MONGOLIA:
FRONTIER EXPLORATION POTENTIAL IN AN EMERGING ECONOMY

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AIM MATD

Contents

- Introduction to Mongolia
- Summary of E&P Industry
- Petroleum Geology Overview
- Economics & Infrastructure
- Conclusions

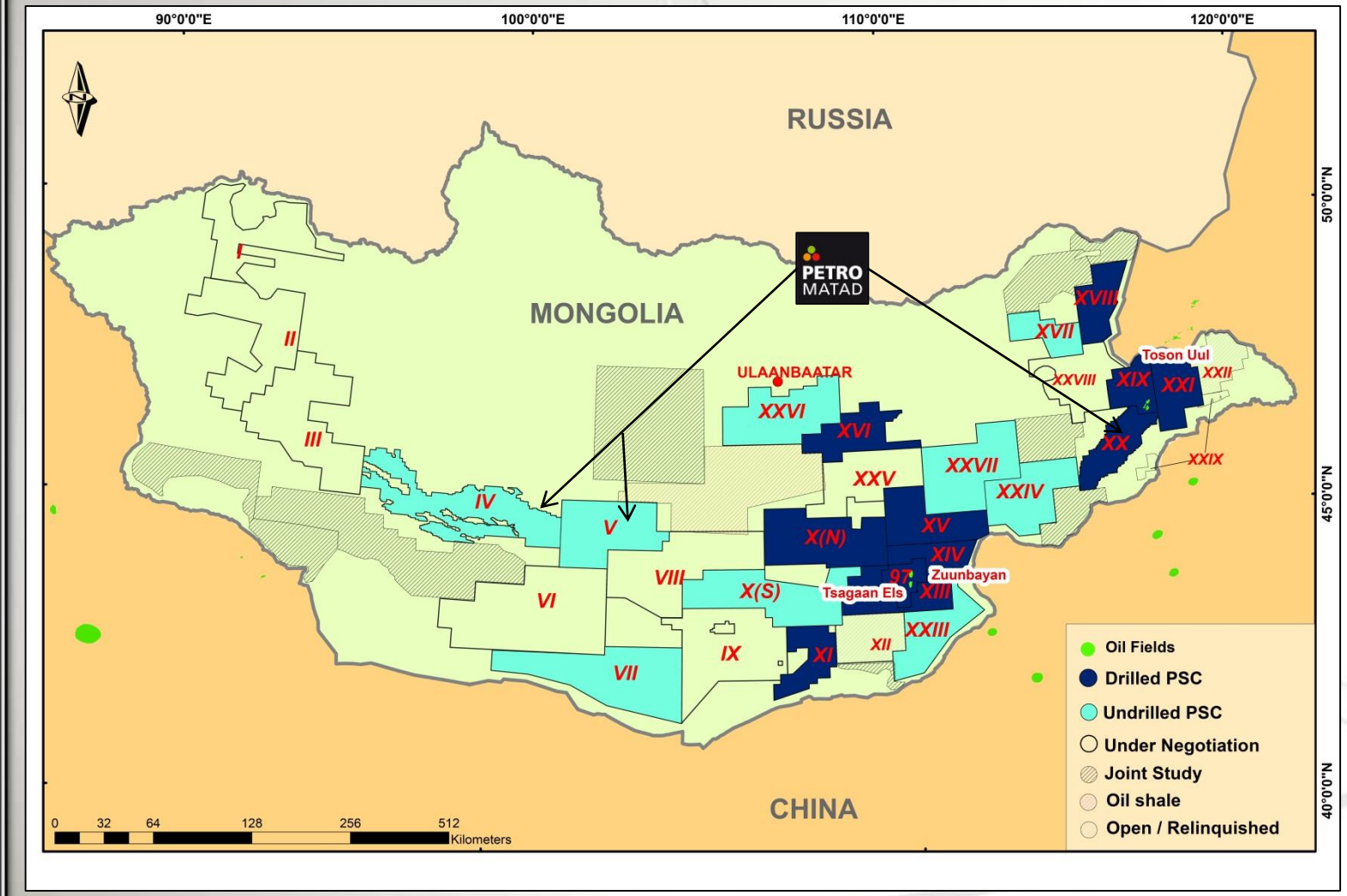
Snow Leopard comes to visit

Ghengis Khan

Mongolia - a Developing Market for Oil and Gas

- Became a democracy in 1990, growth now in double digits
- Coal, copper & gold (Oyu Tolgoi) are the main economic drivers
- Domestic market uses c.25,000 bbls/d of refined products, most imported from Russia
- Current domestic production is c.17,000 bbls/d, all exported to China
- Mongolia is planning a refining sector, to meet growing domestic demand and use domestic production
- Mongolia needs more domestic production and is very under explored
- Investment climate being helped by new Investment & Petroleum Laws

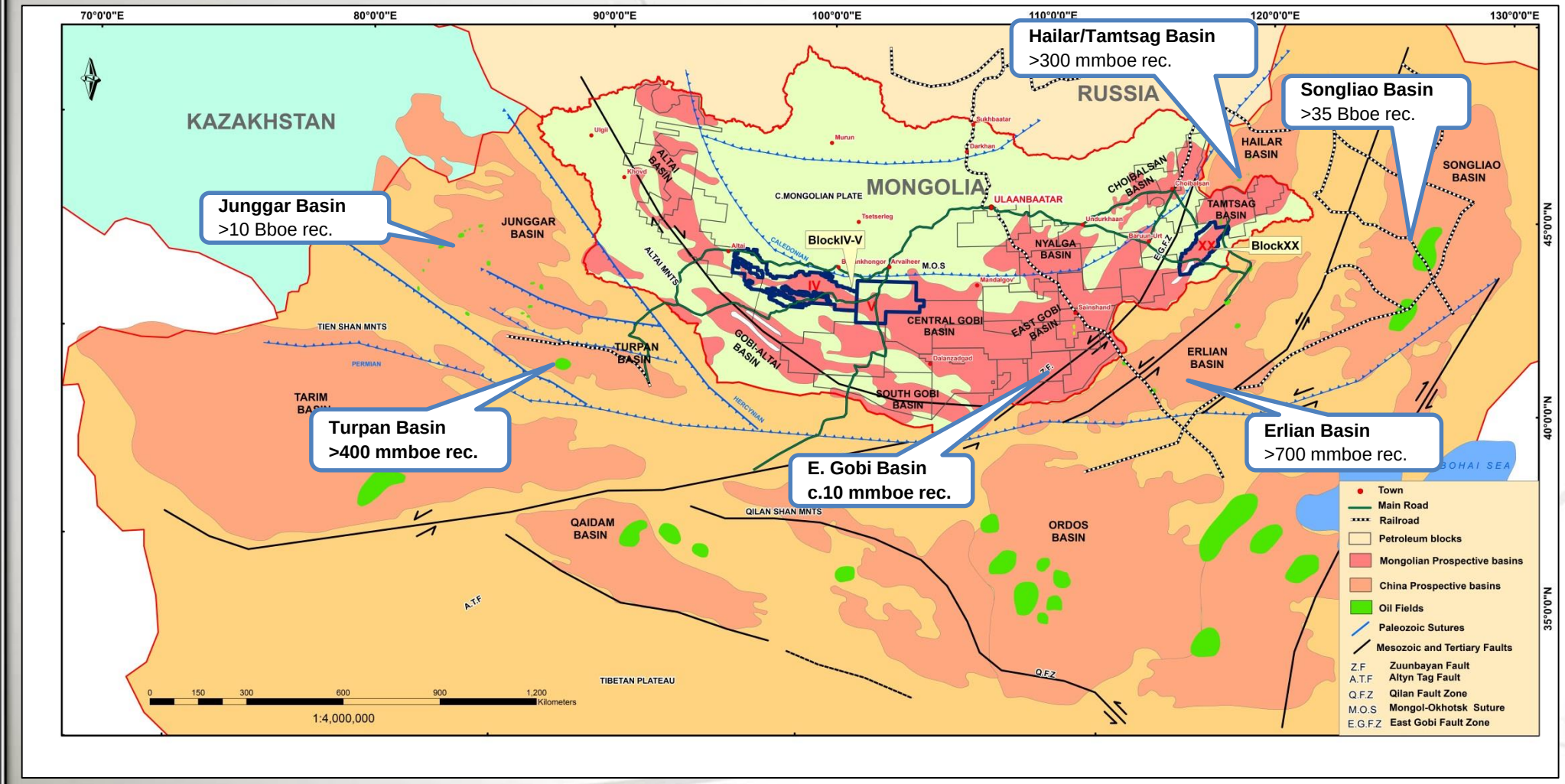
Current PSC's - Mongolia



- Currently c.290,000km^2 licensed & c.240,000kms^2 are pending or open.
- 14 companies have an interest, but most small or inactive.
- Most PSC areas sparsely or undrilled.
- Only Petro-China is producing (Block XIX & XXI) with Petro Matad the most active frontier explorer, with 100% in IV, V & XX.
- Most production from Blocks XIX & XXI, eastern Mongolia (Toson Uul). Small production from SE of country, Tsagaan Els & Zuunbayan, discovered in the 1940's (Block 97).

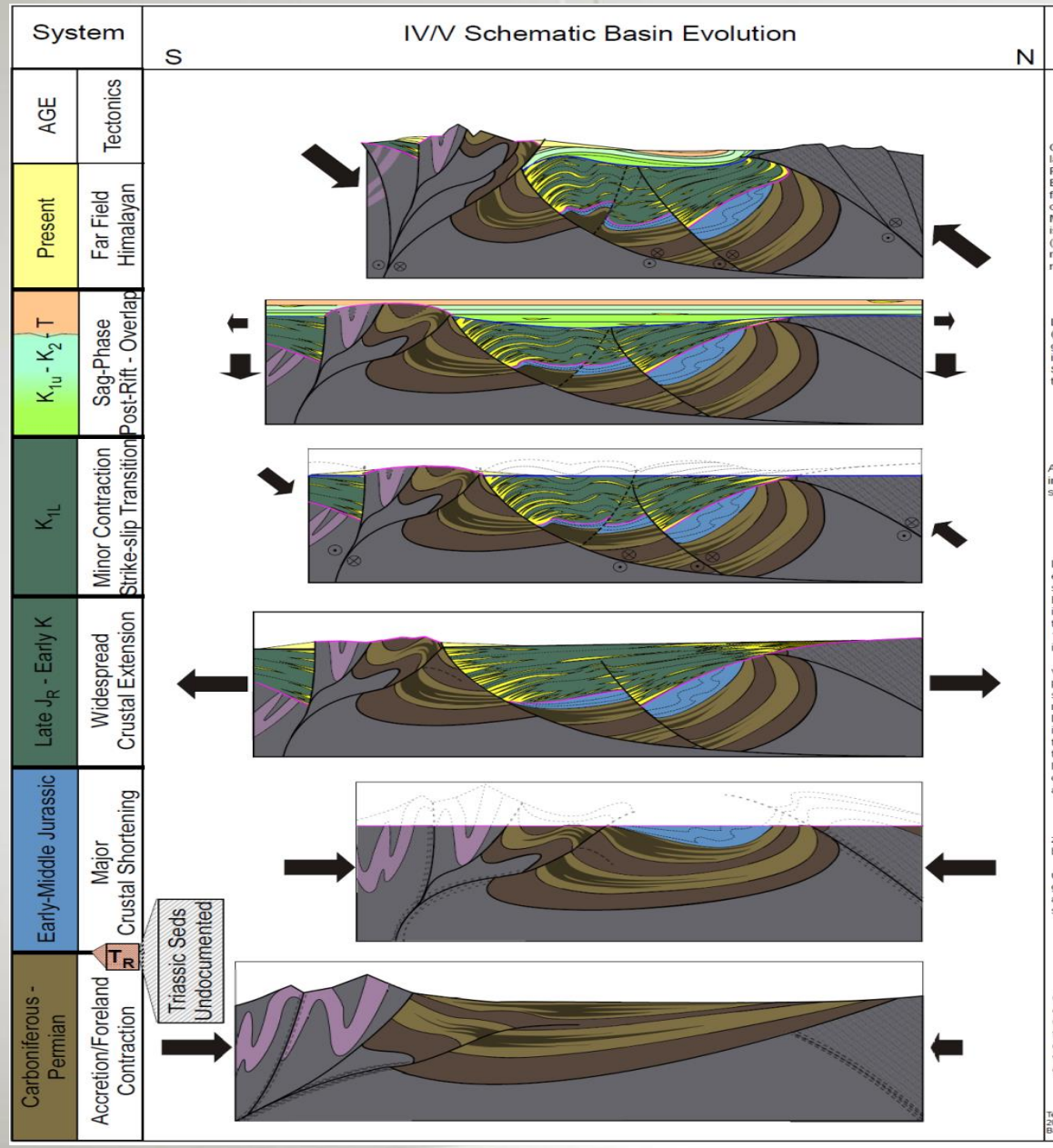
Sedimentary Basins of Mongolia

Plus Analogue Basins in China



- Mongolian basins analogous to Chinese basins, all of which contain commercial hydrocarbons.
- Toson Uul area, Block XIX & XXI, has >2 Bbbls OOIP.
- All Mongolian fields produce from U. Jur – L Cret 'Syn-Rift'.
- Chinese fields produce from this, plus the mainly Permian 'Pre-Rift'.

Tectonic Evolution Blocks IV & V



Ca. ~20 Ma continent-continent collision of India with the Asian landmass brought far-field deformation to Mongolian systems. Regionally this collision event has been accommodated through ESE directed tectonic escape along lithospheric scale strike-slip fault systems, reactivating boundaries and fabrics inherited during Paleozoic continental assembly.
Mongolia represents the northern limit of tectonic escape and is dominated by sinistral strike-slip systems. In Blocks IV&V (Central Mongolia) the deformation is largely in a transpressive regime with large restraining bend ranges overthrusting the margins of Cretaceous rift & intra-montane basins.

Late Early Cretaceous time records the thermal subsidence (Sag-Phase) of rifting and displays a typical "steers-head" geometry where it has not distrupted/eroded by recent uplift and inversion.
Sag-Phase subsidence is then followed by late K - Oligocene terrestrial overlap of fluvial/alluvial sequences.

A minor contractional even is recorded during late Early K time in the form of a regional angular unconformity separating the syn and post rift sequences.

