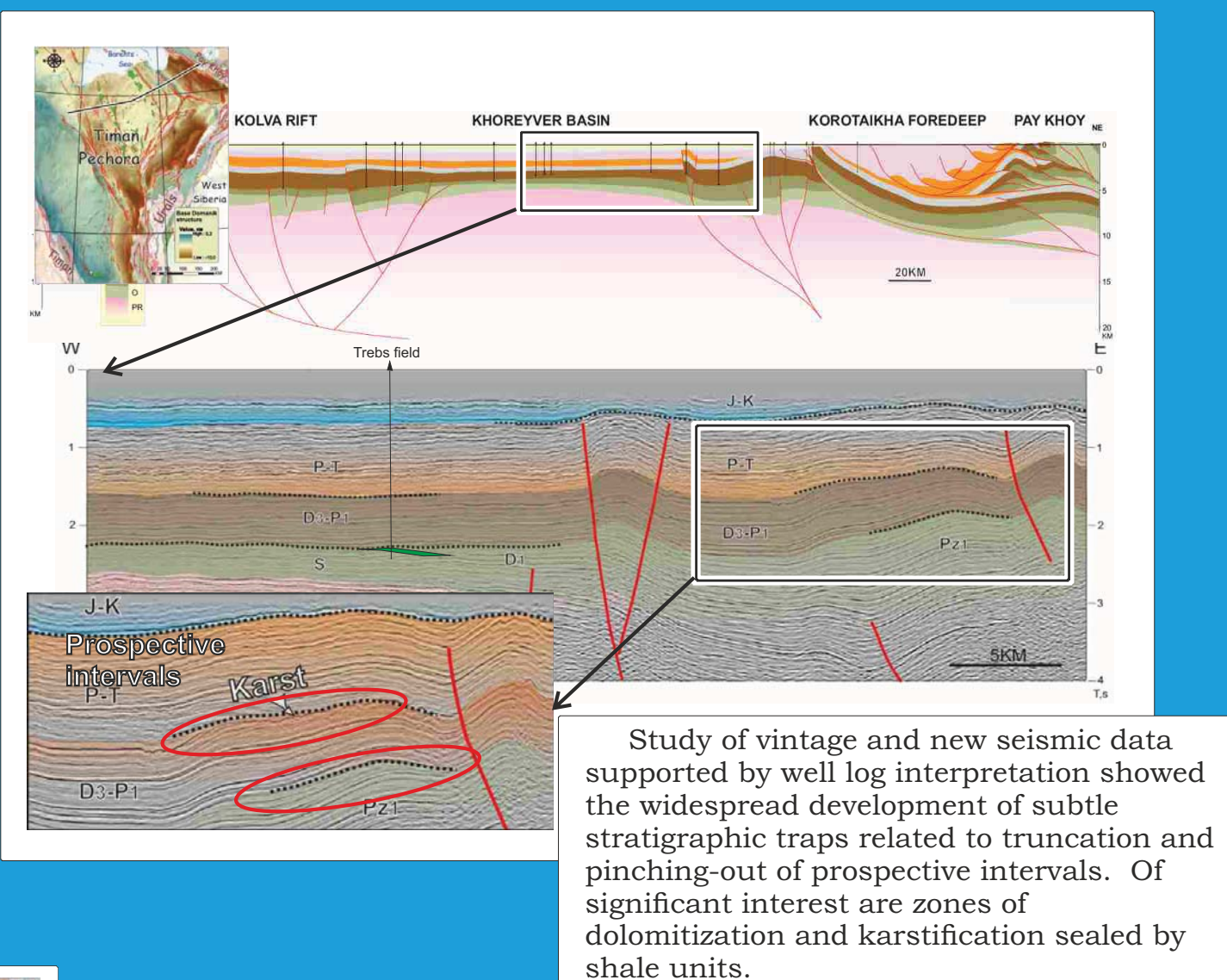
Missed pools

The missed oil and gas pools are exemplified with a case in the Upper Pechora foredeep. Log re-interpretation showed untested oil saturated intervals in several stratigraphic units in the 1 Shor'el well. The most significant interval is in the top of the Upper Devonian section within an interpreted reefal zone with an aggregate thickness of pays of about 60 m.

Conclusions

A critical review of G&G data shows that high impact conventional opportunities exist in the North Uralian foredeep. Of prime interest in this area are thrust-related high-relief 4-dip closures, buried reefs and associated traps, and numerous subtle traps. There is additional upside potential related to missed pools. Unconventional deposits, mainly the Domanik shale, may also provide large volumes of hydrocarbons.

Crucial for successful exploration in fold belts are the integration of various exploration methods, expertise in structural geology, drilling technology, overpressure prediction and basin modeling.