Structural Development, Styles and Hydrocarbon Potential of the Karachi Arc*

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Abstract

Karachi Arc is located in the southeastern part of the Kirthar Fold Belt. It is an arcuate structural feature, verging towards eastward in a Thin Skin fashion. Sedimentary rocks ranges from Palaeocene to Recent age are exposed in the area. Counterclockwise movement of the Khuzdar Block in the Kirthar Fold Belt during late Oligo/Miocene time, after the collision of the Indian plate with the Eurasian (Afghan Block) has resulted in the opening of the Porali Trough in the southwestern part and development of the Karachi Arc in the southeastern part. Two main detachment horizons, the older one lies in the early Cretaceous Semabr Formation, while the younger one lies in the Eocene age Ghazij Formation has identified in the area. Presence of detachments and thin-skin movement in the Karachi Arc is also supported by the presence of asymmetric nature of anticlines together with flat ramp geometries and fault-induced folding. Movement of the Karachi Arc in a thin-skinned fashion resulted in the development of number of strike slip faults in the area, acting as lateral ramps, which facilitating the thin skin movement of the cover sequence on the frontal ramps. The main structural style of the area is proposed as a thin skinned, however some thick-skinned deformation has also been reported in the area.

Satellite image interpretation of the Karachi Arc indicates NNW-SSE trends of the anticlinal axis in the northern part, nearly N-S in central part and NNE-SSW in southern part. This change in the anticlinal trends from north to south in the Karachi Arc has been proposed by the presence of major strike slip faults movements in the northern and southern parts of the Arc.

Karachi Arc exhibit a good hydrocarbon play potential ranging from Cretaceous to Palaeocene age; some has been already proven by the hydrocarbon discoveries in the area. However, a number of structures are still undiscovered and contains a hydrocarbon potential of several TCF of gas in place, which needs to be explored in the context of regional structure and tectonics of the area. Geochemical data on the main source rock including Semabr Formation indicates that most of the area is within the gas generation window at present day conditions.

The southeastern part of the Karachi Arc has a good exposure of the different members of Nari (Oligocene-age) and Gaj (Miocene-age) formations. These formations contain good reservoir potential within sandstone and reefal carbonates members, and it can be used as an analogue for the Indus offshore exploration, where these are the main objectives.

This paper will help in understanding the structural development, structural styles and remaining hydrocarbon potential of the Karachi Arc in detail, together with regional structure and tectonics, and also as an analogue for Indus offshore exploration (i.e. southeastern part of the Karachi Arc area).

Reference Cited

Bannert, D., 1992, The structural development of the Western Fold Belt, Pakistan: Hannover Press, Stuttgart, Germany, 60 p., 3 maps.

Structural Development, Styles and Hydrocarbon Potential of the Karachi Arc

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Outline

- Objective of the Paper
- Introduction
- Exploration History & Previous work
- Regional Structural Development
- Structural Interpretation
  - Satellite Image & Seismic interpretation
  - Structural Cross Sections
- Main Hydrocarbon Plays
- Conclusion / Main Findings
- Acknowledgements

Objectives of the Paper

<u>This Paper will help in Understanding:</u>

- Structural development in relation to the regional structure and tectonics
- Structural styles (both from Surface & Sub Surface data)

&

- Hydrocarbon potential of the Karachi Arc

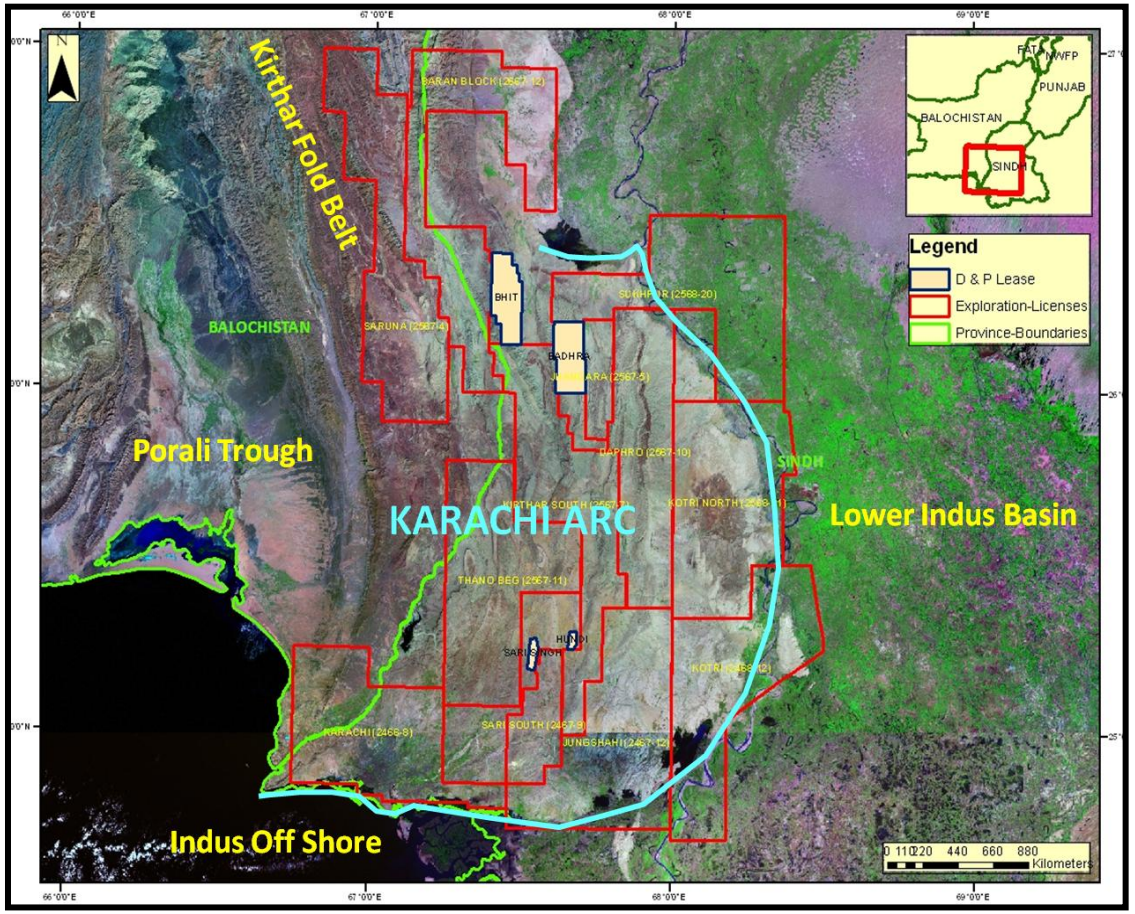
Location Map of the Karachi Arc Area

Karachi Arc is Located in the:

- SE part of the Kirthar Fold Belt
- East of the Porali Trough
- Western Part of the Lower Indus Basin
- North of the Indus Off Shore

Arc Currently Contains:

- 12 Exploration Licenses
- 4 D&P Leases



Location Map of the Wells Drilled in the Karachi Arc Area

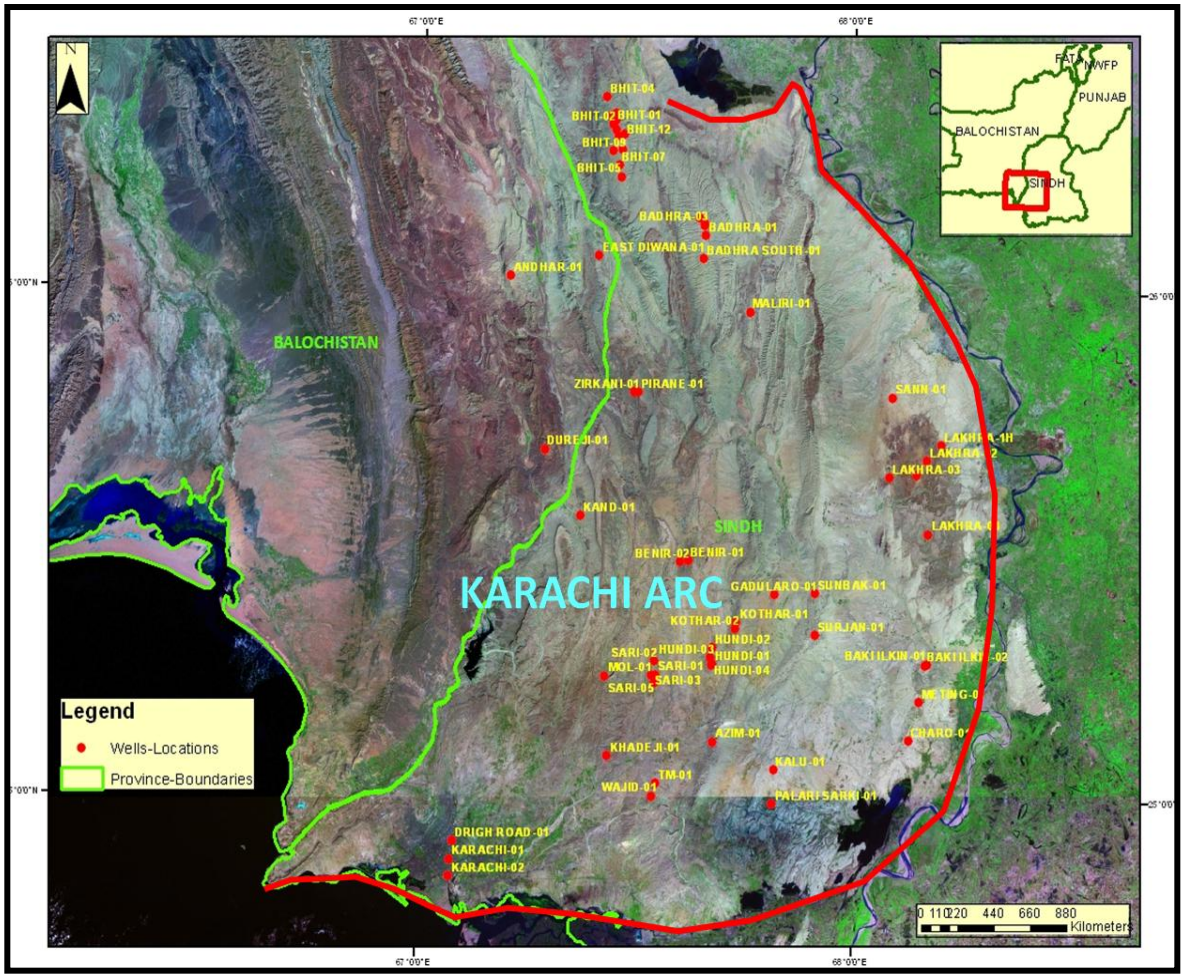
Pakistan Section

To Date in the Karachi Arc:

- Around 65 wells has been drilled
- 4 Hydrocarbon fields has been discovered
- Deepest well is drilled up to the Chiltan formation

Main Failure Causes:

- Structural breaching by shallow crestal faulting
- Absence of main targeted horizons due to facies change



Exploration History & Previous Work

- First well drilled in 1948 on Lakhra Structure - Dry & Abandoned
- To date - 65 wells has been drilled
- First Commercial gas discovery – 1965 from Sari-1 well
- At present Karachi Arc contains four D&P Leases
- Discovered reservoir includes Lower & Upper Ranikot & Dunghan (Paleocene), Pab & Mughalkot fm (Cretaceous)

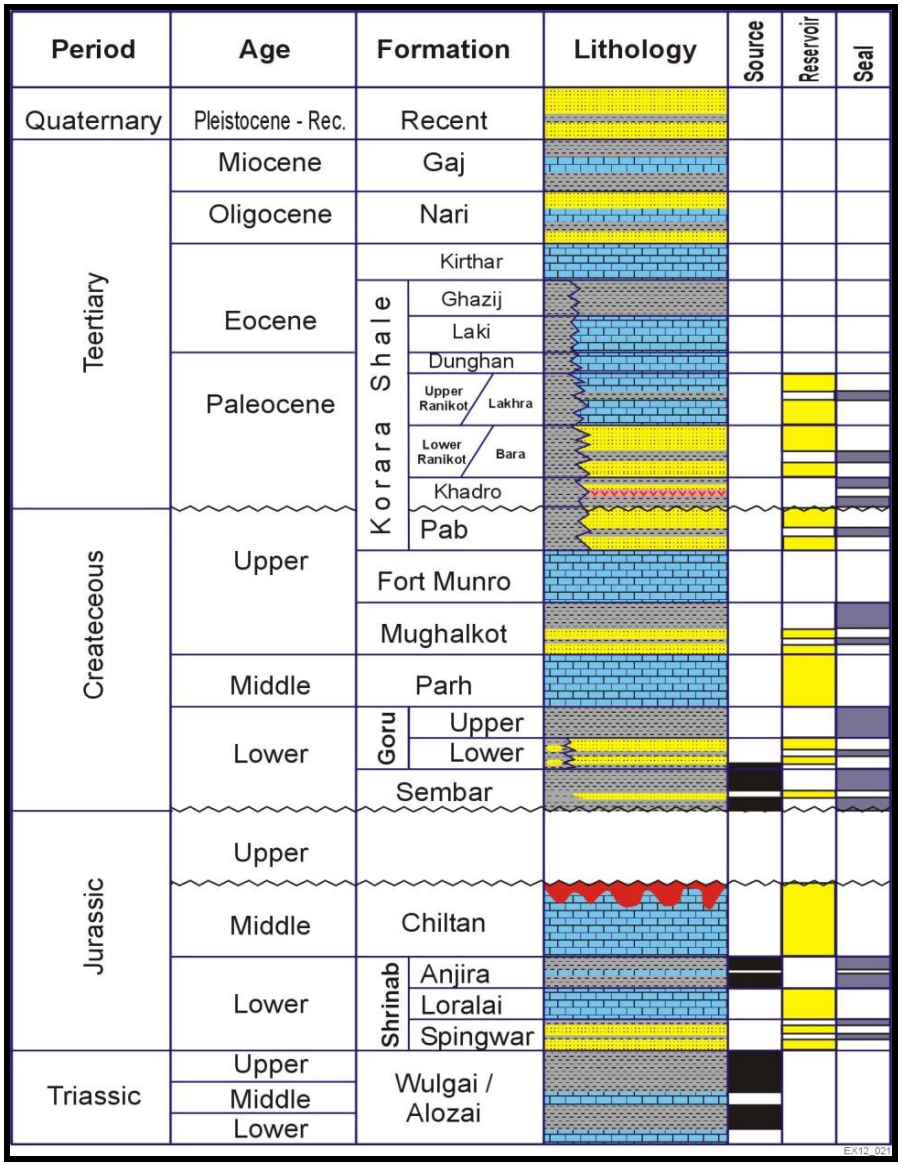
Geologically the area is mapped by

- Hunting Survey Corporation in 1960
- Bannert et al in 1992
- Geological Survey of Pakistan
- Different authors in technical research papers