Latest Jurassic-Early Cretaceous time saw widespread extensional tectonics in the form of discontinuous rift basin systems spanning ~3,000km of the central Asian landmass. Extensive magmatism is observed at the onset of rifting in all the basin sequences and occurs intermittently throughout the successions. Basin fill is largely fluvio- lacustrine derived, 1-5km thick and comprised of moderate-rich organic shales intercalated with porous sandstone assemblages.
The massive region affected by extension tectonics and the voluminous magmatic activity suggests lithospheric scale processes and large-scale elevated heatflow. Meng et al. 2003 suggest that the rapid (~10Ma) transition to an extensional regime, following the severe crustal thickening event of the Middle Jurassic, is not adequately explained by geothermal insulation heating; a process requiring typically 30-40Ma to initiate rift tectonics. Thus, another mechanism is necessary to explain the sequence of events. Meng et al support an hypothesis of detachment of the subducted Mongol-Okhotsk ocean slab, allowing accelerated asthenospheric interaction and eventual foundering and flow of the lower lithosphere.

Triassic strata have been documented, in literature, to have a zero edge south of the contract area of Blocks IV & V. Triassic basalt has been dated in Petro Matad core in Block V.
In Middle Jurassic time considerable crustal contraction, uplift and erosion of some 5km of section is recorded across the greater Mongolia-China Boarder region. This event is observed as a considerable angular unconformity seen in outcrop and seismic underlying the Late Mesozoic lacustrine basin fill.

Carboniferous though Permian time accommodated docking and accretion of the Mongolian continental lithosphere. Closure of paleo-ocean basins and transition to continental foreland basin style sedimentation. Strong contractional deformation is recorded in these sedimentary successions which exhibit extensive organic shale and clastic depositional environments.

Tectonics of the late Mesozoic wide extensional basin system in the China-Mongolia border region. 2003. Qing-Ren Meng,n Jian-Min Hu,w Jiu-Qiang Jin,z Yan Zhangz and Da-Feng Xuz, Basin Research, Vol. 15, p. 397-415

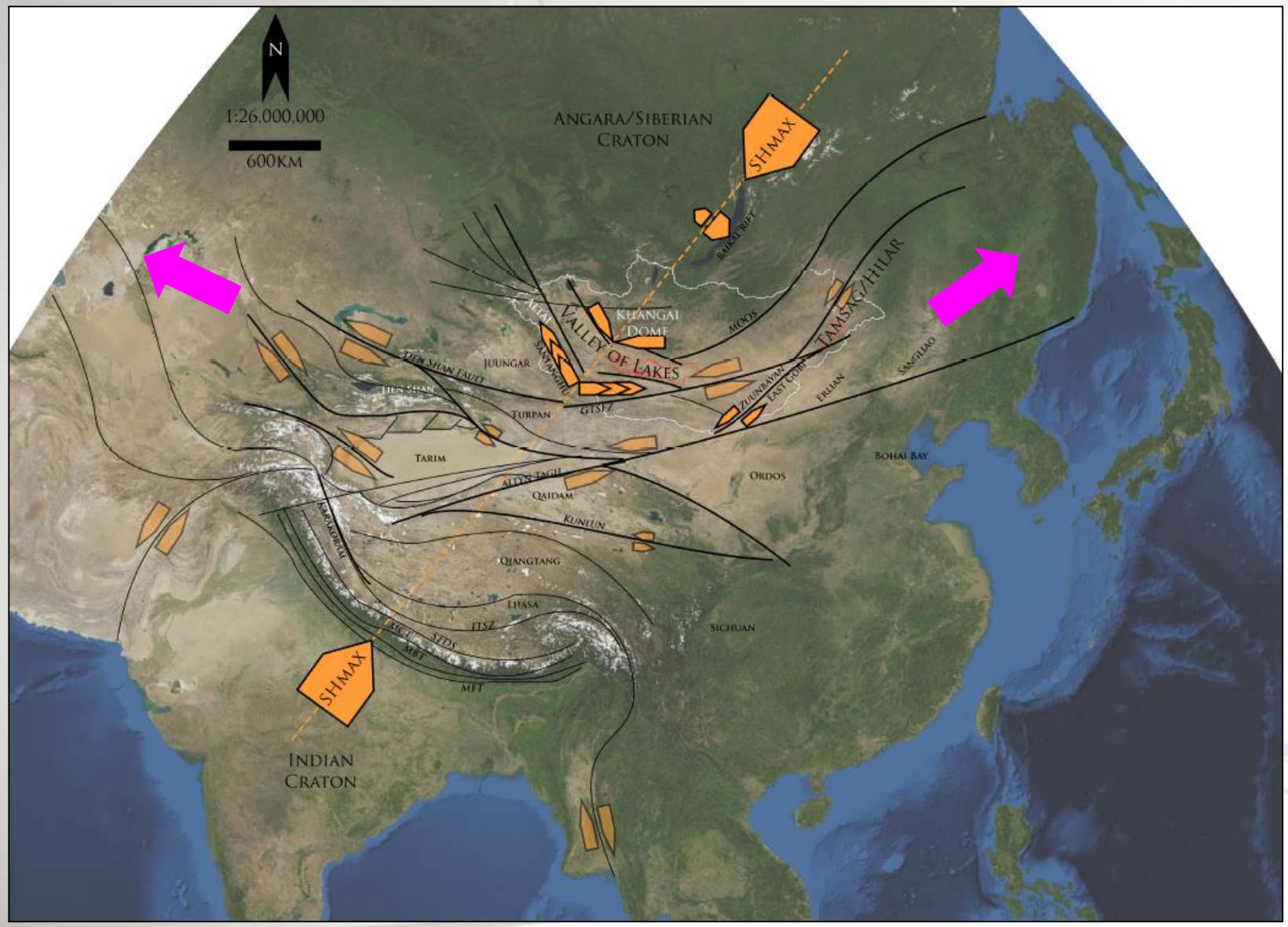
This figure describes the main tectonic events that generated the 3 stratigraphic megasequences and associated bounding hiatuses.

1.Pre-Rift: (E Juras.-Carboniferous)
2.Syn-Rift: (L Juras.-E Cret.)
3.Post-Rift: (Cret.-Recent)

Rift-based terminology has been carried over from numerous publications investigating the structural, stratigraphic and sedimentologic aspects of equivalent sequences throughout the continuous belt of basins and ranges that span >3,000km of the Central Asian continent.

The term "rift", in this case, must be considered at a very broad scale, wherein crustal extension has been distributed across a vast latticework of accreted crustal fragments rather than focused along a discrete lithospheric boundary.

Present Day Tectonic Framework, Central Asia



- NNE collision of India from c.20Ma resulted in tectonic escape and largely sinistral strike-slip systems through our area, becoming dextral to the west. Mongolia represents the northern limit of this system. The regime is predominately transpressive in Blocks IV & V.

- This has resulted in c.800m uplift in basin centres and c.1500m on margins

Regional Petroleum Geology

Megasequence 1: Permo-Carboniferous - Jurassic 'Pre-Rift'

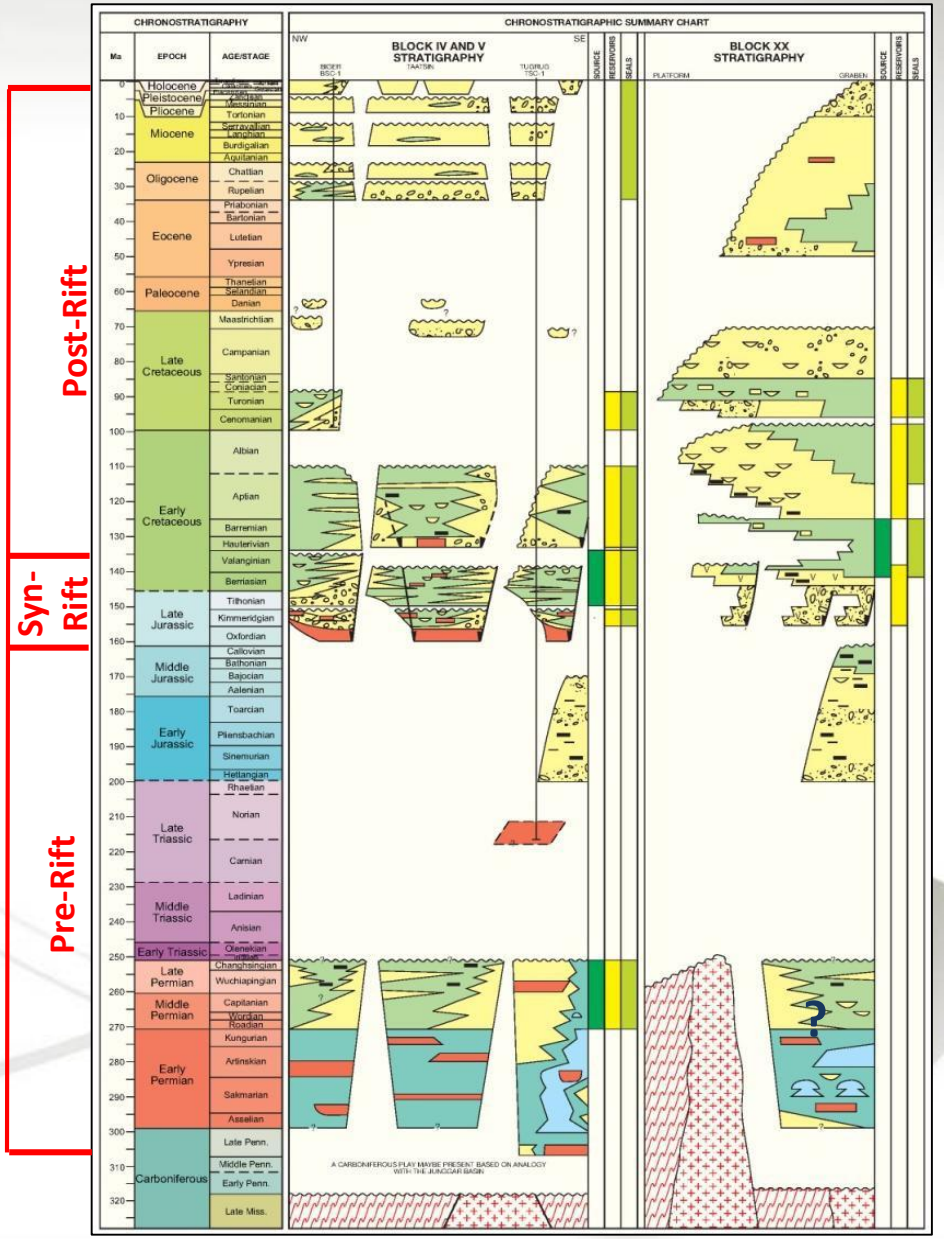
- Transitional marine–continental facies following closure of Palaeo-Tethys Ocean – compressional tectonics
- Lithology = Limestones overlain by coals and clastics
- Major oil & gas play in Chinese basins (eg Junggar, Tarim, Turpan), unproven in Mongolia so far

- **Megasequence 2: L. Jurassic-E. Cretaceous 'Syn-Rift'**

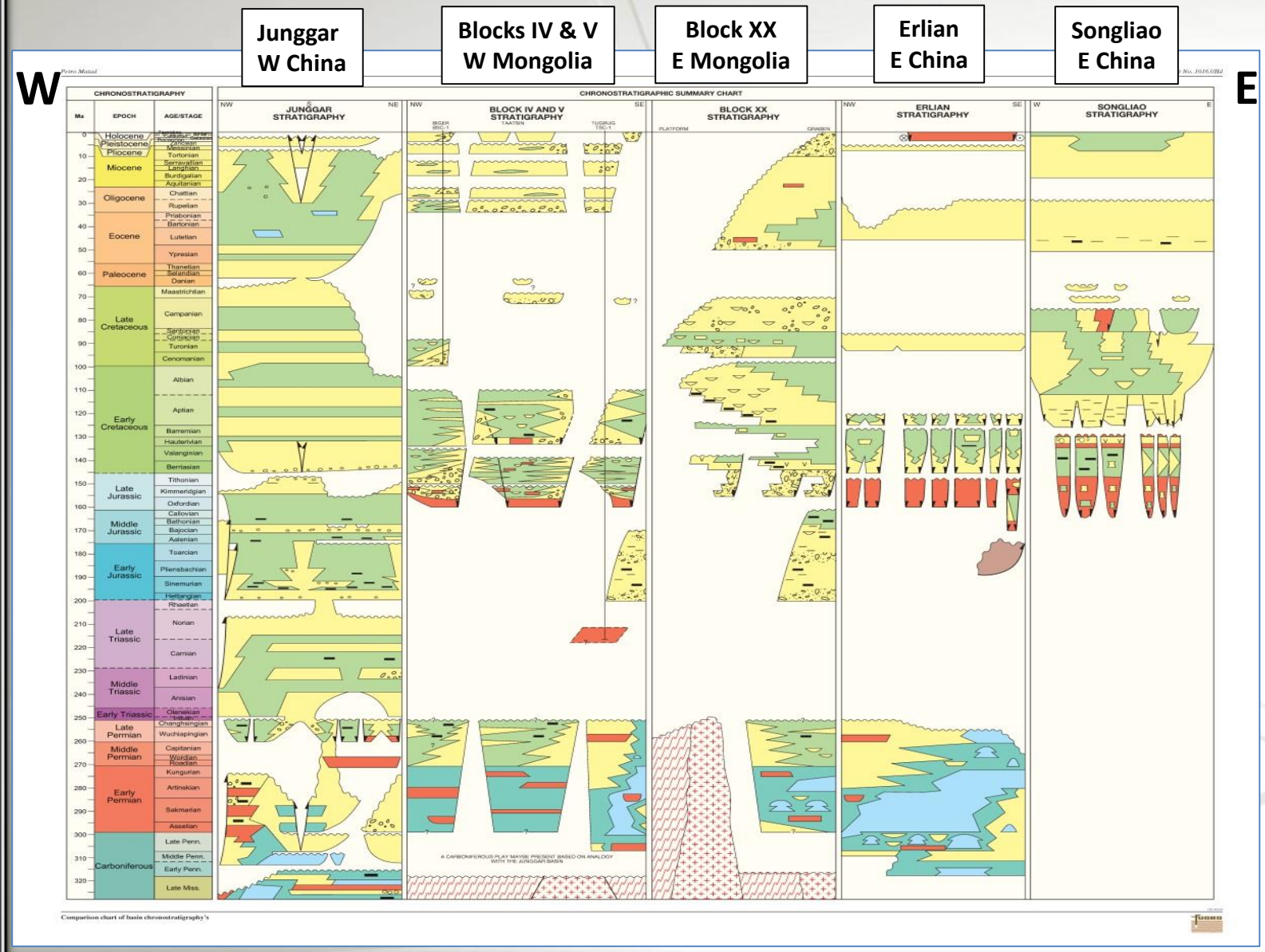
- Major u/c on Pre-Rift, extensional & strike slip tectonics
- Lithology = interbedded fluvio-lacustrine shales and sandstones
- Major oil & gas play in Chinese Basins (eg Songliao, Erlian), and proven play in Mongolia

