Hydrocarbon Exploration Challenges in Fold and Thrust Belts—Bhittani Range, Trans Indus Range, Pakistan*

Moin Raza Khan[1], Mudassar Z. Khan[2], and Ali Raza[2]

Search and Discovery Article #10842 (2016)**
Posted February 1, 2016

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

[1]Exploration, Pakistan Petroleum Limited, Karachi, Sindh, Pakistan (k_moin@ppl.com.pk)
[2]Exploration, Pakistan Petroleum Limited, Karachi, Sindh, Pakistan

Abstract

The Bhittani Range is located in the western part of the Trans Indus ranges and separates the Bannu Basin in the north from the Tank depression in the south. It represents the leading deformational front of the Kohat fold and thrust belt believed to be the most recent thrusting phase. Pezu is northwest-southeast oriented asymmetric, faulted surface anticline, forming the main topographic expression of the Bhittani Range; it is a structural high interpreted as a complex pop-up bounded on each side by steeply dipping reverse faults. A gas seep is present in the Bhittani Range which confirms maturity of source rocks and subsequent migration of hydrocarbons. Analyses of the gas seep shows that it is mainly methane derived from a deep thermogenic source. An exploration well was drilled in 1968 near gas seepage on a surface anticline down to 2,222 m in the Datta Sandstone of Jurassic age which was plugged and abandoned since the well flowed water with combustible gas. Drilling results confirmed the presence of good quality reservoir seal pairs in clastics of Cretaceous and Jurassic formations which could be charged from adjacent basin. Post drill seismic acquisition reveals steeply dipping reverse faults that pop-up in the central part. The most likely traps of supra-thrust and sub-thrust structural geometry may be much more complex as strike-slip faults mapped on the surface are not properly imaged by seismic. It is interpreted that crestal geometries of supra and sub-thrust structures is uncertainly due to meager quality of seismic data. Available seismic is unable to compute throw of bounding faults, therefore fault seal and juxtaposed lithologies across faults are questionable, especially for sub-thrust play. Based on active petroleum system and multiple target reservoirs at drillable depth including Tertiary, Mesozoic, and Paleozoic rocks; this area merit detailed G&G studies with new seismic to mature supra-thrust and sub-thrust play which will lead to firm up a drillable prospect.

AAPG SEG International Conference & Exhibition 2015
13-16 September • Melbourne, Australia
PESA Incorporating PESA's Eastern Australasian Basins Symposium

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PPL

September, 2015

Moin Raza Khan, Mudassar Z. Khan, Ali Raza

TALK OUTLINE

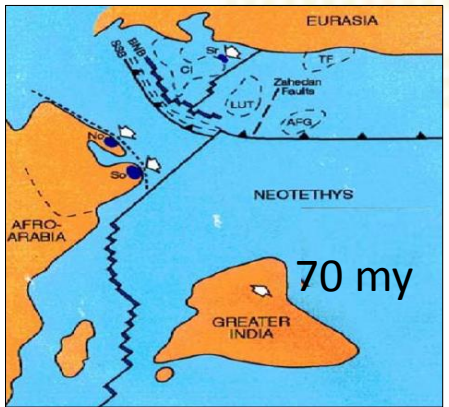
- Objective
- Introduction
- Location and Regional Tectonic Framework
- Petroleum Play and Stratigraphy
- Exploration History
- Generalized Structural Models
- Trap Complexity and Challenges
- Conclusions
- References