Lithostratigraphy of the Karachi Arc Area

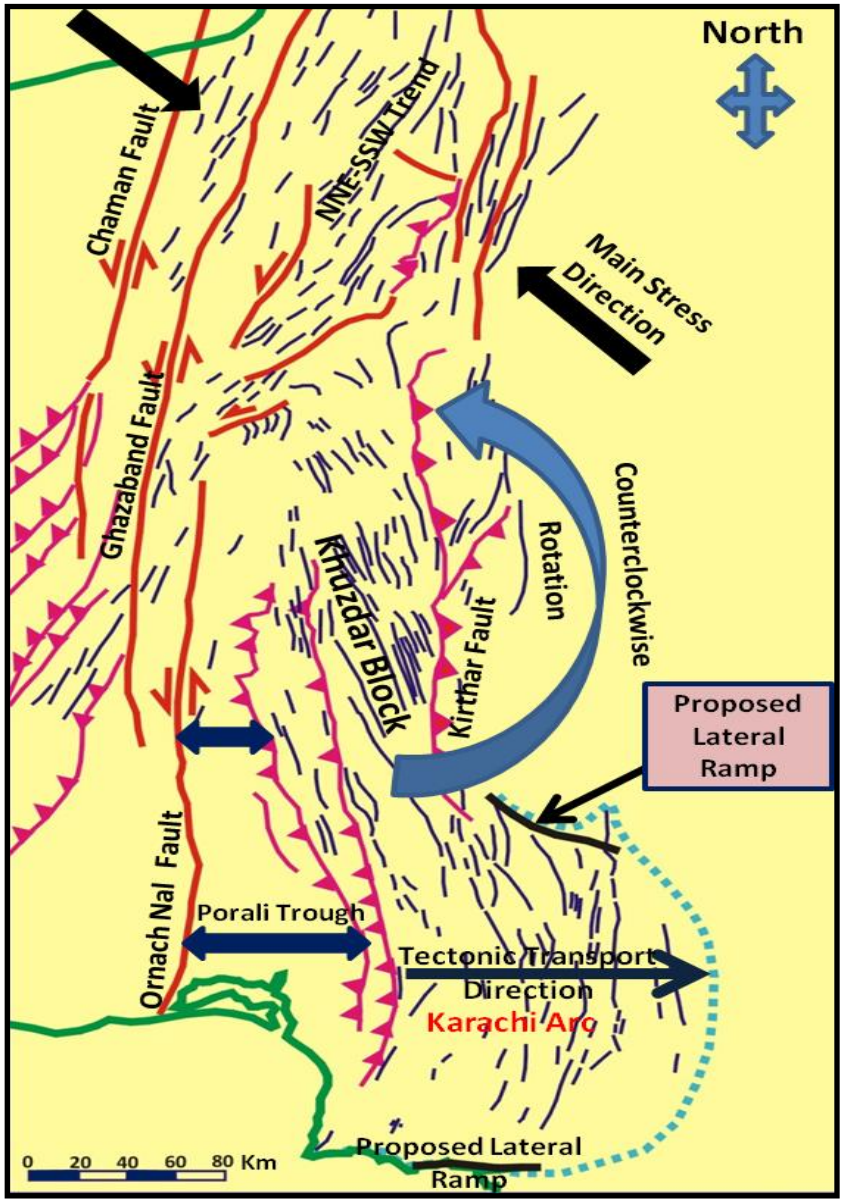
Pakistan Section

- Rocks from Paleocene to Recent age are exposed.
- Stratigraphy up to Chiltan formation - drilled in the wells in area.
- Stratigraphic column is shown up to the Triassic formation.
- Triassic formation has been drilled in the wells including Marvi-1 & Nabisar-1 in Lower Indus and Jhatpat-1 in the Middle Indus basin.
- Major Variation in sedimentation during Late Cretaceous to Tertiary time.



Regional Structural Development

- Late Eocene-Oligocene time, collision of the Indian plate and Eurasian- Afghan block in the north west.
- This collision resulted in NNE-SSW structural orientation in KFB.
- Counterclokwise movement of the Khuzdar block- Change in orientation from NNE-SSW to NNW-SSE direction.
- This counterclokwise movement also resulted in development of Karachi arc structure in SE and opening of the Porali trough in SW.



Satellite Image Showing interpretation of the Anticlinal Axis

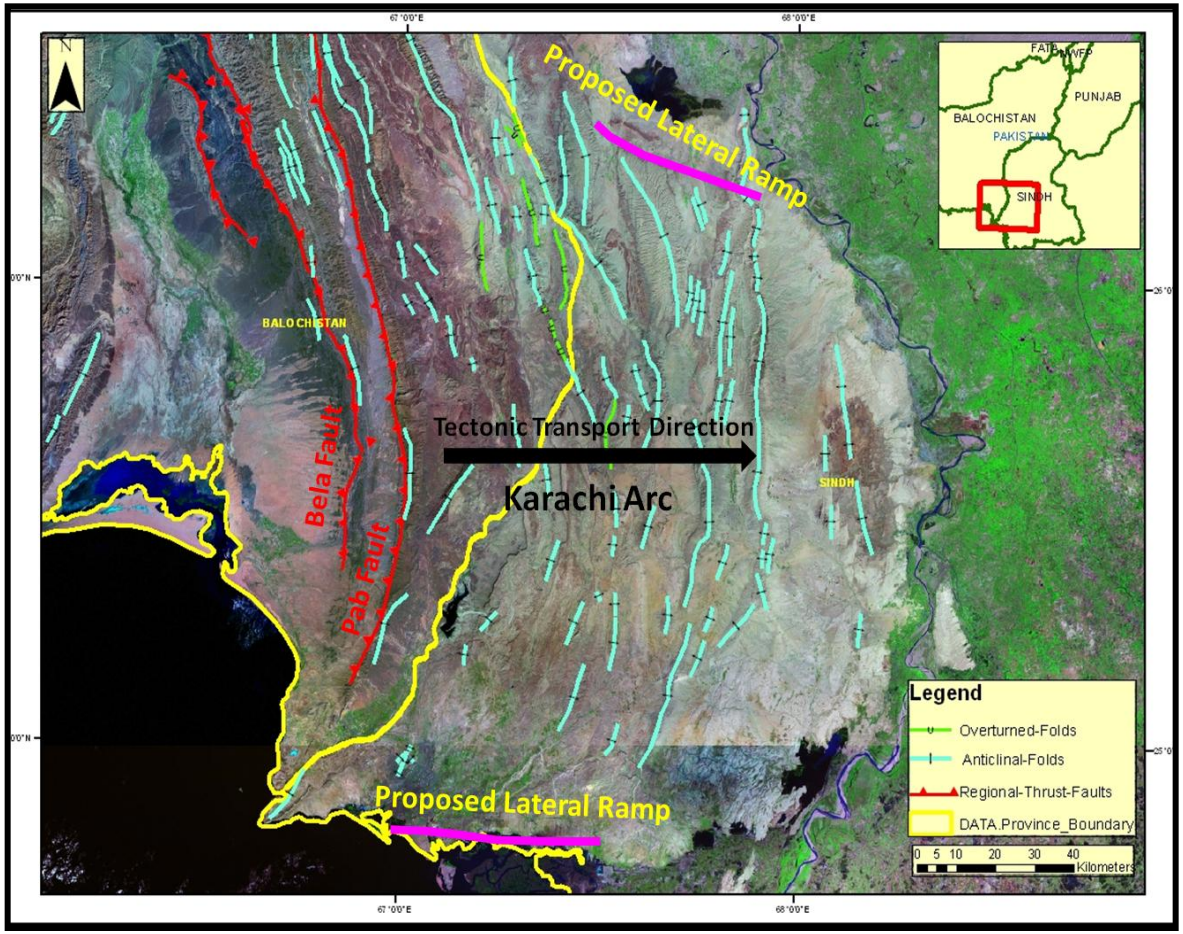
Pakistan Section

Three main Anticlinal Trends:

- NNW-SSE in northern part
- Nearly NS in central part
- NNE-SSW in southern part

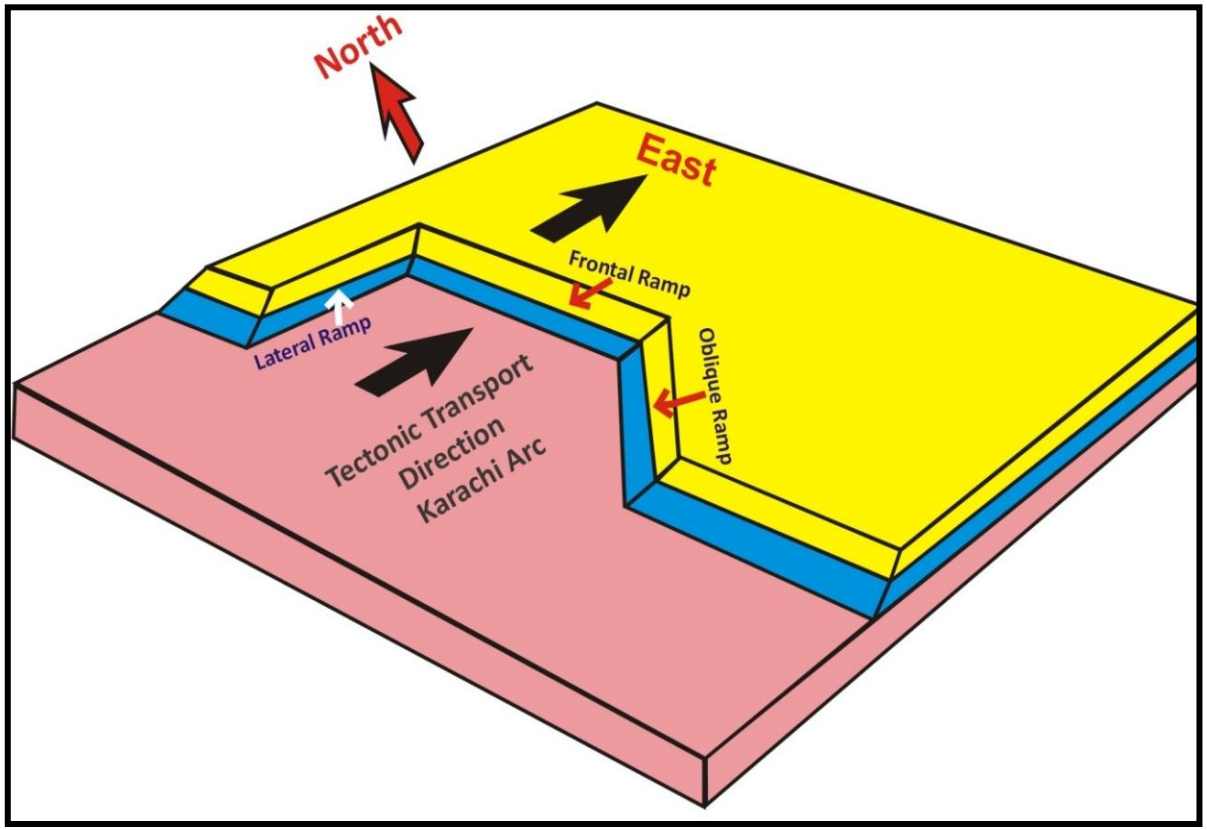
Change in Trend from N-S:

- Result of the movement along the proposed lateral ramps in north & south part of the arc
- And maximum slip on detachment in central part



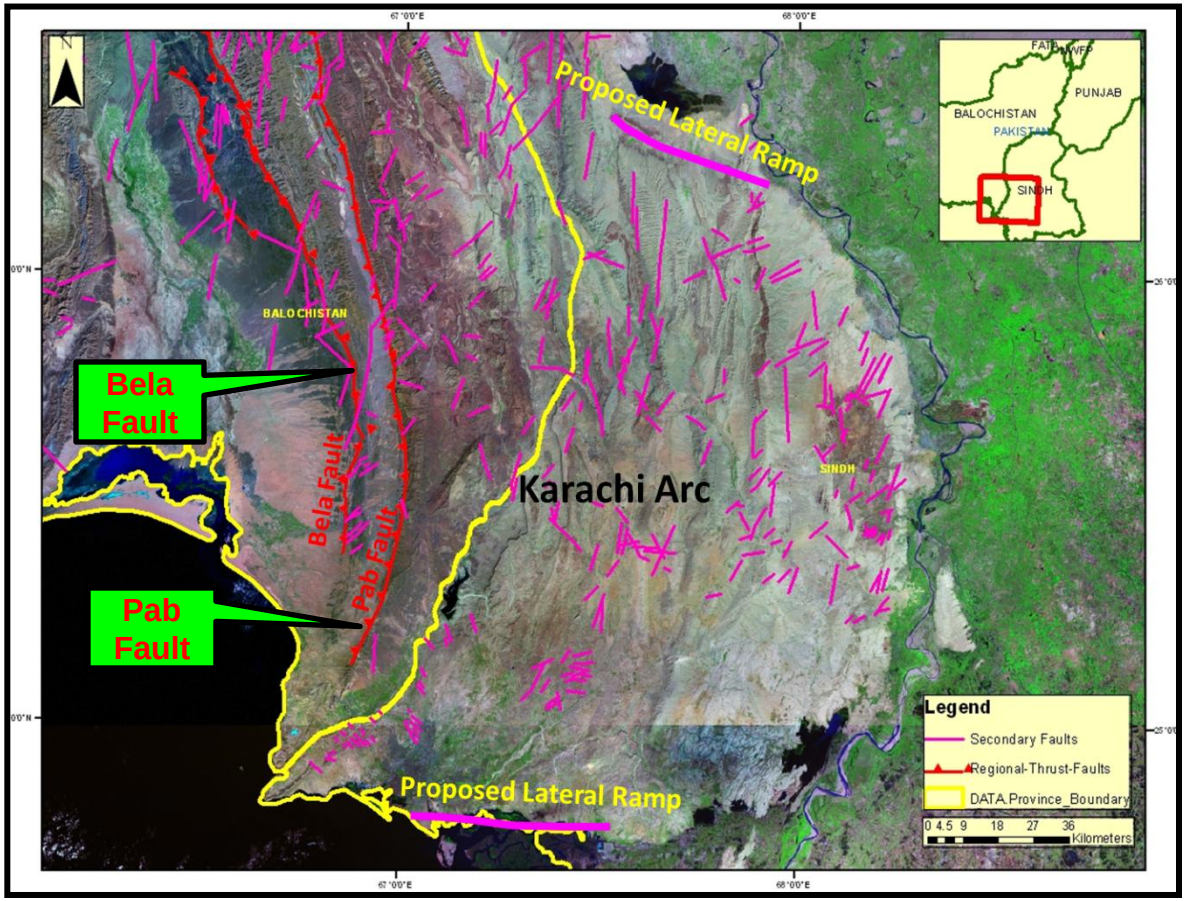
Model Showing the Ramps & Tectonic Transport Direction in the Area