- **Megasequence 3: L. Cretaceous – Recent 'Post-Rift'**

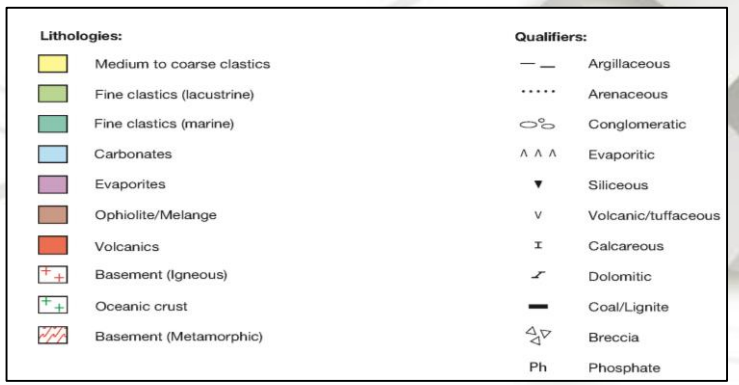
- Post-rift sag, overprinted with Himalayan compressional & strike-slip tectonics
- Lithology = fluvial-lacustrine/alluvial shales and sandstones
- Unproven oil & gas potential in Mongolia, limited in China



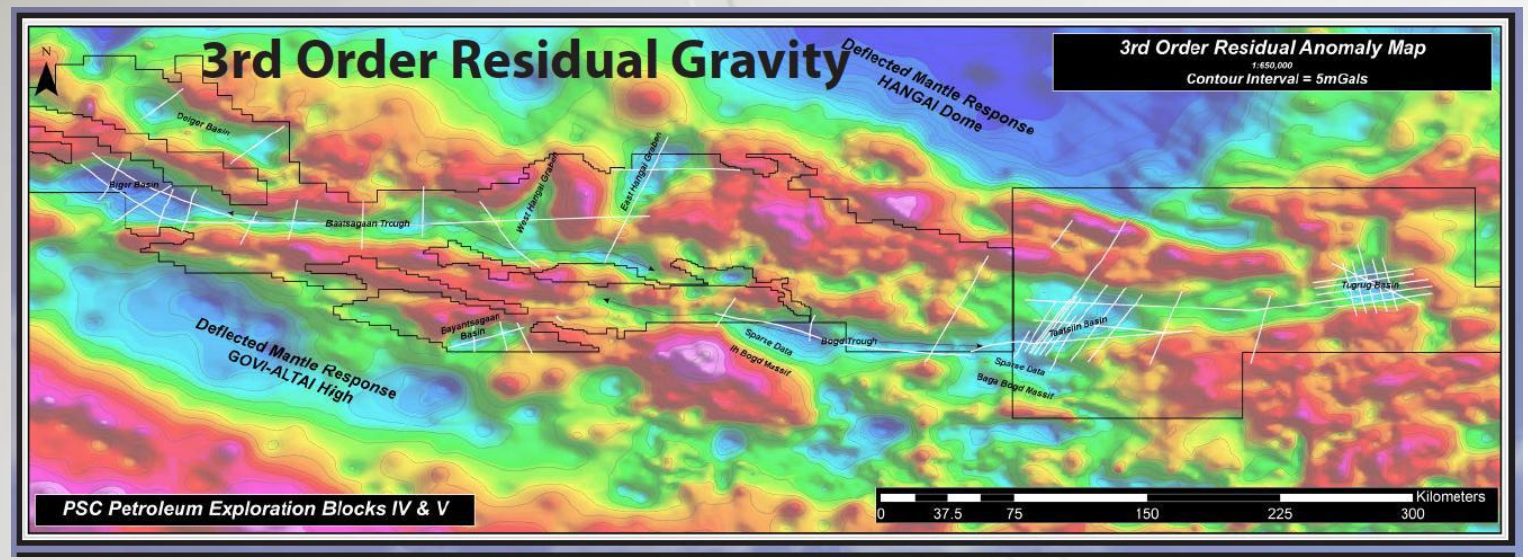
Analogue Basins – China vs Mongolia

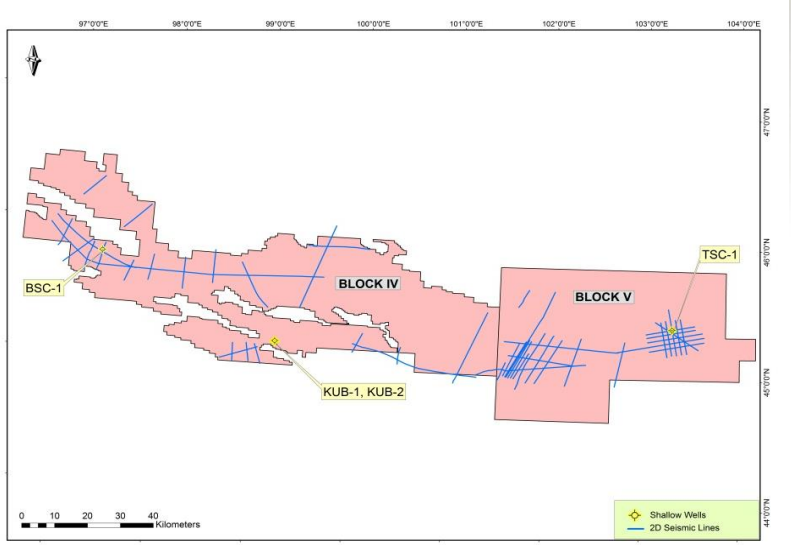


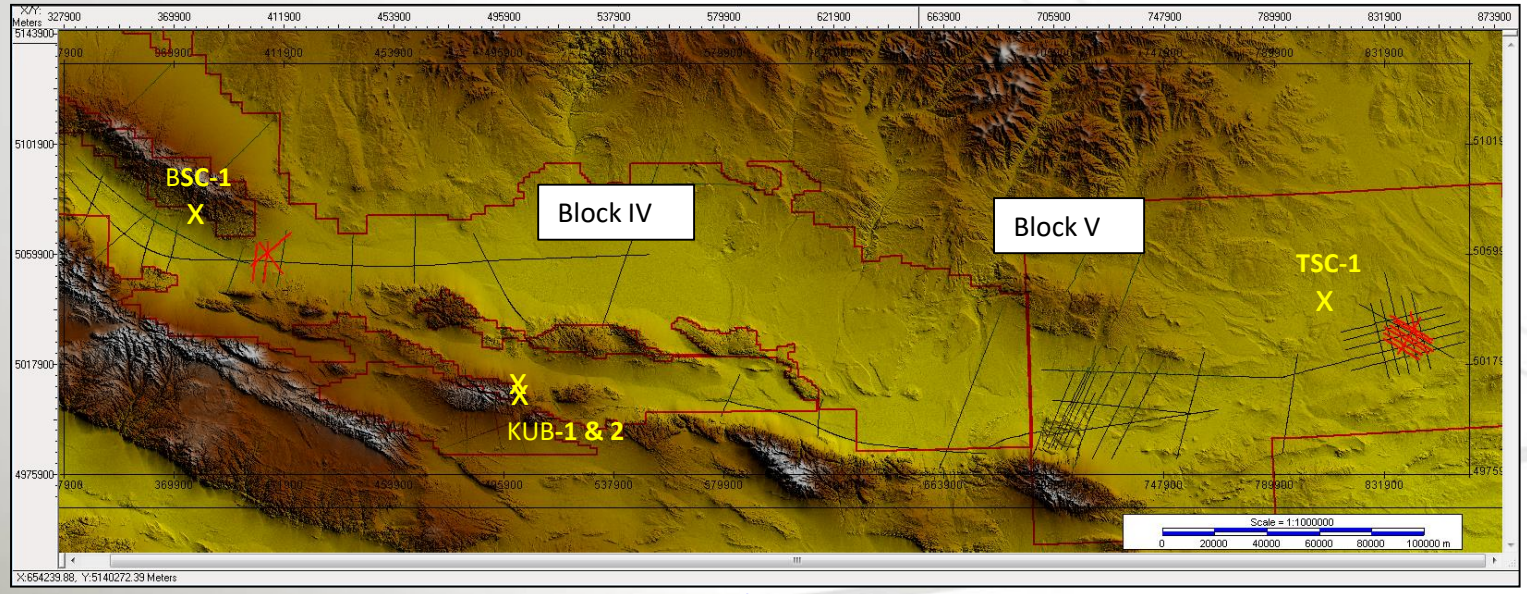
- The productive Syn-Rift megasequence of China's Songliao & Erlian basins is repeated across Mongolian Basins.
- The Pre-Rift Megasequence so productive in China's foreland basins of Junggar , Turpan & Tarim is present in western Mongolian Basins, although not as well developed.
- ALL Chinese analogue basins that have had significant exploration are proven producers.