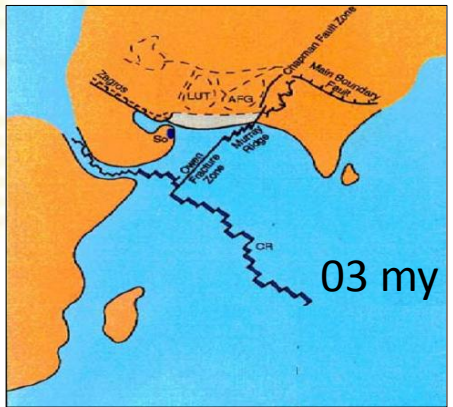
Objectives

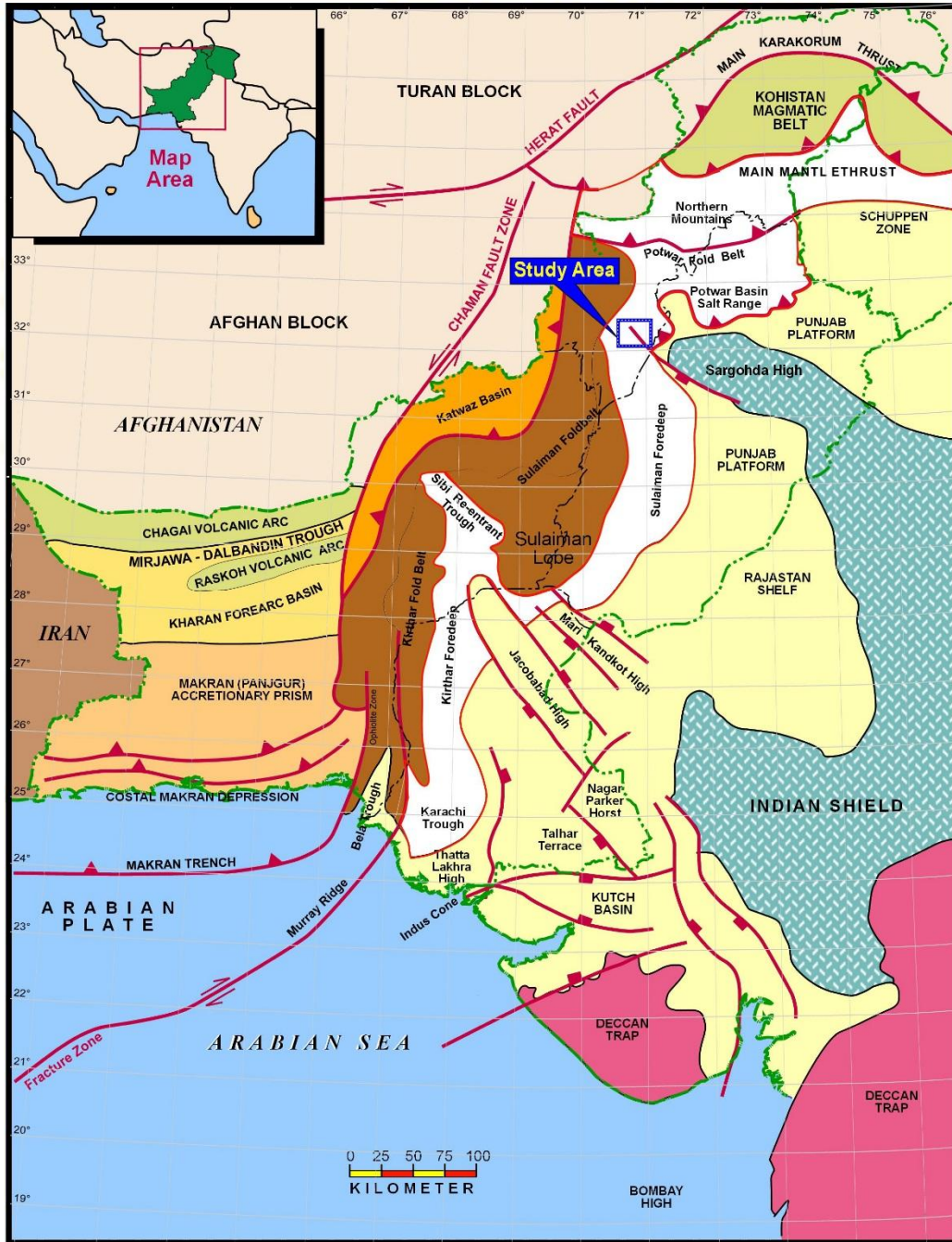
- Fold and thrust belts have been explored and most of the wells were drilled decades back based on surface geology with mixed results – Several significant discoveries albeit dozens of dry wells
- Lack of proper data results in improper imaging of sub surface picture
- Inapt understanding results in failure; thus relinquishment of potential area
- Precise elucidation of these complex area may reveal that these are under explored areas contrary to explored / low potential area
- Key to success would be correctly deciphering the subsurface geometries and eventually precisely locating the trap culminations