- Eastward tectonic transport on frontal ramps
- Thin skinned style of deformation
- Major Lateral Ramps present in the north & south of the arc- a result of the thrust sheet movement on frontal ramps
- These Major lateral ramps are also present in Sulaiman & Potwar fold belts of Pakistan



Satellite Image Showing Interpretation of the Primary & Secondary Faults

- Pab & Bela thrust faults are present in the west of the arc.
- No major exposed thrust fault is present or interpreted in the Karachi arc area.
- Thrust faults are blind in area.
- Proposed lateral ramps in north & south of the arc.
- Central & northern part of the arc is more complex due to presence of number of small scale faults.



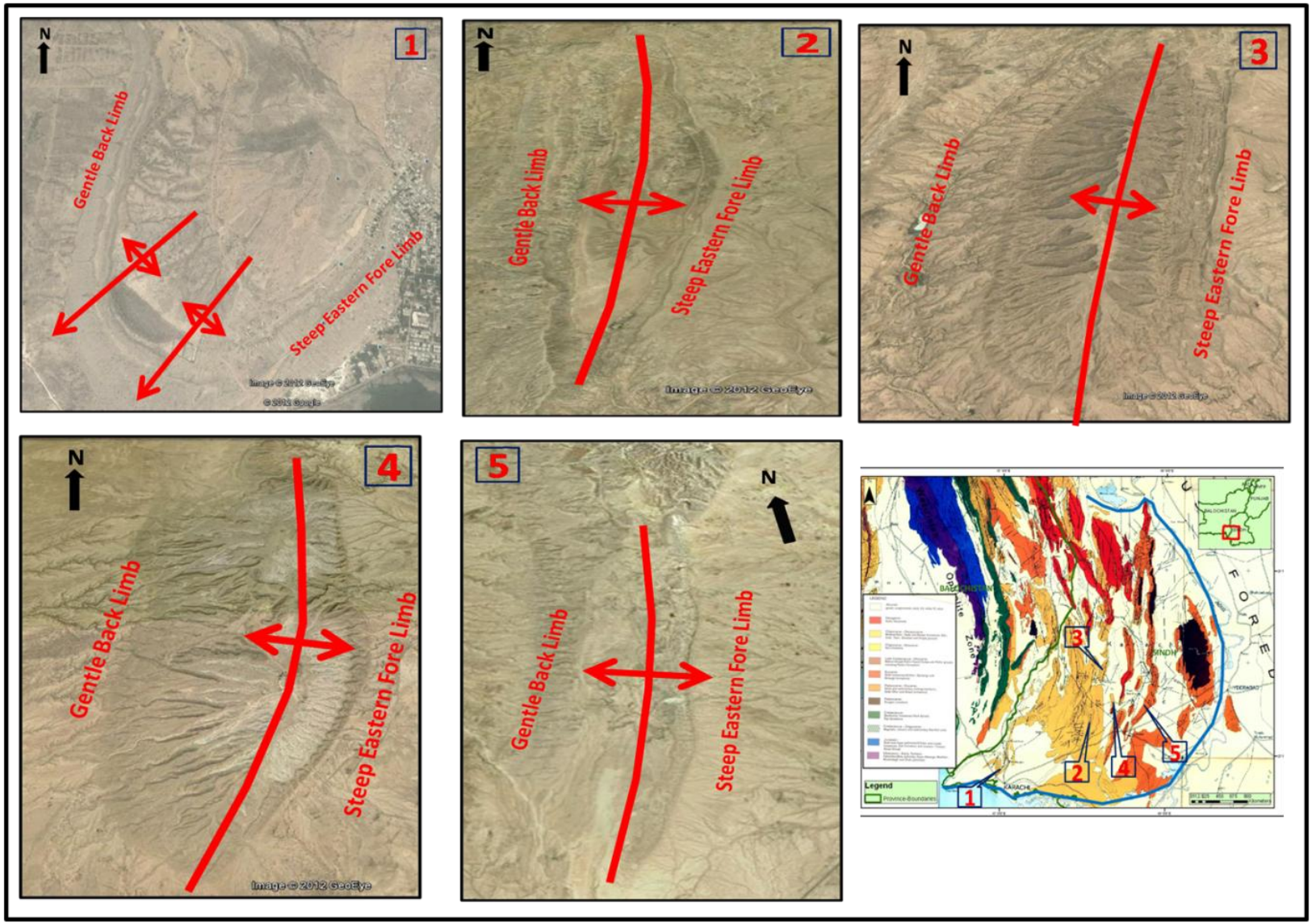
Main Structural Styles

- **Thin Skinned - Eastward Verging Structures**
  - Main Decollement horizons- Semabr (Cret) & Ghazij (Eocene)

- **Main Evidences - Thin Skinned Deformation in Karachi Arc;**
  - Presence of fault induced & asymmetric types of folding
  - Presence of the Anticlines with steep fore limb (low outcrop width) & gentle back limb (large outcrop width)
  - Presence of the lateral ramps in the area
  - Presence of blind thrust faulting
  - Higher amount of structural shorting & arcuate nature of the Arc