Residual Gravity, Seismic & Wells – Blocks IV & V



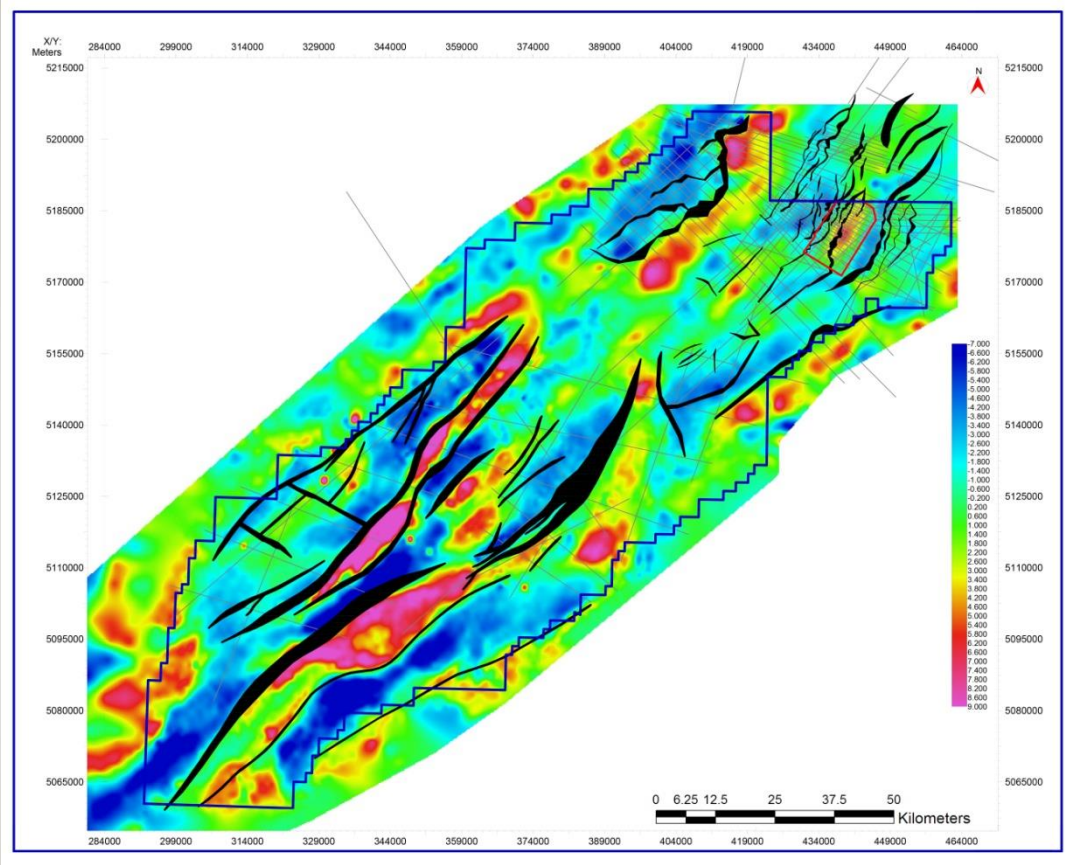


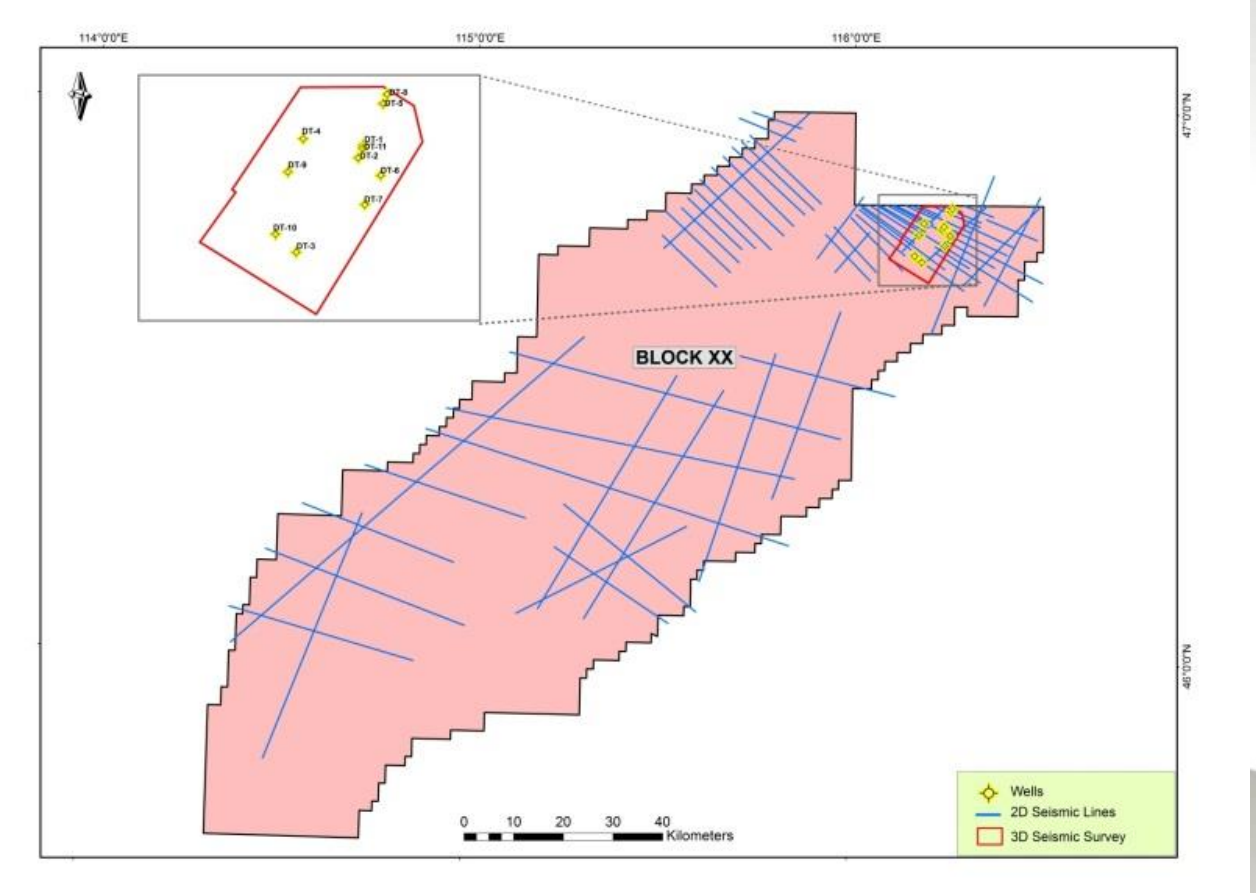


c.500kms

- 2660kms of 2D,
- 4 stratigraphic boreholes

Residual Gravity, Seismic & Wells – Block XX





- 3510kms of 2D
- 133km^2 of 3D
- 11 wells on Davsan Tolgoi

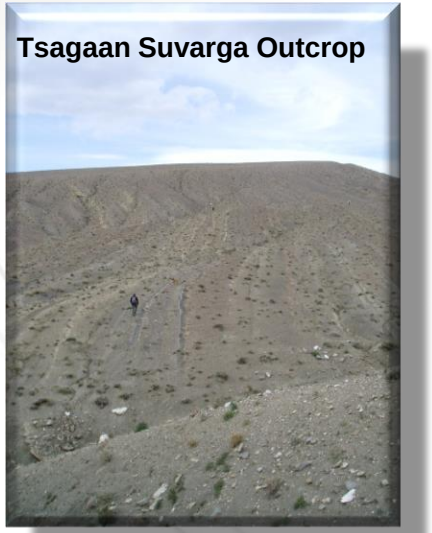
Petroleum System Elements (data from Blocks IV & V)

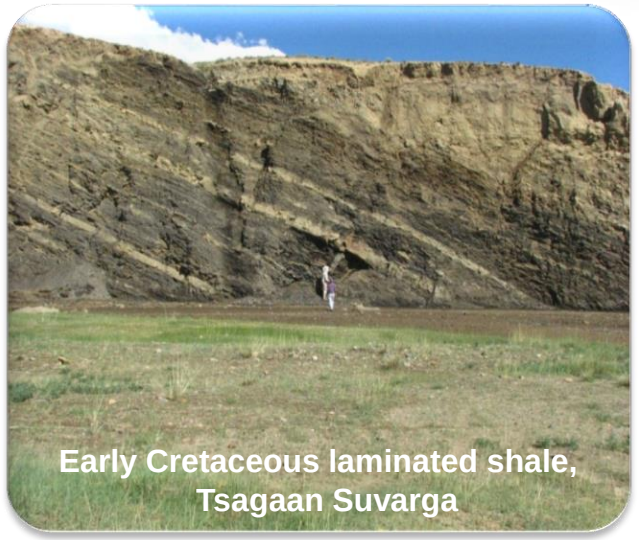
4 field seasons (2010-2013) , 4 stratigraphic boreholes with c.3500m of core & >6000kms of 2D over frontier areas have resulted in a new understanding of the potential petroleum system in frontier areas

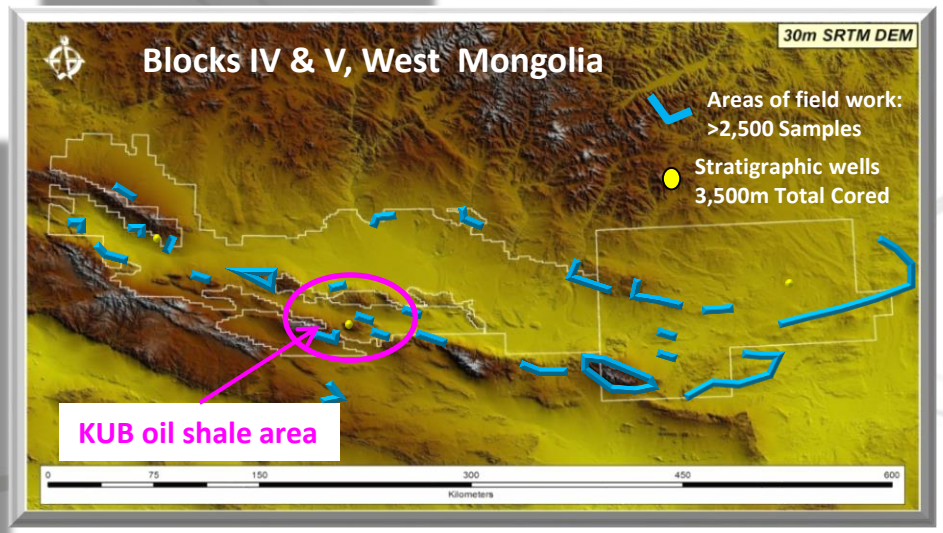
SOURCE

Thick rich world class lacustrine oil shale was sampled from outcrops:

- ***Up to 900m net shale (Tsagaan Suvarga oil shales)***
- ***Tith.-Val. age (early Syn-Rift)***
- ***3-27% TOC, ave 15.1% TOC (72 samples - KUB)***
- ***Type I & II, max HI = 800-900***
- ***c.0.6 VRo% at outcrop***
- ***Potential for oil shale development***
- ***Basin modelling indicates extensive generation potential in subsurface***





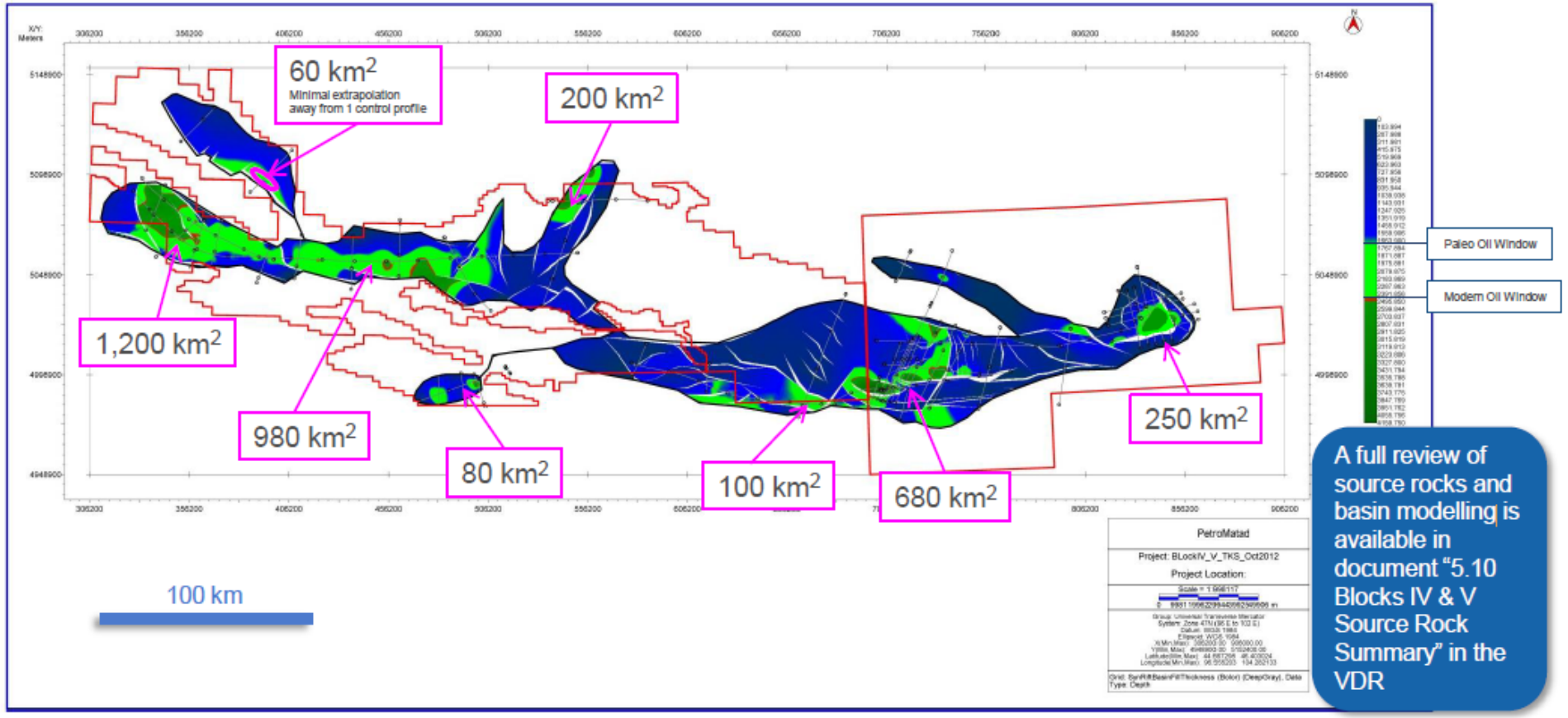


Cored Oil Shale, Block V

Source Kitchens – Syn-Rift, Blocks IV & V)

Total area of mature SR1 is c.3,550km^2 (approx 20% of total prospective area)

- Basin fill isopach, surface to average first Syn Rift source rock (~300m above Pre Rift top)
- The 1,600m contour (light green) is modelled to be approx top of paleo-oil window (TR>10% - see modelling)
- Areas covered by green were in the oil window from Early-mid Cretaceous
- Total Post Rift erosion is uncertain, regional estimates suggest modern generation below ~2,500m MD (Dark Green)

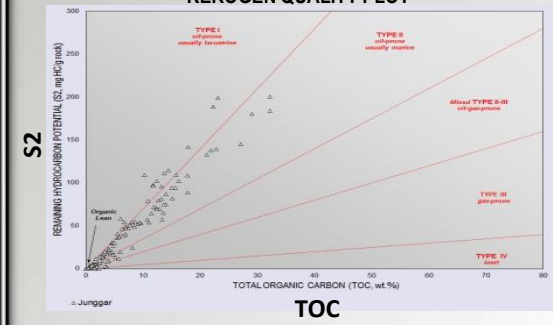


A full review of source rocks and basin modelling is available in document "5.10 Blocks IV & V Source Rock Summary" in the VDR

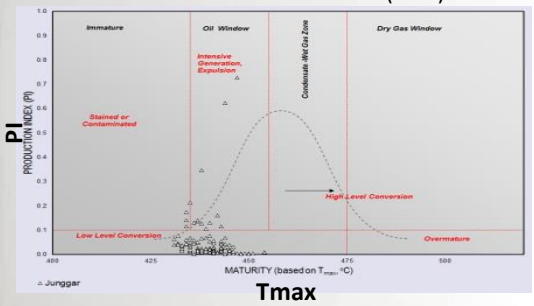
Overview of Source Potential of the Pre-Rift Petroleum System, South Western Mongolia

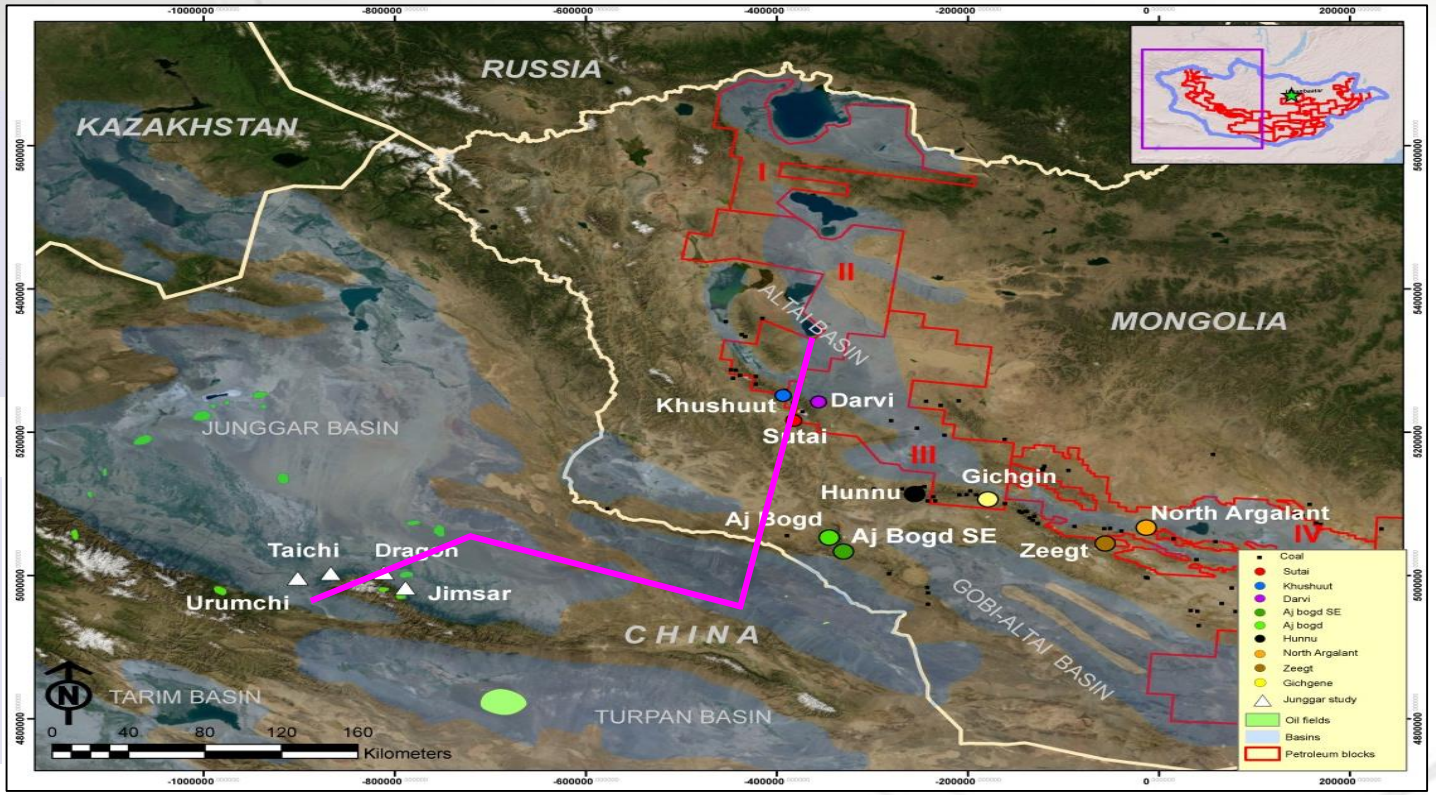
Geochemical analysis of Junggar Basin (Carroll et al., 1992 and Tao et al., 2012)