Location and Regional Tectonic Framework

- Pakistani basins have acquired their primary structural and stratigraphic features from events associated with plate dynamics that occurred since Pre Cambrian to present
- Since Eocene, continued under-thrusting of Indo-Pakistani Plate beneath the Eurasian Plate produced the spectacular mountain ranges of Himalayas and a chain of foreland fold-and-thrust belts as thick sheets of sediments thrust over the Indian Craton
- Trans-Indus ranges constitute the mobile flank of Kohat and Potwar fold and thrust belt and is mostly characterized by decollement thrust-fold assemblages
- The recent most thrusting is believed to have occurred along the frontal thrust system in the Salt Range to the east and in the Trans-Indus Ranges to the west
- It has been interpreted that along Trans-Indus ranges major convergence started at ~ 1 Ma and has accommodated about ~10 km of shortening





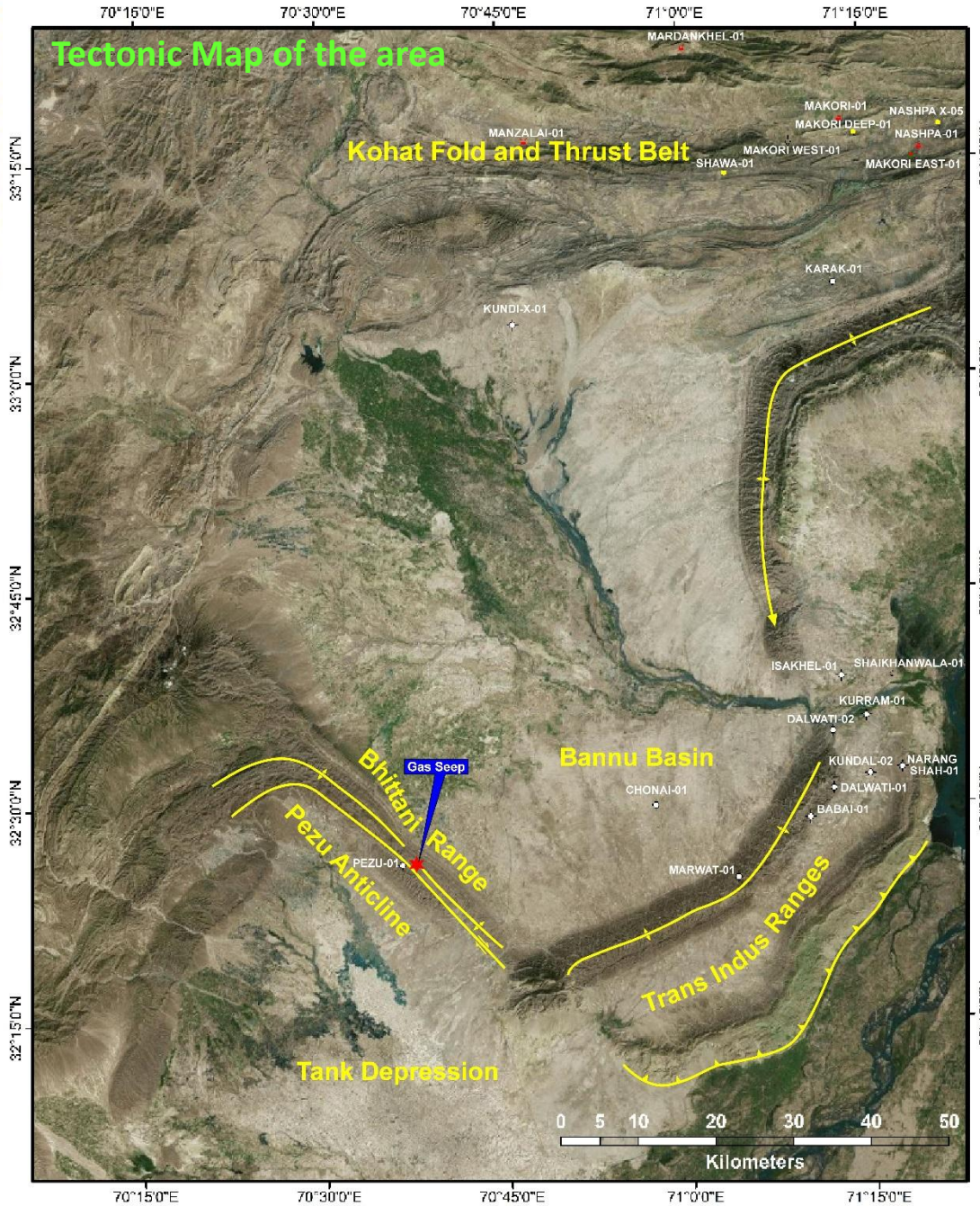


Introduction

- Pezu - Bhittani Range represents the leading deformational front of the Kohat fold and thrust belt believed to be the most recent thrusting phase

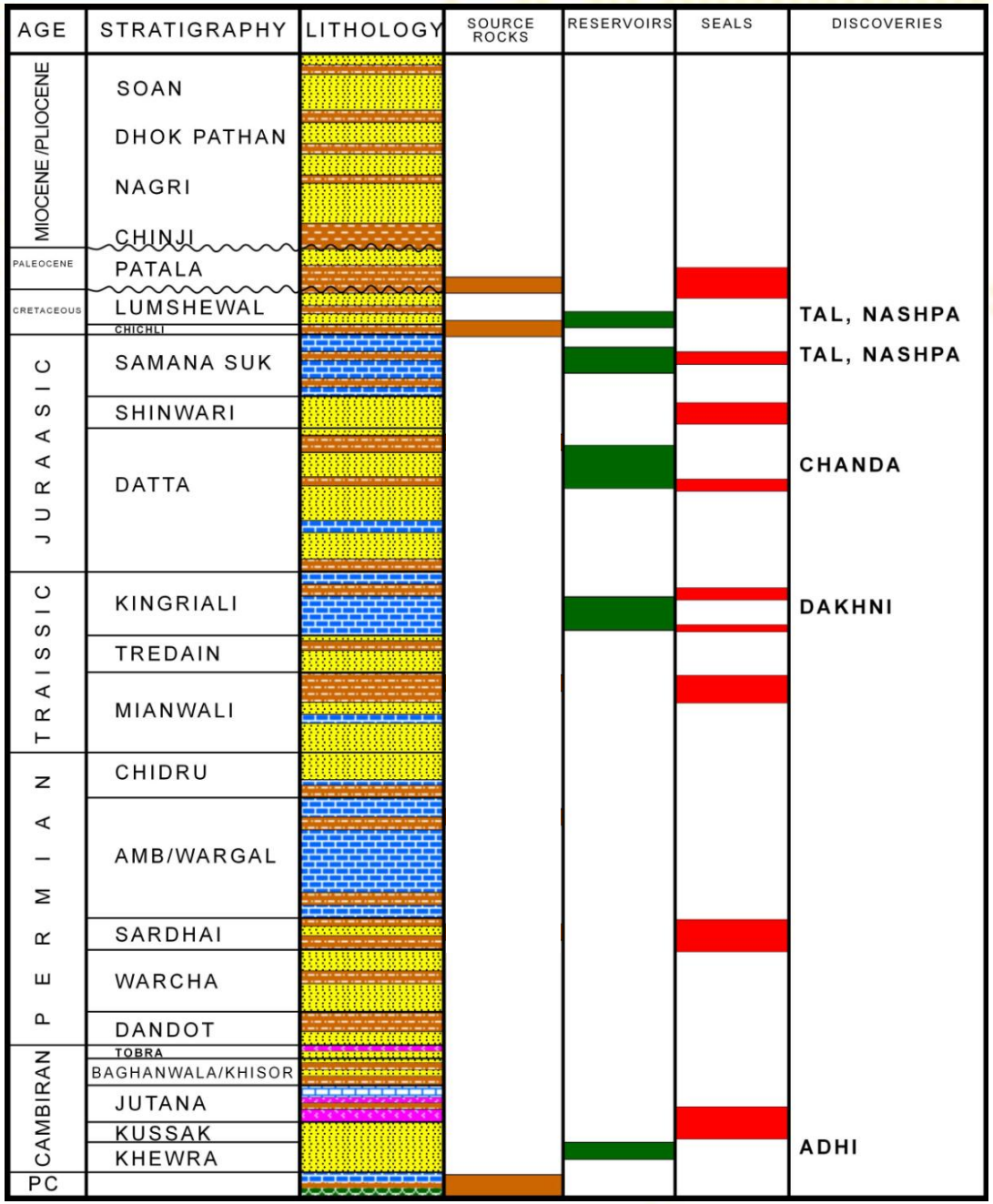
- It is a structural high interpreted as a complex pop-up bounded on each side by steeply dipping reverse faults