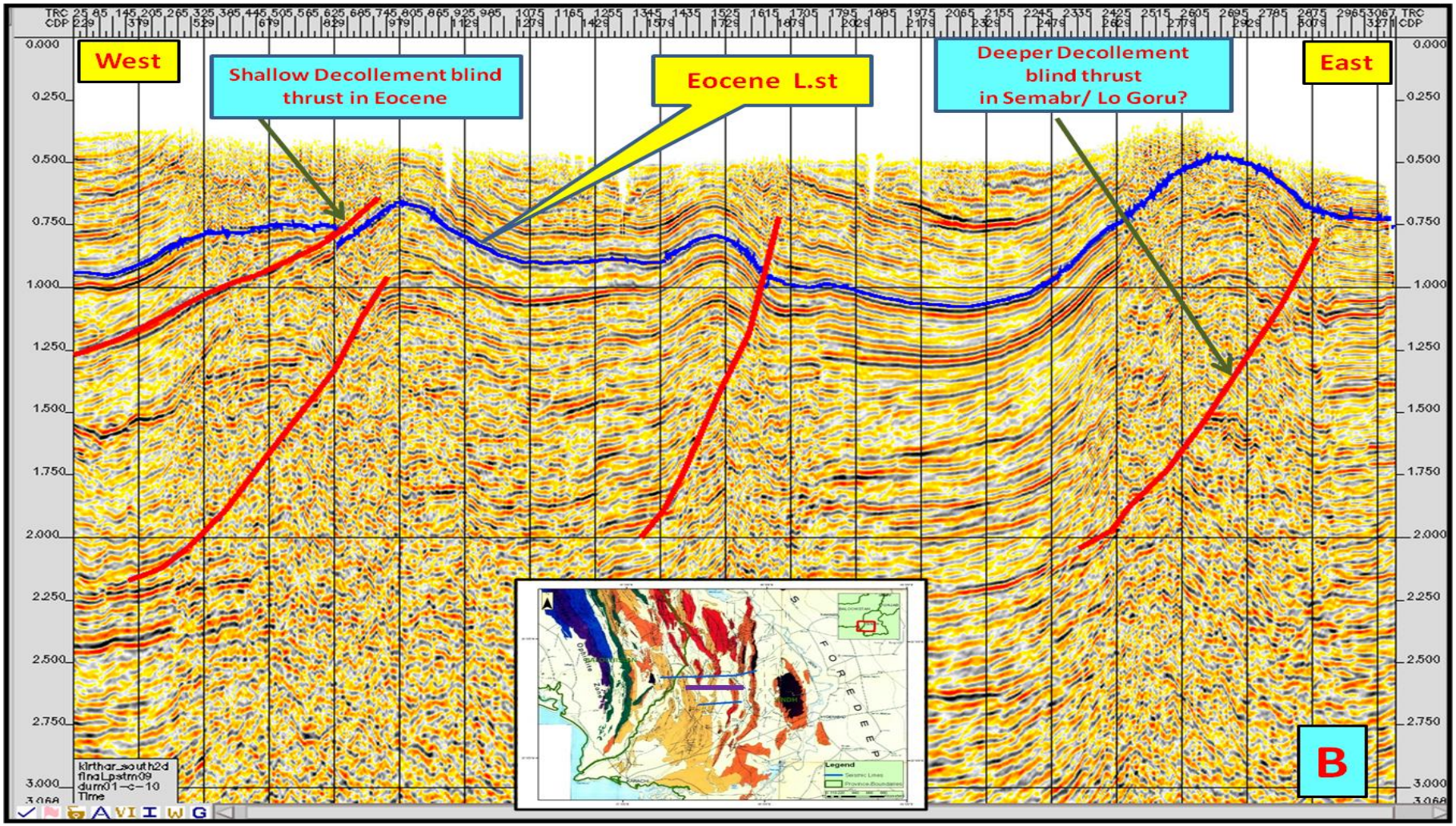
- **Some thick skinned structures are also present, but mainly in northern western part**

Google Image Showing Anticline Behaviors- Supporting Thin Skin Model



East West Seismic line through Central Part of the Karachi Arc

Pakistan Section



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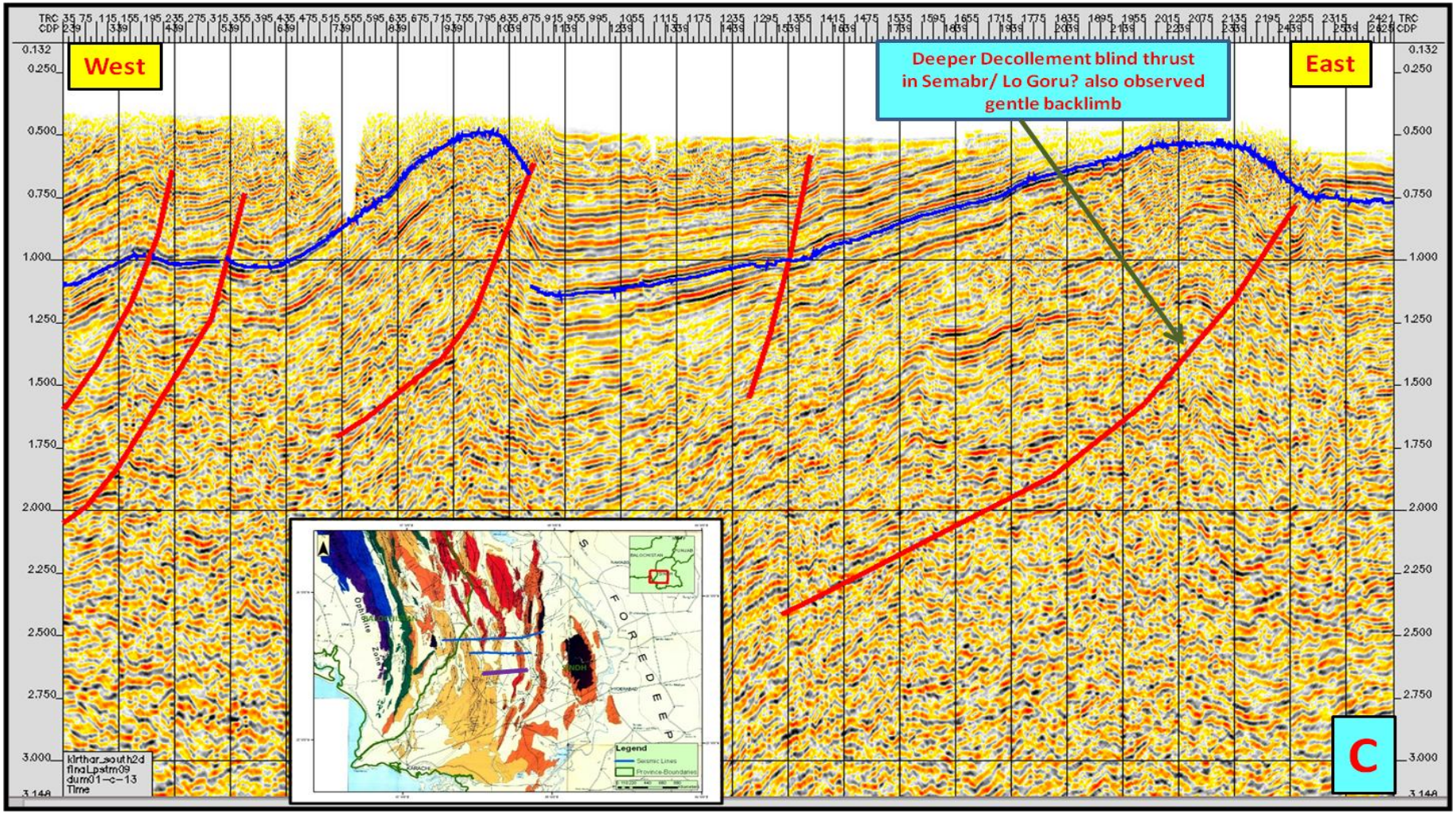
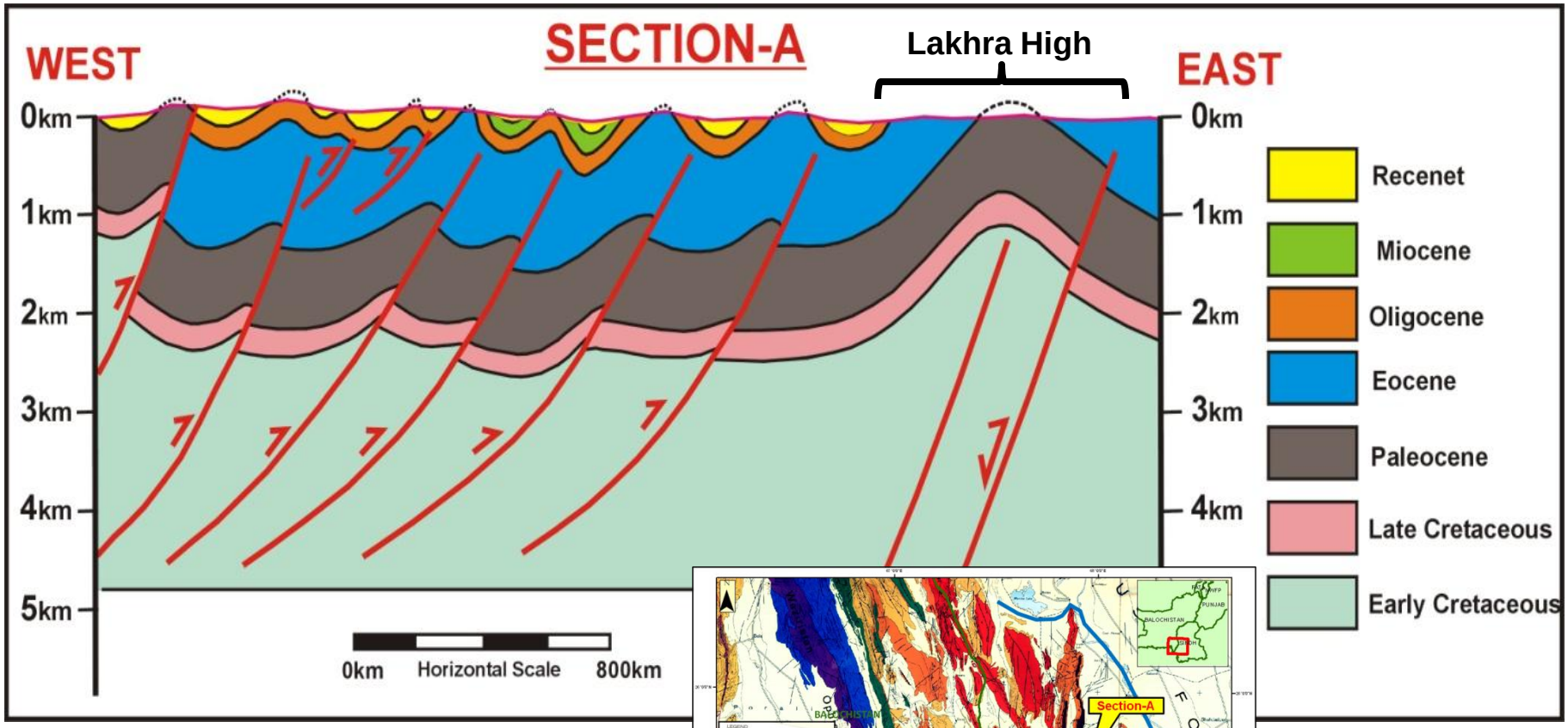
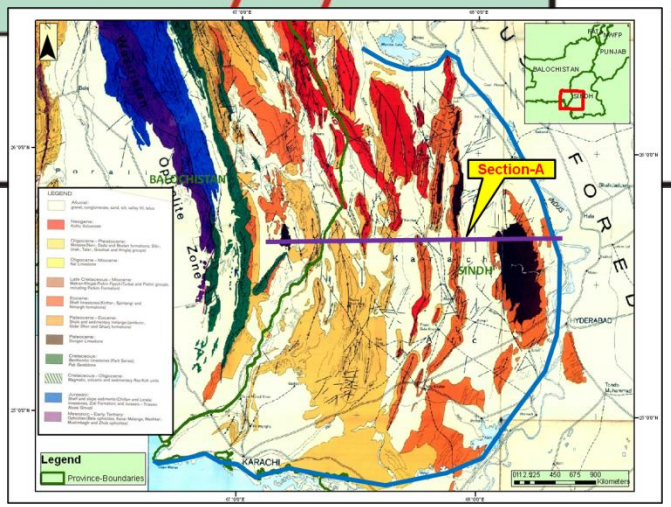