KEROGEN QUALITY PLOT



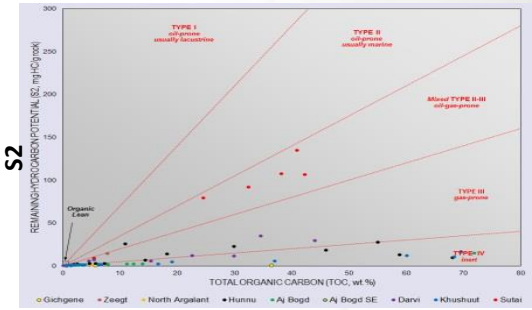
KEROGEN CONVERSION AND MATURITY (Tmax)



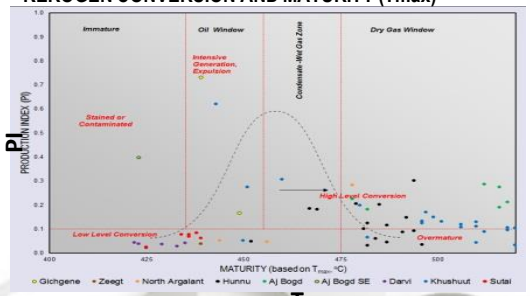


Geochemical analysis of this study

KEROGEN QUALITY PLOT

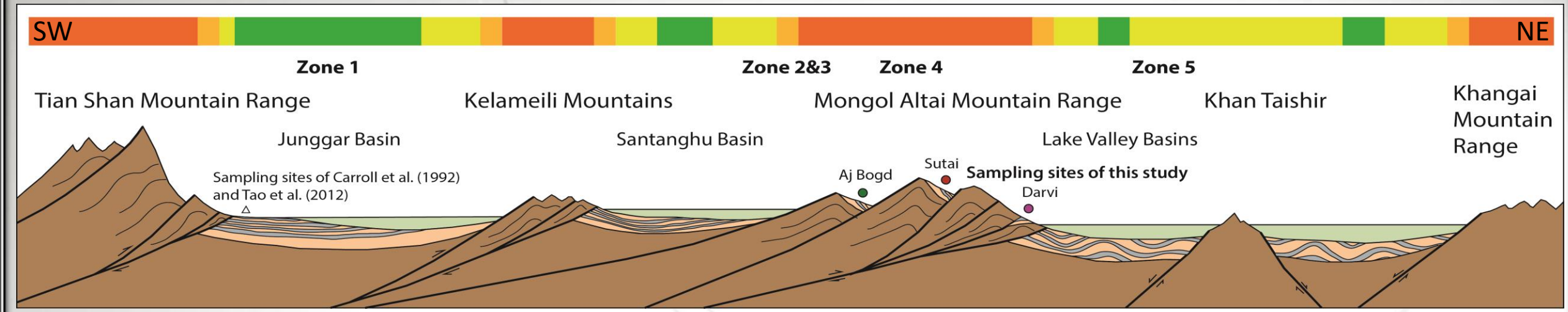


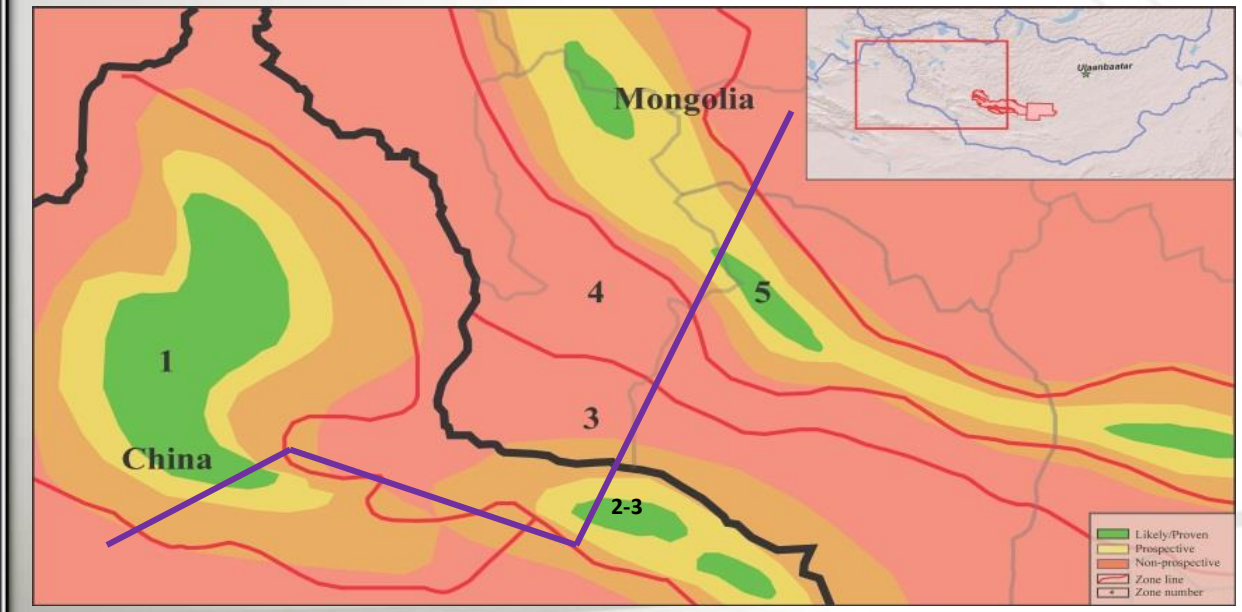
KEROGEN CONVERSION AND MATURITY (Tmax)



- **Good quality oil-gas prone source rocks were found**, although many samples were lean
- **Mature source rocks were found**. Although many samples were overmature in the fold & thrust belt and some immature
- **High quality source rocks generating oil are very possible below the Mesozoic basins in Southwestern Mongolia.**
- **This sample set represents only initial scoping efforts. Positive results justify further examination of many additional exposures across a vast region of southwestern Mongolia.**

Overview of Source Potential of the Pre-Rift Petroleum System, South Western Mongolia





- Petroliferous Paleozoic basin fill thins regionally from the productive Junggar Basin northeastward to the productive Santanghu Basin.
- Across the Mongol Altai Range the Pz section thickens NE into the Mongolian Lake Zone with evidence of quality SR development (from coal studies)
- Upper Permian rocks were sampled from the highly faulted mountainous outcrops. Tectonic preservation of these sections are expected to be more favourable (less disrupted) in the basin centre

Petroleum System Elements (data from Blocks IV & V)

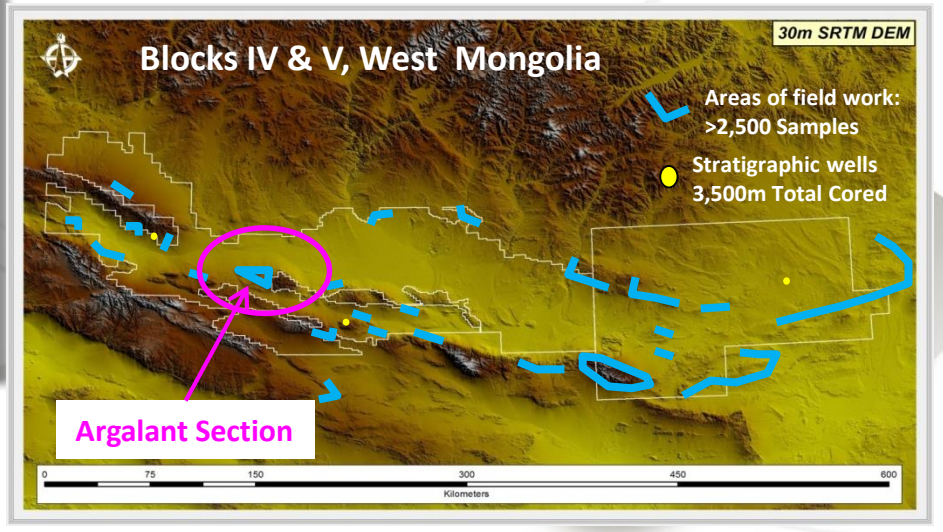
RESERVOIR

High porosity fluvial-deltaic sands extensive in outcrops.

- ***10-30% porosity***
- ***Tith.-Val. age (early Syn-Rift)***
- ***Often interbedded with source rocks***
- ***Clean granitic source***
- ***Laterally continuous***

Distributary channel sandstones - upper delta top deposits of Early Cretaceous Shinhudag Fm, TSH subsection. Original porosities range from 19-26%

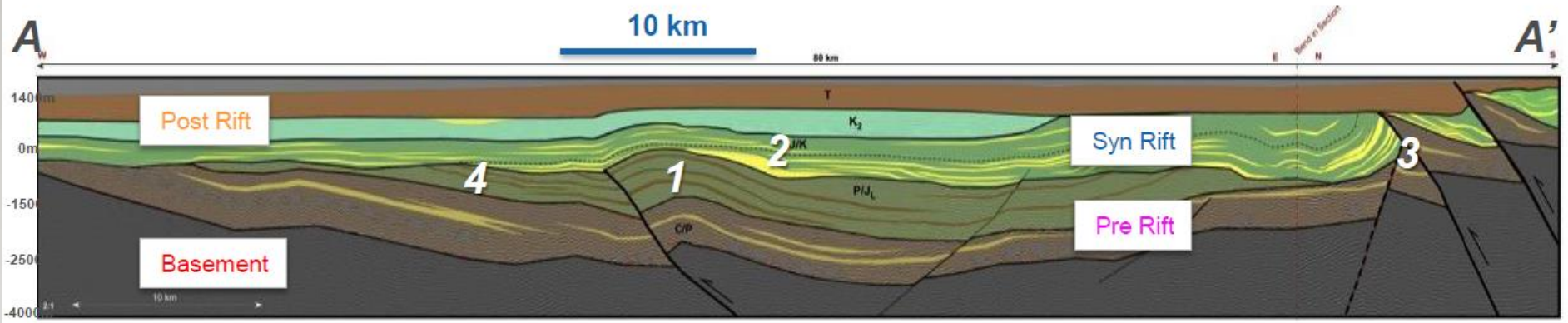
Syn-Rift lacustrine sandstones, Argalant section

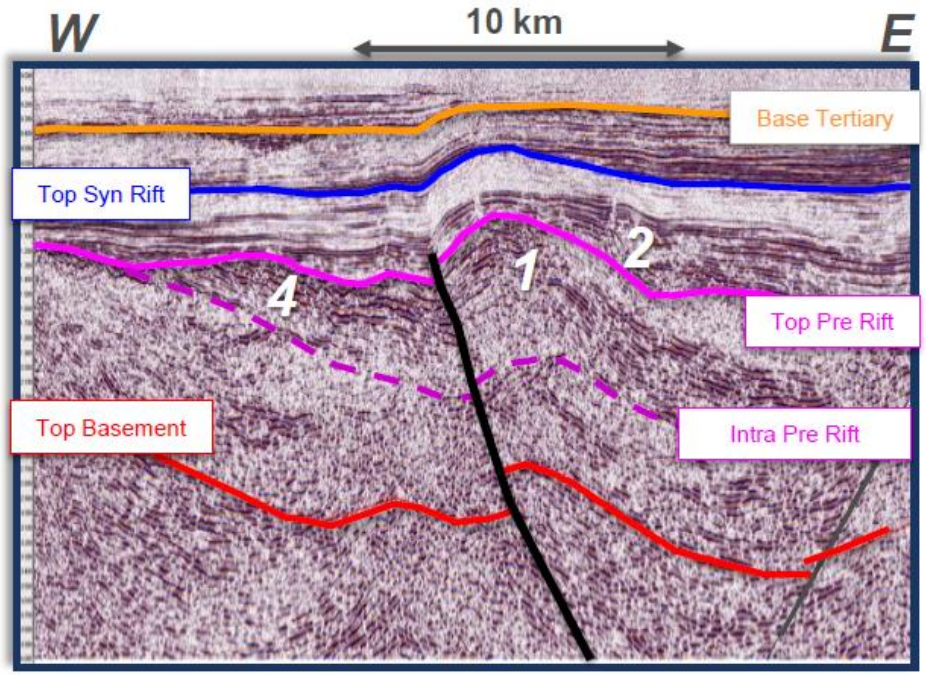


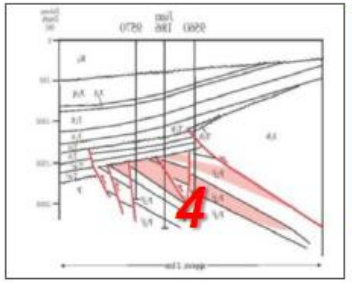
SEALS

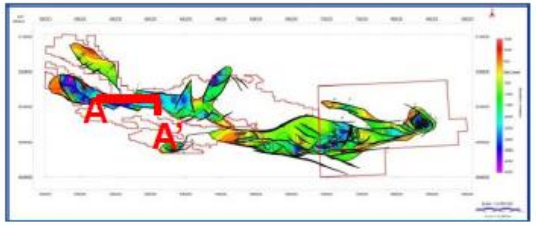
- ***Proven reservoirs sealed by intra-formational shales***