- A gas seep is present in Bhittani Range which confirms maturity of source rocks and subsequent migration of hydrocarbons



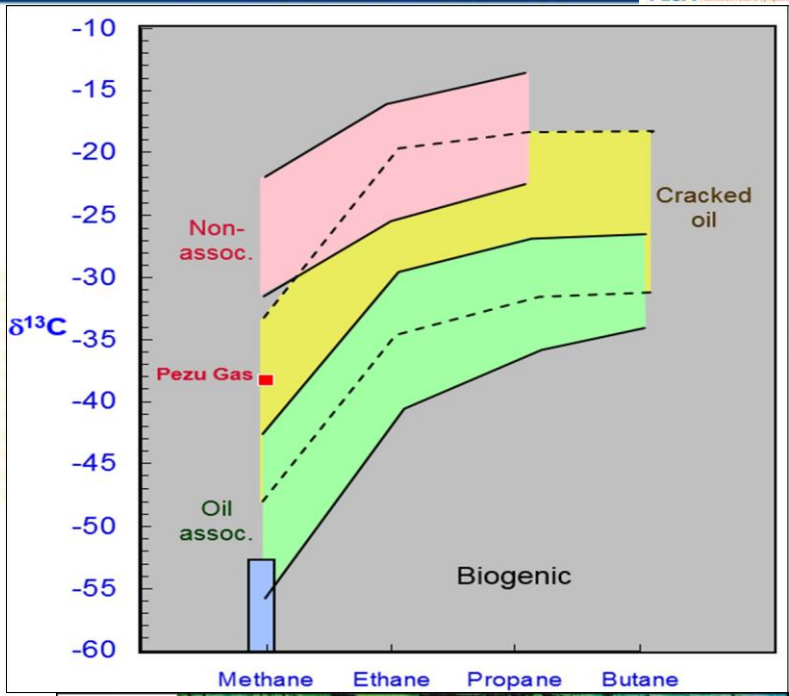
Petroleum Play and Stratigraphy

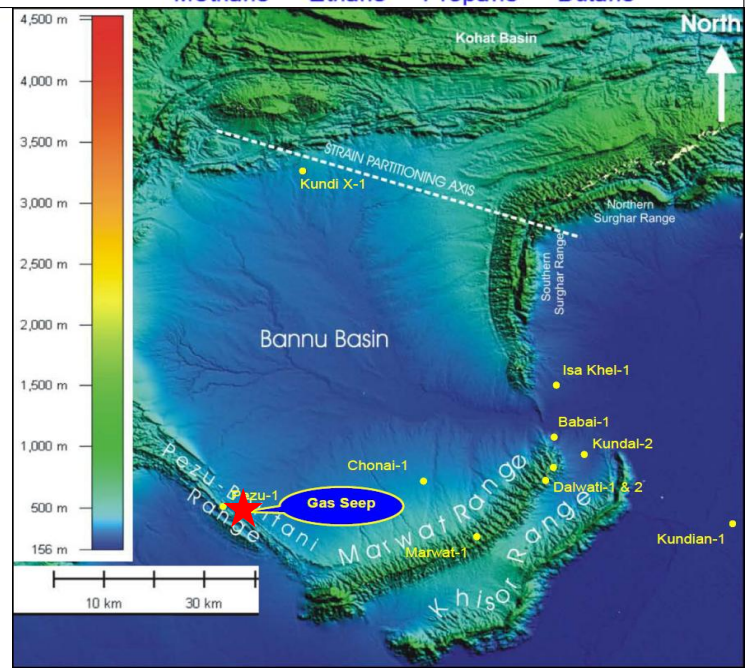
- **SOURCE**
  - Patala — Paleocene
  - Chichali — Cretaceous
  - Salt Range — Precambrian
- **RESERVOIR**
  - Lumshiwal — Cretaceous
  - Samanasuk — Jurassic
  - Datta — Jurassic
  - Kingriali — Triassic
  - Khewra — Cambrian
- **SEAL**
  - Kussak, Sardhai, Mianwali, Patala & Intraformational Shales
- **TRAP**
  - Anticlinal / Fault associated