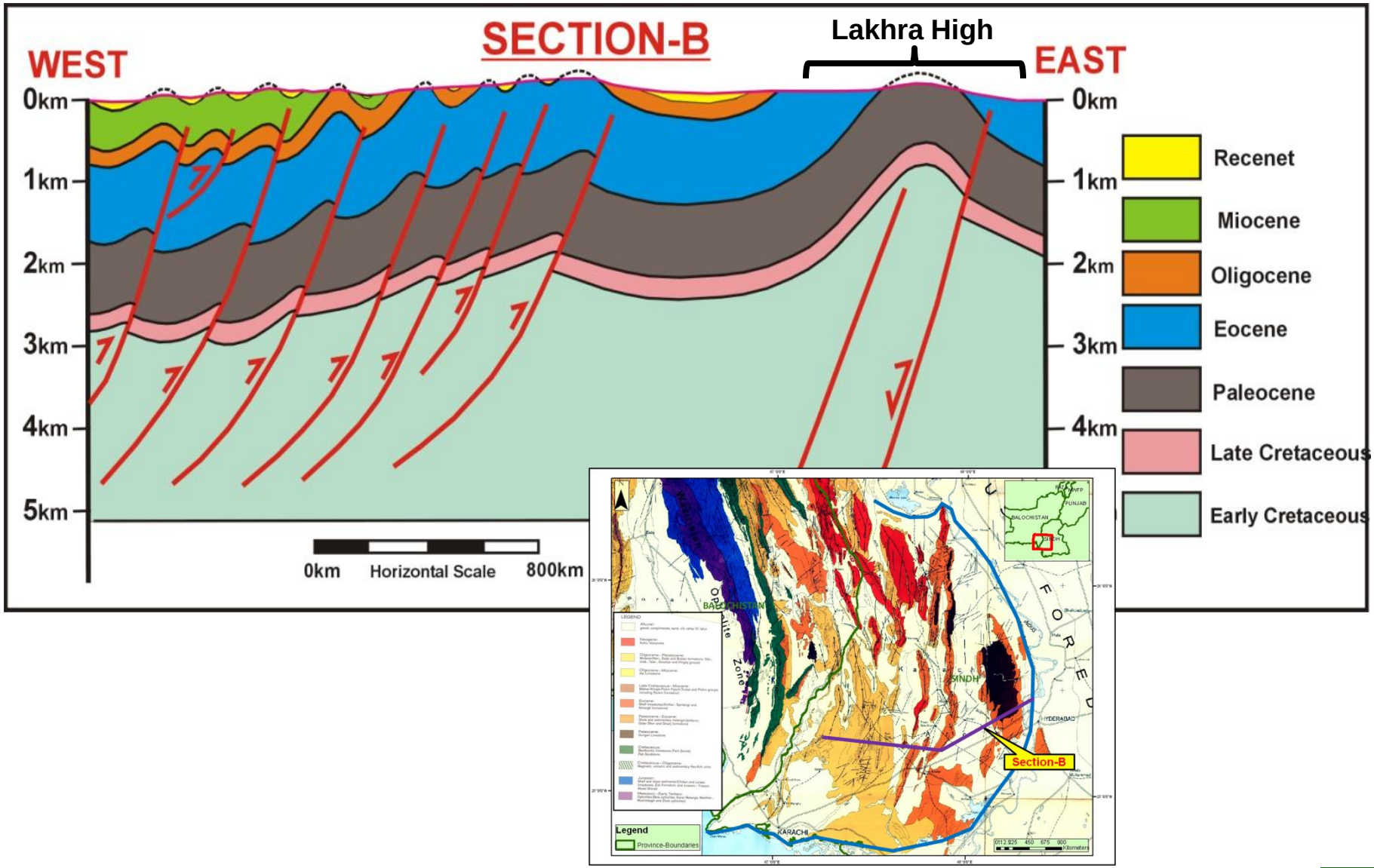
East West Structural Cross Section through Central Part of the Arc