PLAY CONCEPTS
BAATSAAGAN BASIN, CENTRAL BLOCK IV





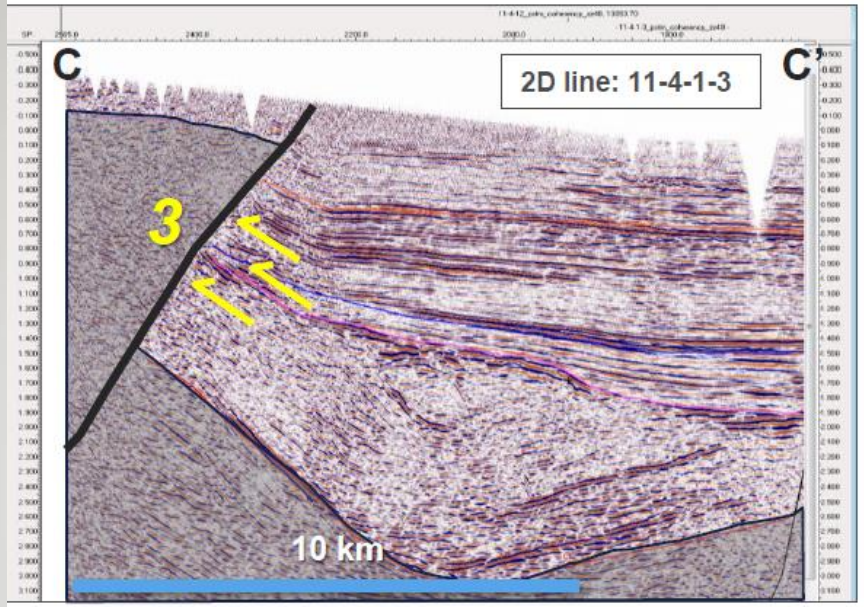




PLAY TYPES

1. **Inversion anticlines**
2. **Combination: Stratigraphic-Structural**
3. Sub-Thrust traps
4. **Sub-Unconformity play**
5. Structural Traps (e.g. tilted fault blocks, pop-ups)
6. Stratigraphic

PLAY CONCEPTS
BIGER BASIN, WESTERN BLOCK IV



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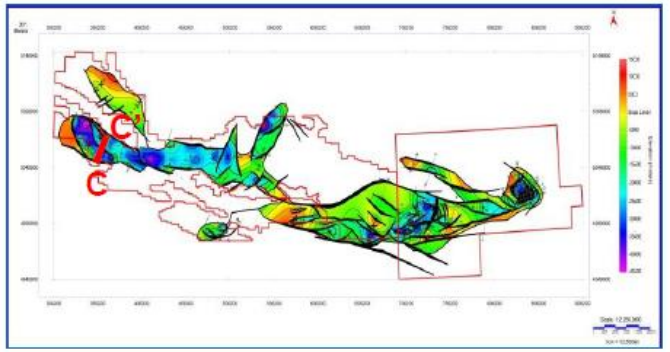


- Sub-thrust/reverse fault play, sealed by thrust plane or Basement
- Stacked reservoir objectives throughout Pre-Rift & Syn-Rift
- Local Pre-Rift source rocks, adjacent to kitchen
- Analogous to discoveries in Junggar Basin, NW China
- Age of trap: Neogene-Recent
- Proven in Junggar – see: Zhijun Jin et al, 2008, Bull AAPG, V92, no. 9, P1225-1243

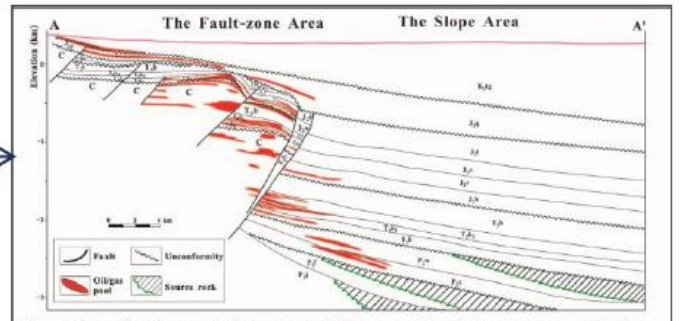
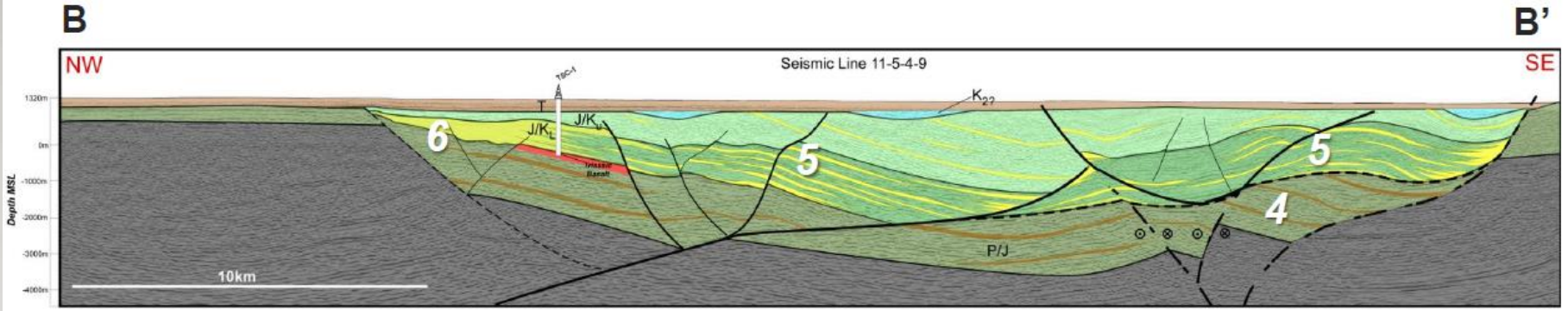
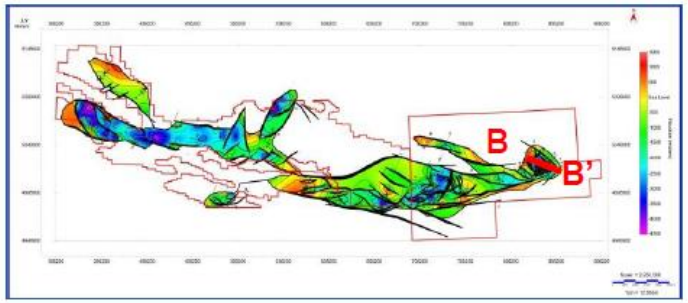


Figure 3. Cross section AA' represents the fault-controlled tectonic framework and its relation to hydrocarbon accumulation (Zhang and Wang, 2000). Courtesy of the PetroChina Xinjiang Oilfield Company. See Figure 1 for the location.

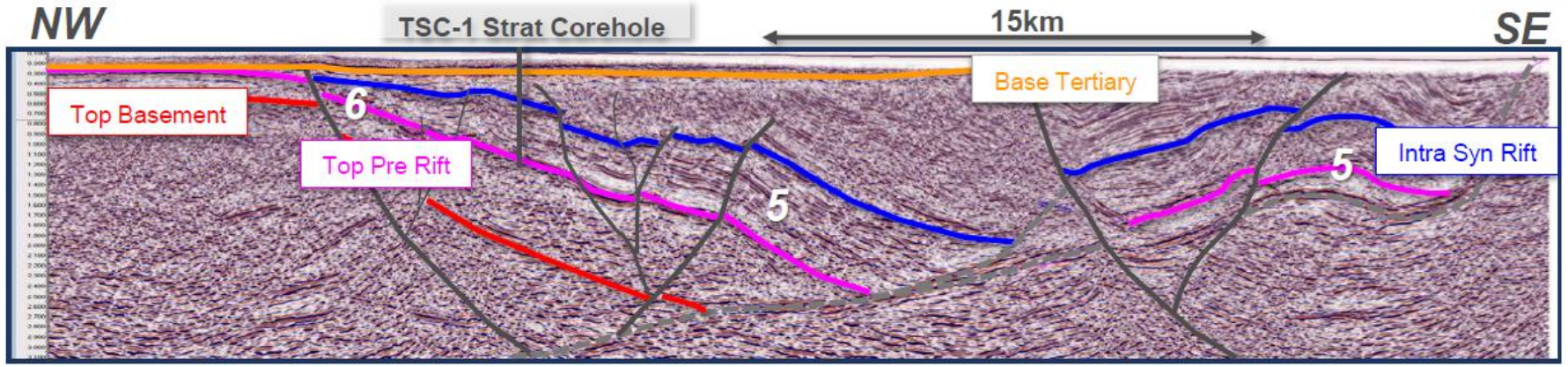
PLAY CONCEPTS
TUGRUG BASIN, EASTERN BLOCK V





PLAY TYPES

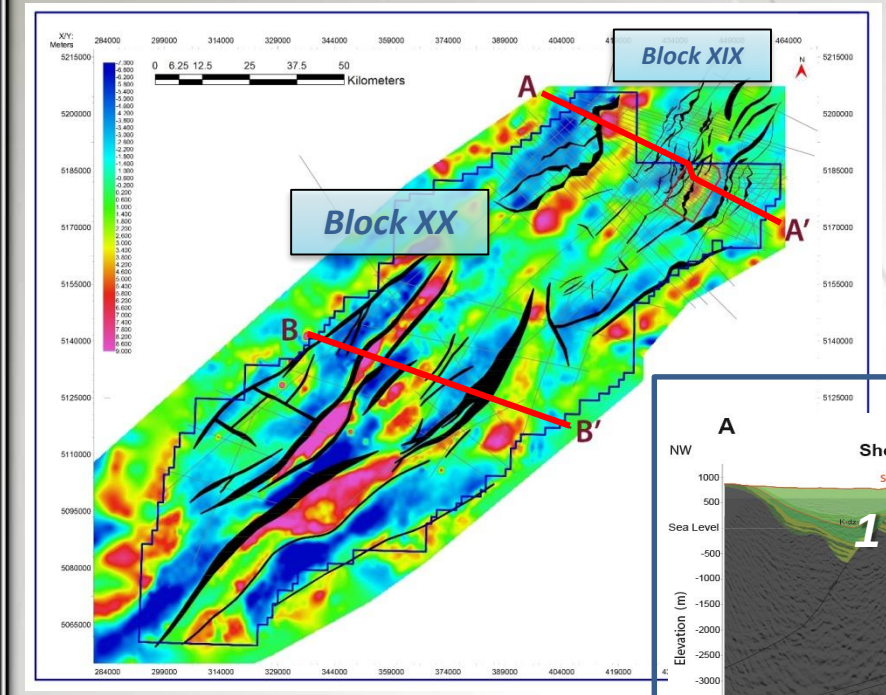
1. Inversion anticlines
2. Combination: Stratigraphic-Structural
3. Sub-Thrust traps
4. Sub-Unconformity play
5. **Structural Traps (e.g. tilted fault blocks, pop-ups)**
6. **Stratigraphic**

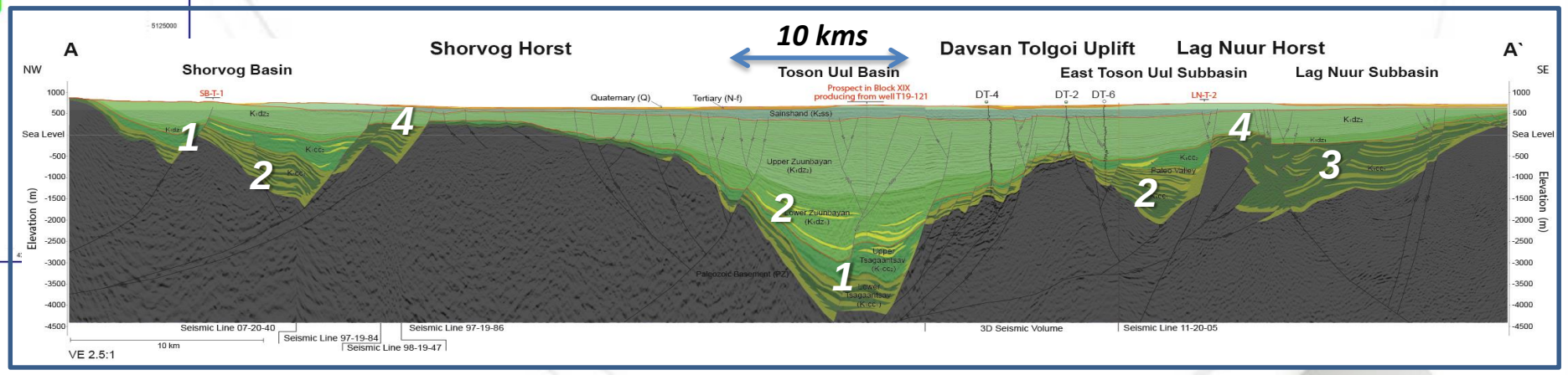


Play Concepts

Seismic Examples from Block XX

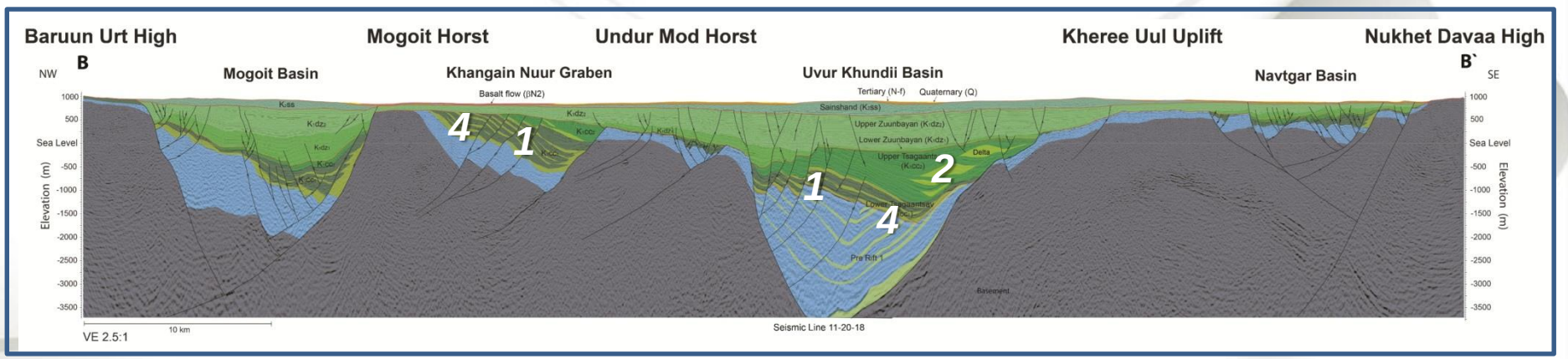
- Block XX analogues to proven play types from Blocks XIX and XXI and the adjacent Chinese basins (Erlian/Songliao etc.)