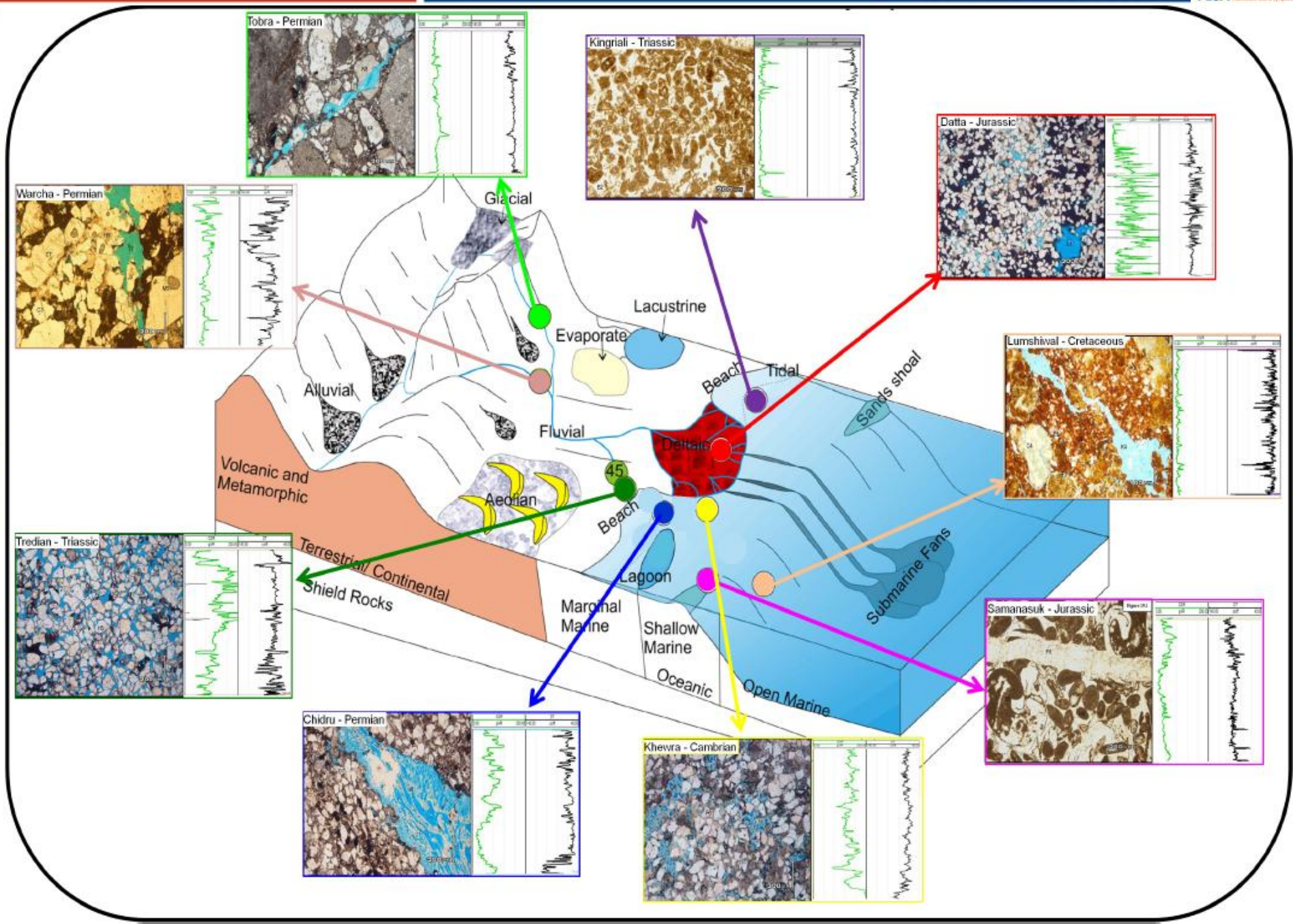
An Active Gas Seep

- Gas seep in Bhittani Range confirms maturity of source rocks and subsequent migration of hydrocarbons
- It is dry gas mainly composed of Methane (86.9%) derived from a deep thermogenic source, Nitrogen (12.7%), very little carbon dioxide, along with ethane and higher hydrocarbons
- The gross heating value is 884 Btu / cubic feet
- The C^{13}/C^{12} isotope ratio corresponds to that of gas generated from thermal cracking of oil, which implies that the source rock is of kerogen type I & II
- There may be some oil associated with gas