East West Structural Cross Section through Southern Part of the Arc

Pakistan Section

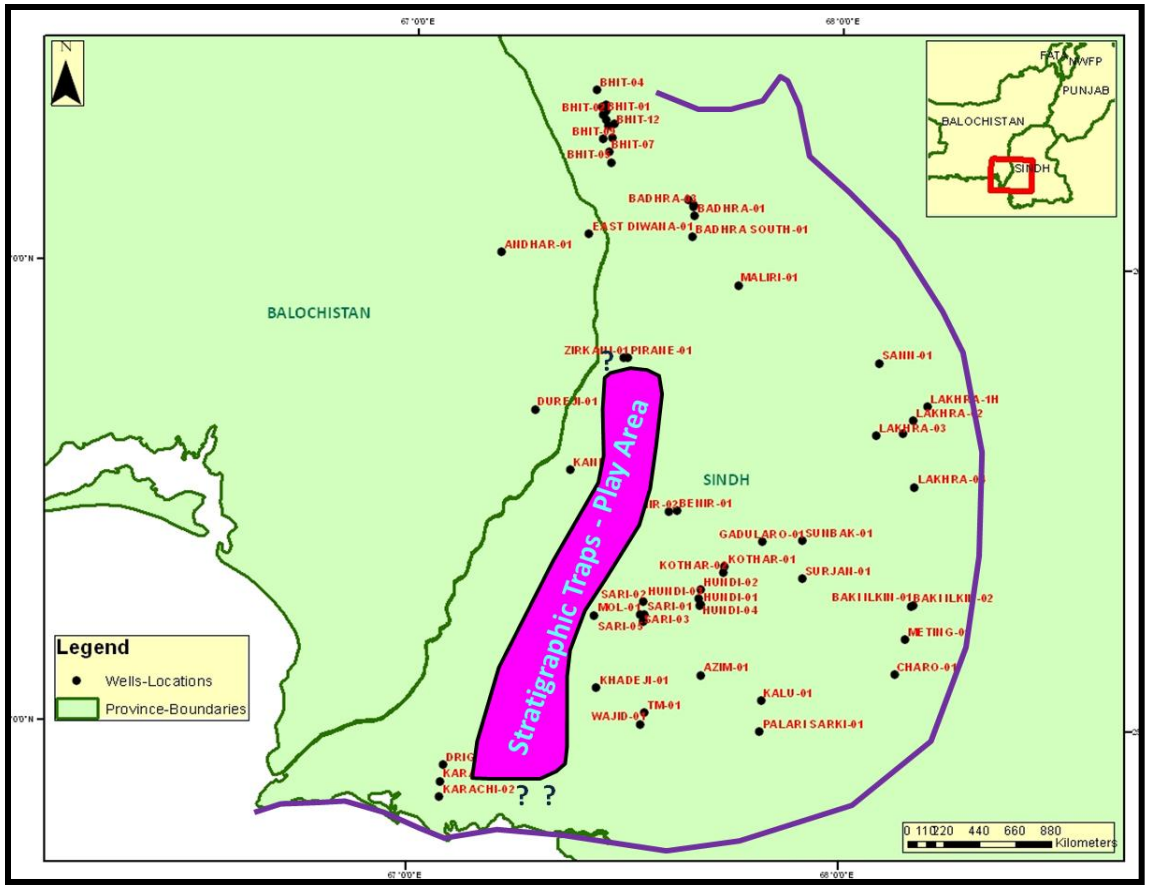


Main Play Components of the Karachi Arc Area- Structural

Play	Age	Reservoir	Source	Seal	Trape Type	Migration	Trap Timing	Example
Ranikot Sand	Early Paleocene	Lower Ranikot sands	Sembar & Lower Goru shales	intraformational Ranikot shales	Structural (Fault bounded)	Vertically through faults & Laterally through Permeable beds	Late Tertiary	Sari & Hundi Fields
Ranikot Carbonate	Late Paleocene	Upper Ranikot Carbonate	Sembar & Lower Goru shales	intraformational shales & Non reservoir tight carbonate part	Structural (Fault bounded)	Vertically through faults & Laterally through Permeable beds	Late Tertiary	Sari & Hundi Fields
Pab	Late Cretaceous	Pab Sandstone	Sembar & Lower Goru shales	Khadro & Ranikot shales	Structural (Fault bounded)	Vertically through faults & Laterally through Permeable beds	Late Tertiary	Bhit & Zamzama Fields
Mughalkot	Late Cretaceous	Mughalkot Sandstone	Sembar & Lower Goru shales	Intrafrmational & Upper Mughalkot shales	Structural (Fault bounded)	Vertically through faults & Laterally through Permeable beds	Late Tertiary	Badhra Fields
Lower Goru	E-Mid Cretaceous	Lower Goru Sands	Sembar& Lower Goru shales	Intraformational & Upper Goru sahles	Structural (Fault bounded)	Upward Migration through microfracturing of source rock	Late Tertiary	Khaskheli, Sawan, Miano & Kadnawari Fields
Chiltan	Mid Jurassic	Chiltan Limestone	Sembar & Anjira Shales	Sembar shales	Structural (Fault bounded)	up ward and downward from source rock through	Late Tertiary	Zarghun & Salsabil Fields
Spingwar	Early Jurassic	Spingwar Sands	Anjira & Wulgai sahles	intrafomration Spingwar shales	Structural (Fault bounded)	up ward and downward from source rock microfracturing	Late Tertiary	New Play

Map Showing the Location of the Proposed Stratigraphic Play Area

- Lower Ranikot is proven with good quality sand from Sari & Hundi gas fields.
- Westward these sands laterally grades in to Korara shale-Proven from the wells data of Karachi-1, Kand-1 & Dureji-1.
- Stratigraphic traps with several BCF of gas are expected in between these sand shales grading area.
- Traps at lower goru level are also expected in the eastern to central part of the arc.



Conclusions / Main Findings

- Four Hydrocarbon fields- 65 wells
- Main wells failure Cause- Structural Breaching
- Satellite Image interpretation- three main Surface Anticlinal trends NNW-SSE, Nearly NS & NNE-SSW
- Change in trend north to South- result of the presence of lateral ramps & Maximum slip on decollement in the central part
- Main Structural deformations in Karachi Arc- Plio-Pliestocene time as a result of the counterclokwise movemt of Khuzdar block
- Main evidences of counterclokwise movement- Development of the arcuate nature of Karachi arc, Opening of the Porali trough & Generation of the Kirthar back thrust in frontal part of Kirthar fold belt

Conclusion / Main Findings

- Thin Skinned with east verging deformation- Main Structural style
- Main decollement horizons - Sembar (Cretaceous) & Ghazij (Eocene)
- Some Thick Skinned- Mainly in north western part also Lakhra High
- Main Structural plays- Lower & Upper Ranikot (Paleocene) & Pab, Mughalkot & Lower Goru sands (Cret) & Chiltan limestone & Spingwar sandstone (Jurassic)--- Potential of Several TCF of gas
- Stratigraphic traps
  - B/w Lower Ranikot Sandstone (Palaeocene) & Korara Shales
  - At lower Goru Sand levels (Cretaceous)
  - Potential of several Bcf of gas

Acknowledgements

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