1) *Tilted Fault Blocks*
2) *Stratigraphic Traps*
3) *Thrust Truncations*
4) *Unconformity traps*

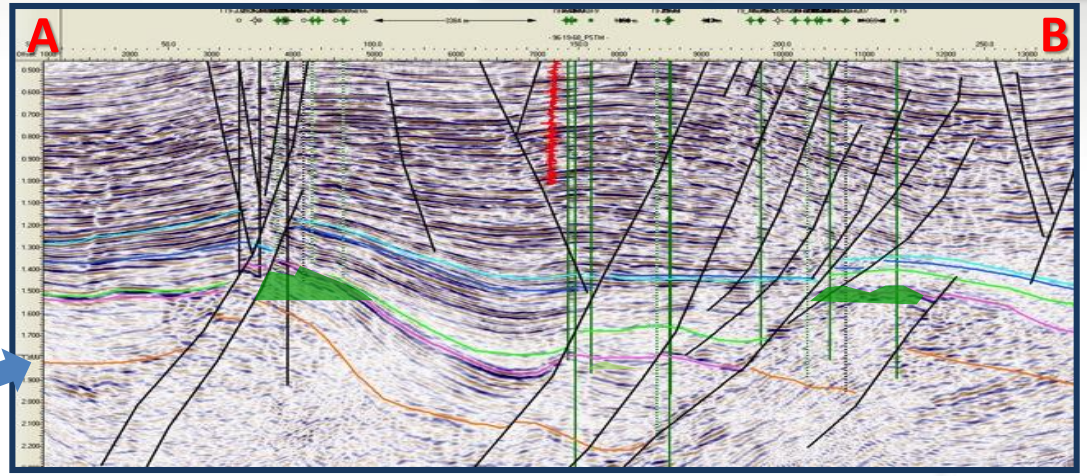
(and combinations thereof)

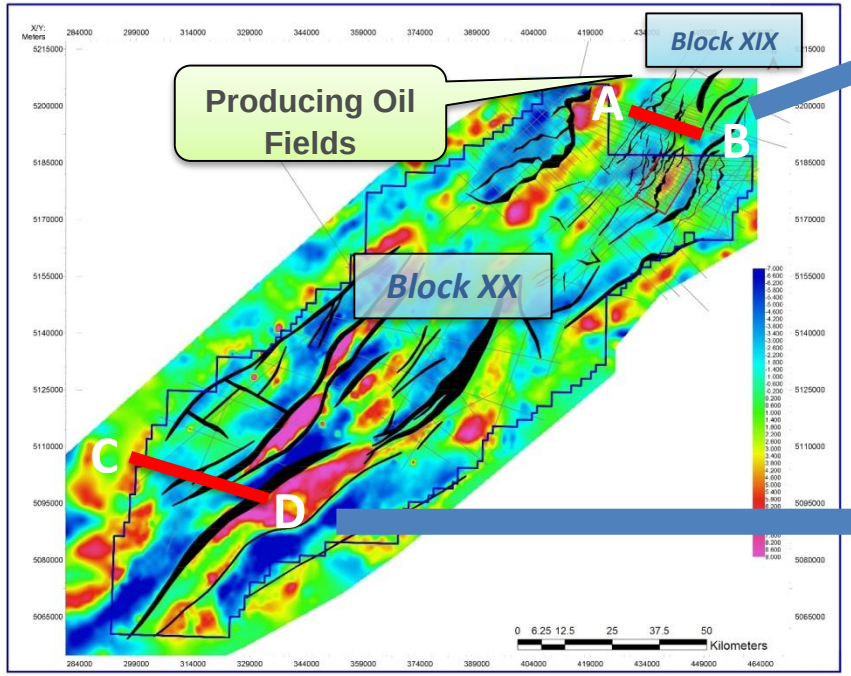


Block XIX - Producing Analogue

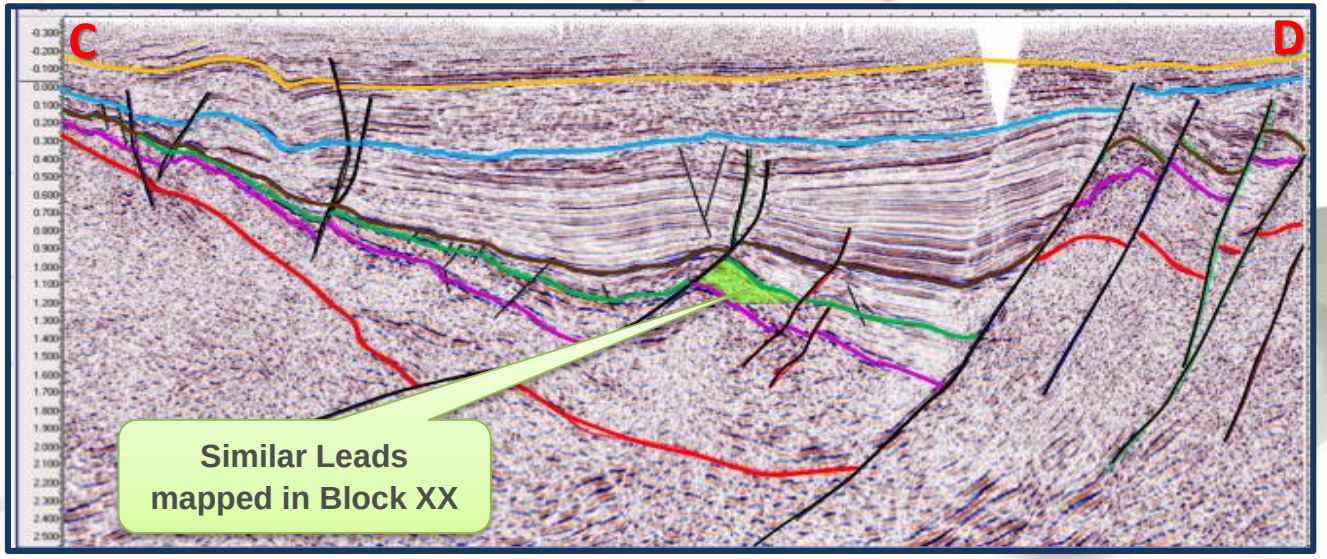
5 km

Toson Uul Sub-Basin – Petro-China operated





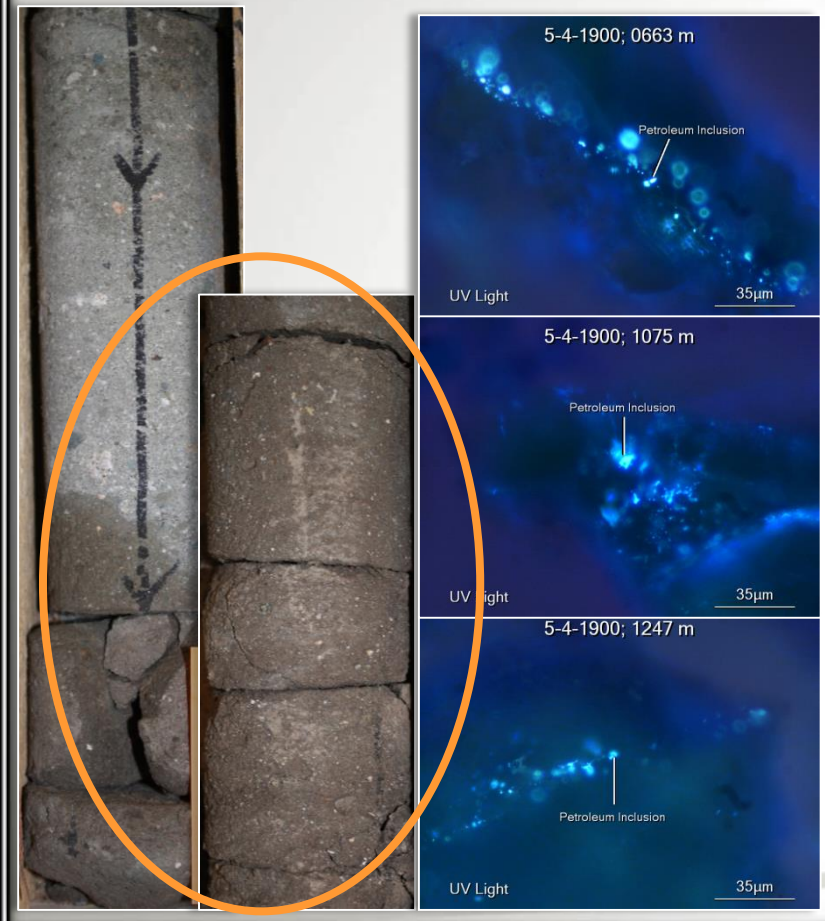
10 km



Direct Hydrocarbon Indicators

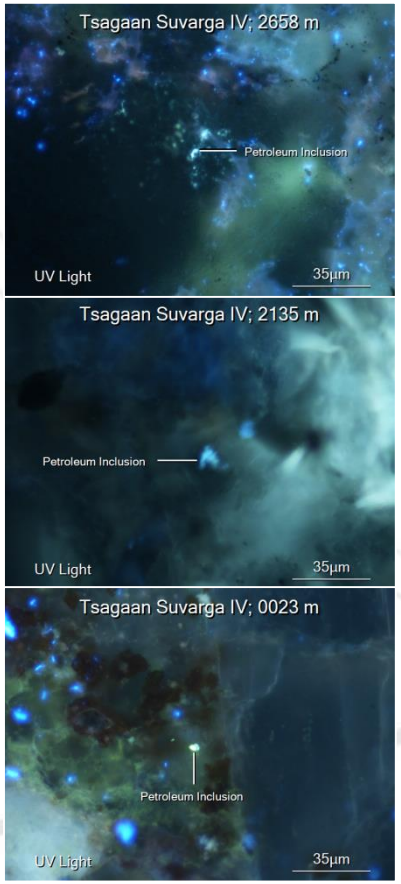
Block V

- Dead oil from core of TSC-1 strat test
- Oily fluid Inclusions from strat well



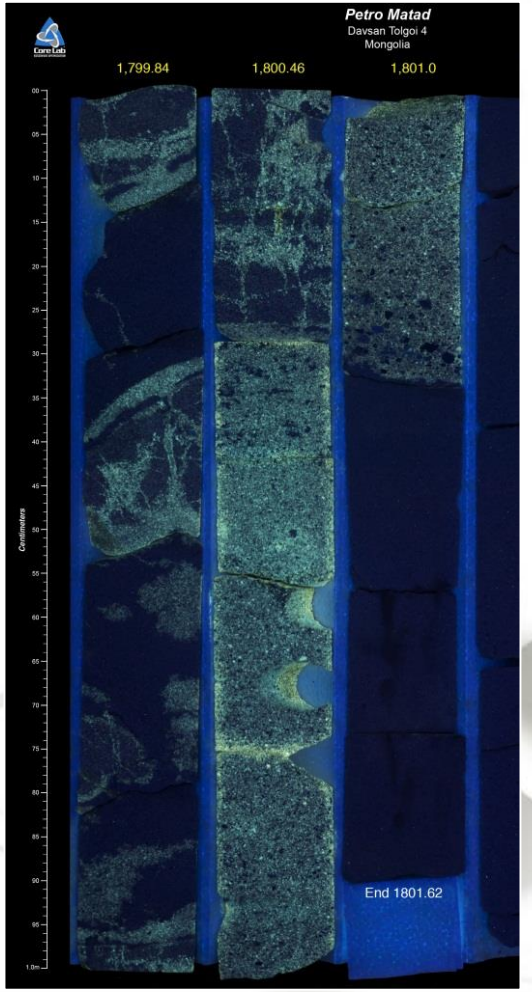
Block IV

- Oily fluid Inclusions from outcrop samples – Tsagaan Suvarga area



Block XX

- Live oil from DT-4 well, fluorescing under UV light



Regional Oil & Gas Infrastructure

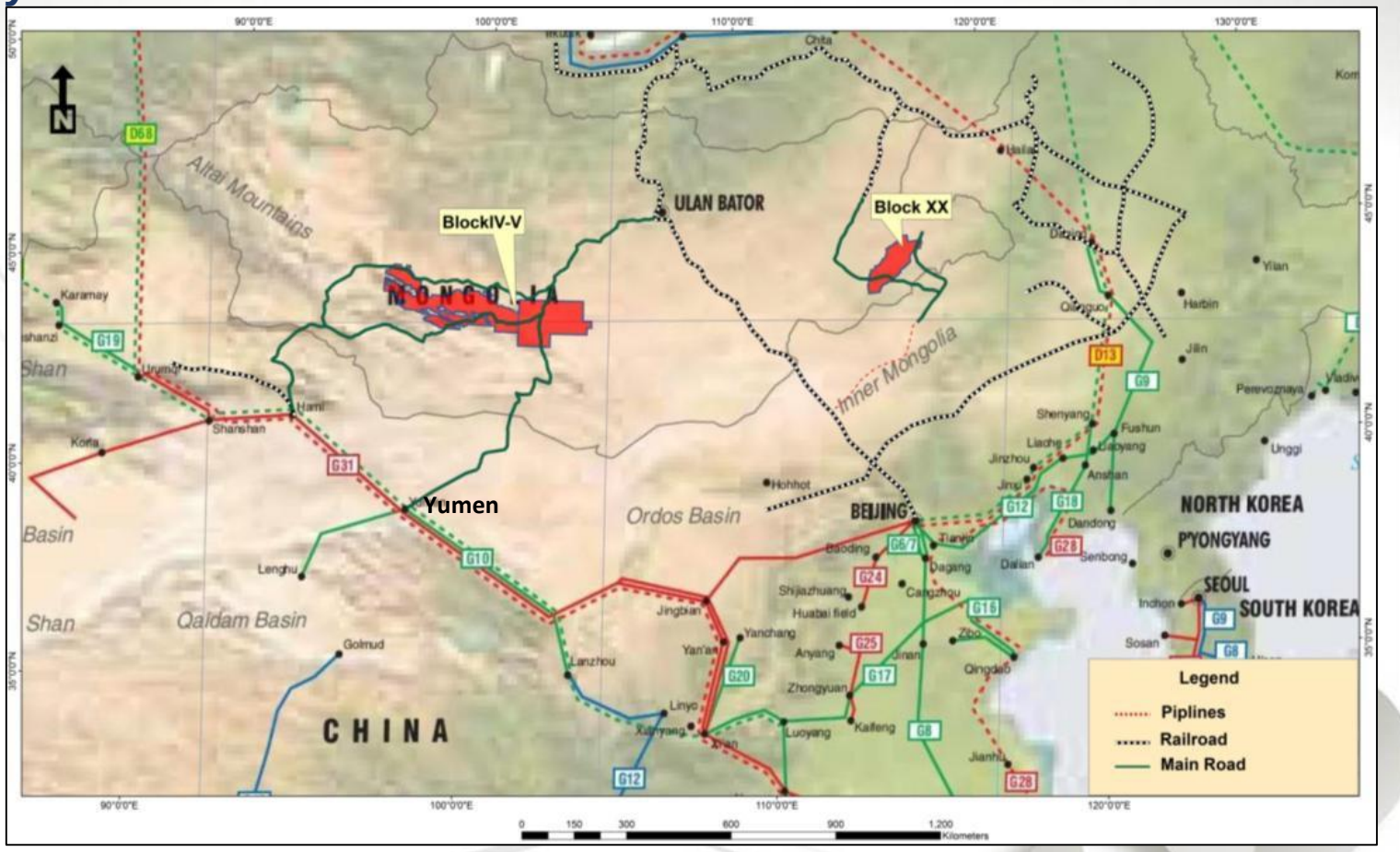
Development concepts following discovery

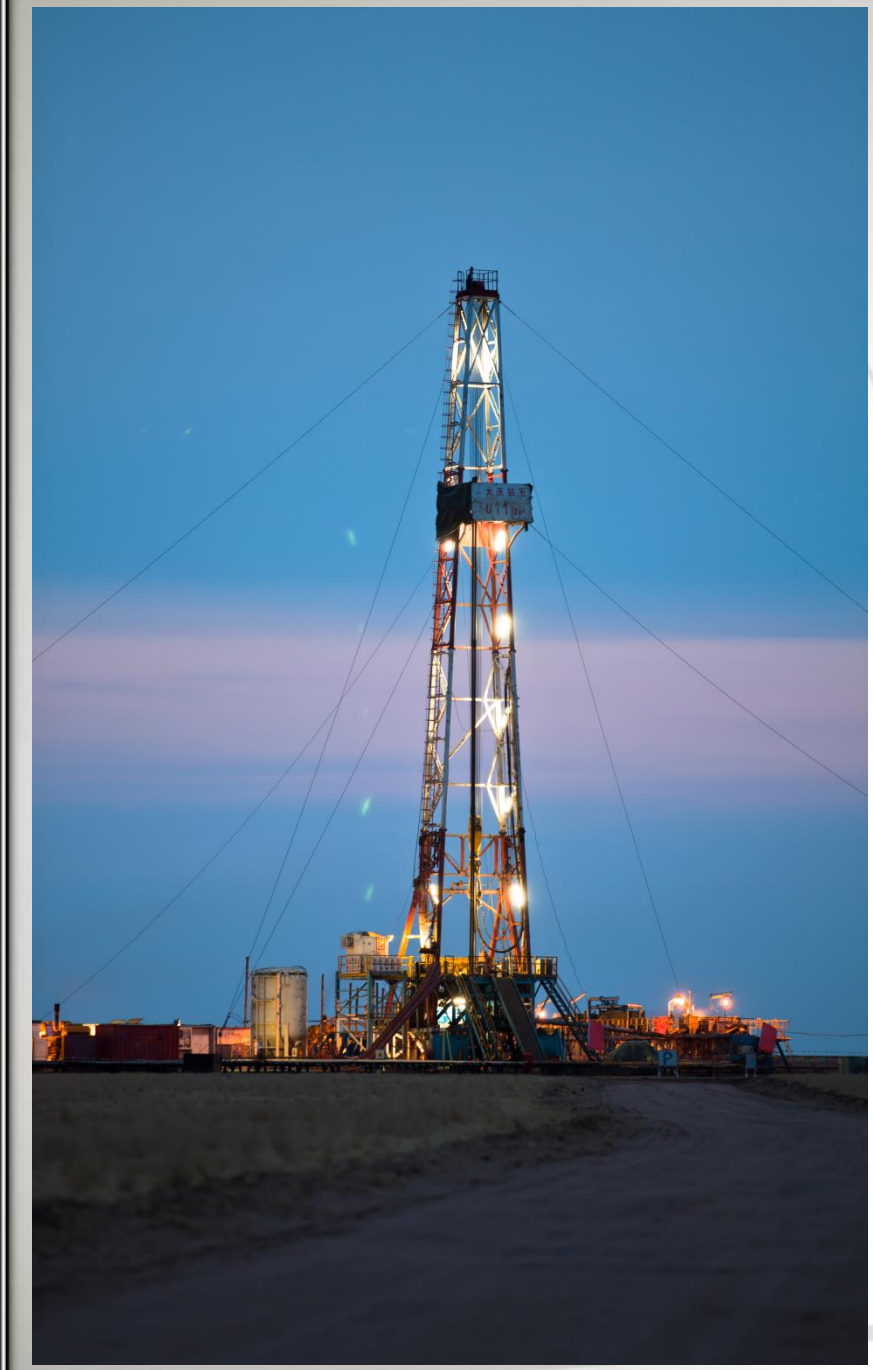
Western Mongolia – Potential Delivery Options

- ✓ Oil trucked c.500 kms to Ulaanbaatar for supply to rail line to China, or trucked/piped to new build refinery
- ✓ Oil pipeline to Yumen in China, which is approx. 500 km south of Blocks IV & V
- ✓ Alternate export route by road to China with a rail line just south of the Mongolian border

Eastern Mongolia – Potential Delivery Options

- ✓ Basic infrastructure already exists in Blocks XIX and XXI
- ✓ Crude from Block XIX is currently trucked c.400 km to a pipeline terminal in the Erlian Basin (China) and then piped and railed to the Hohhot refinery

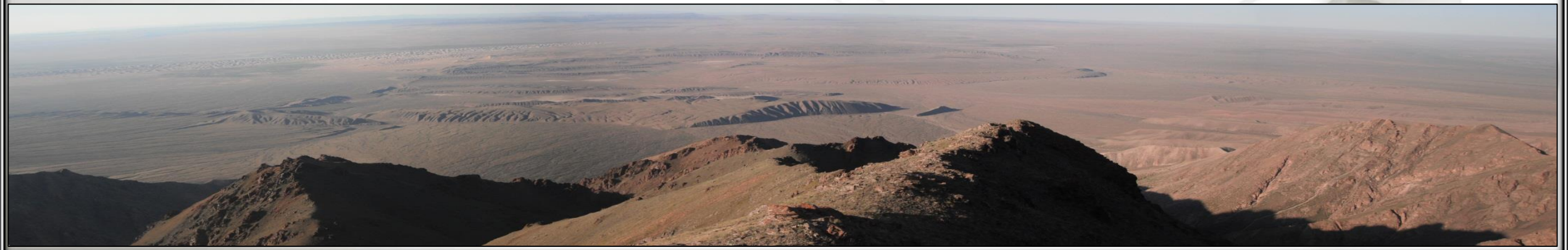




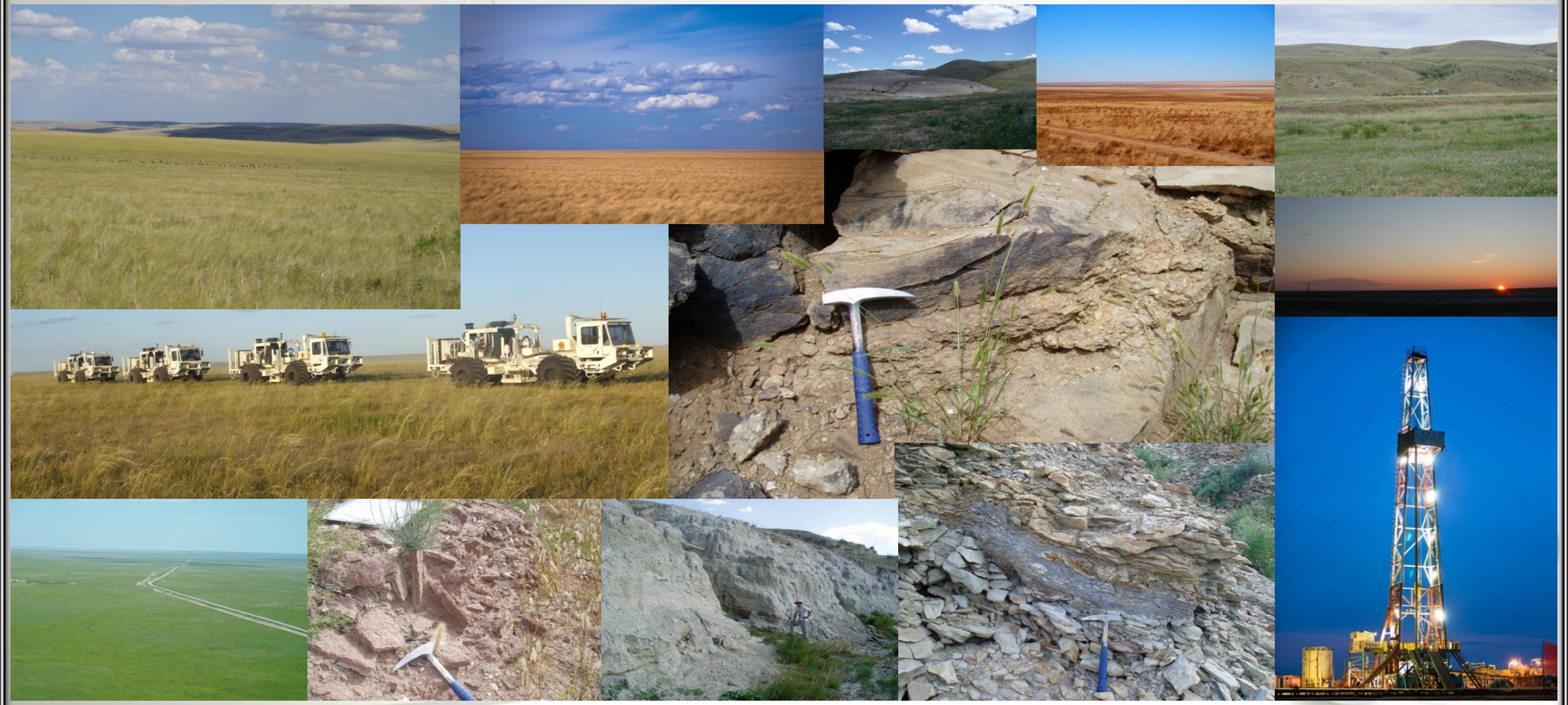
Why Mongolia?

- ✓ ***Contains several large under-explored sedimentary basins that have all the elements for working petroleum systems and large resource potential.***
- ✓ ***These basins are geologically similar to highly productive basins in China, many with multi-billion barrel reserves.***
- ✓ ***Basin opener opportunities***
- ✓ ***Existing producing petroleum province with infrastructure operated by Petro-China (Blocks XIX, XXI - >2Bbbls in-place)***
- ✓ ***Attractive fiscal terms and updated petroleum law***

Blocks IV & V LANDSCAPE



Block XX LANDSCAPE




PETRO
MATAD
Mongolia
THANK YOU

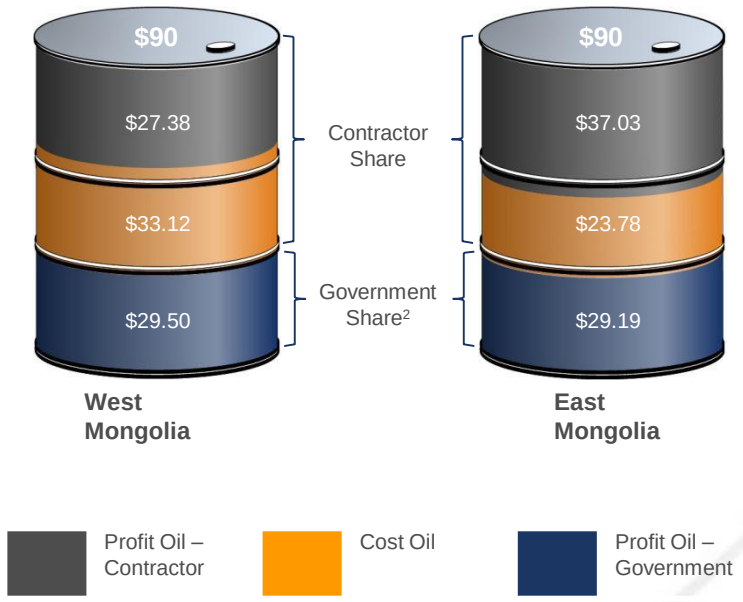
Scoping Economics

Indicative netback per barrel

Key Assumptions

Western Mongolia	Eastern Mongolia
900 km pipeline to planned refinery at Darkhan-uul	Trucking (transport cost US$5/bbl)
Gross recoverable reserves: 100 mmbo	Gross recoverable reserves:100 mmbo
Oil price: US$90/bbl	Oil price: US$90/bbl
Production rate per well: 200 bopd	Production rate per well: 200 bopd

Split Per Barrel[1]



"Depending on the location of the discovery, the development concept and productivity per well, scoping economics for a 100 million barrel discovery at a $90 oil price, shows NPV's (10% discounting) ranging from $0.8 Billion to $1.2 Billion, net to the Contractor. Robust economic results are not surprising due to the onshore environment, expected good oil quality (based on discoveries made to-date in Mongolia) and very good PSC terms. The scoping economics are most sensitive to oil price and production/ reserves, whereas results are not highly sensitive to variations in costs."

Source: Company estimates, excluding capital, operating costs and inflation
1. Typical split per barrel of production 2. Government share includes royalty 3. Other costs based on management estimates