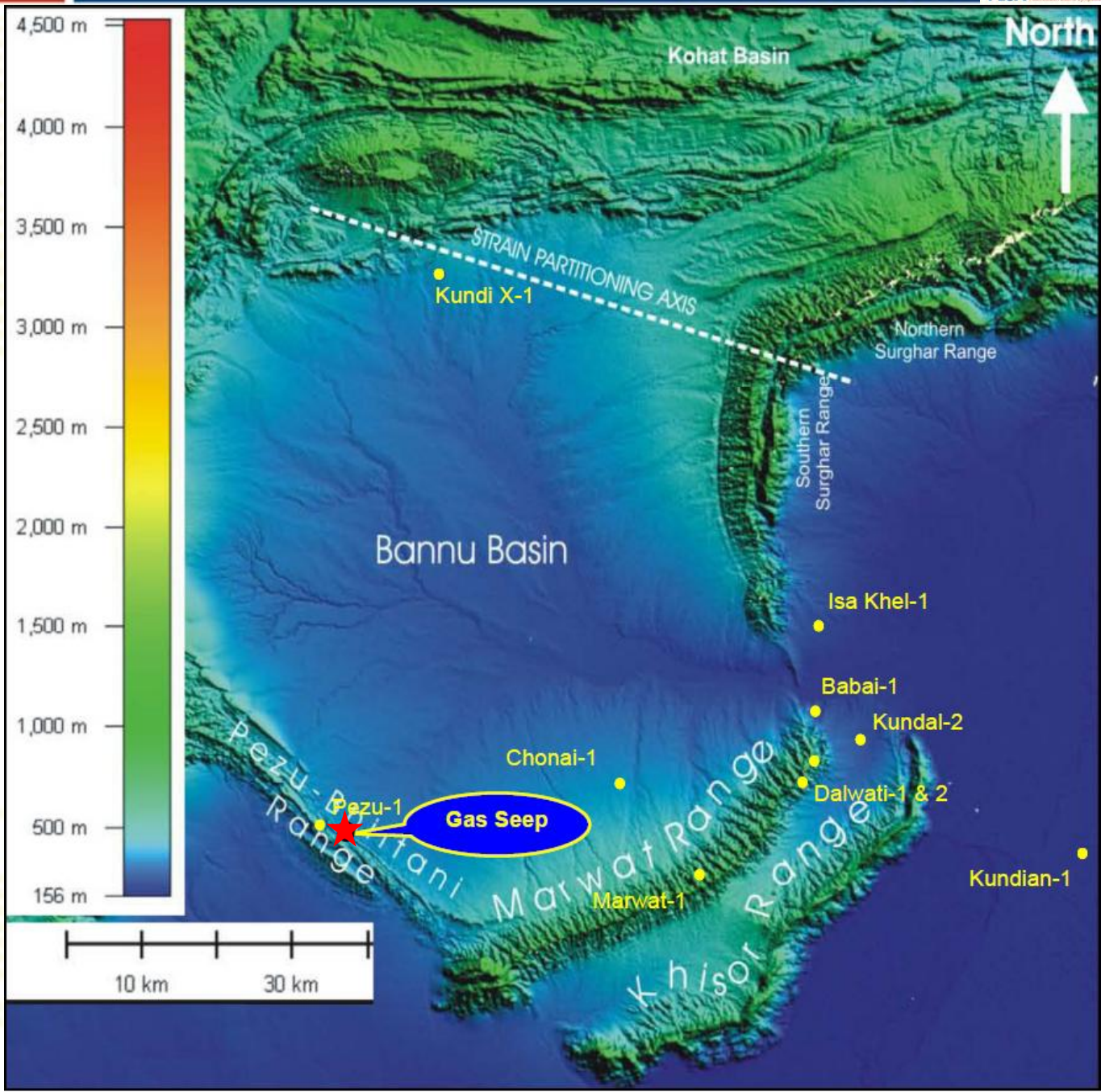


Quality of Multiple Reservoirs



Exploration History

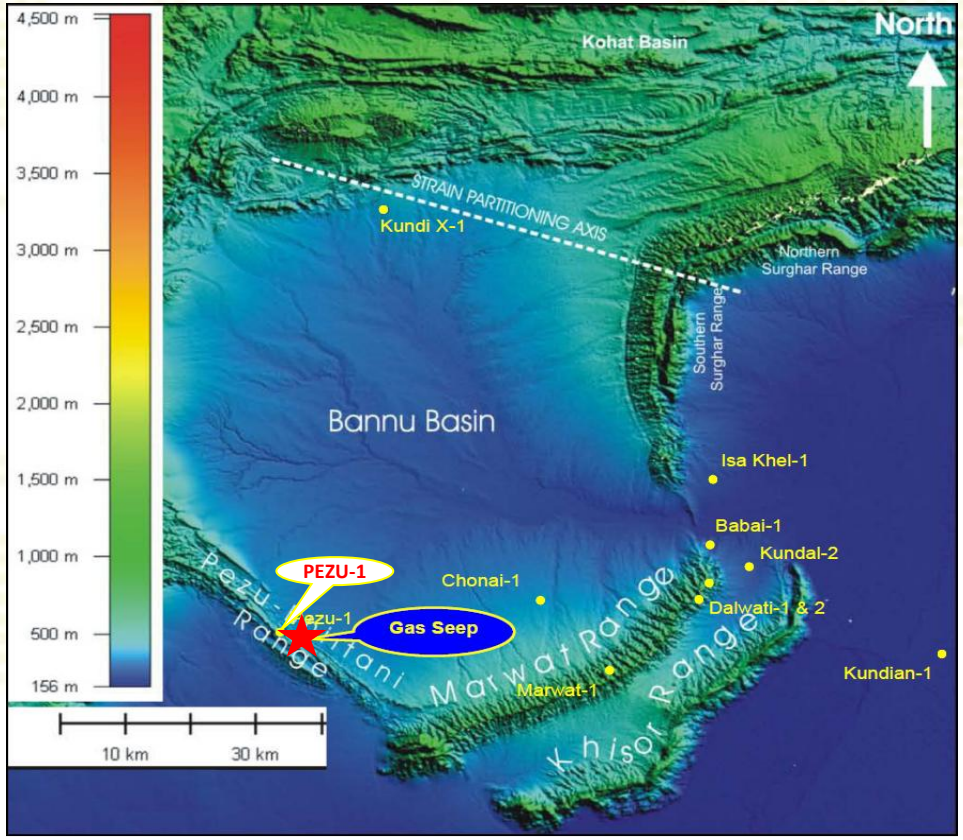
WELLS (YEAR)	TD (m)	Formation @ TD	REASONs OF FAILURE / REMARKs
Kundi X-1 (1994)	6,400	Panoba Cretaceous	Abandoned: Target (Eocene) was not Encountered due to greater thickness of Siwaliks / Kamlial
Isakhel-1 (1993)	4,680	Khewra Cambrian	Abandoned: Fault breaching
Chonai-1 (1990)	3,902	Mianwali Triassic	Abandoned: Shows during drilling, Size of structure is very small
Marwat-1 (1970)	2,210	Khisor Gyp Cambrian	Abandoned: Off structure , no seismic coverage
Pezu-1 (1969)	2,222	Datta Jurassic	Abandoned: Off structure , DST flowed water with minor solution gas
Kundian-1 (1965)	2,160	Jutana Cambrian	Abandoned: DST flowed water. Structural integrity and top seal absent
Babai-1 (1932)	735	Jurassic?	No well data & Seismic coverage
Dalwati-2 (1930)	797	Jurassic?	
Dalwati-1 (1927)	1,116	Siwalik ?	
Kundal-1 (1866)	-	-	



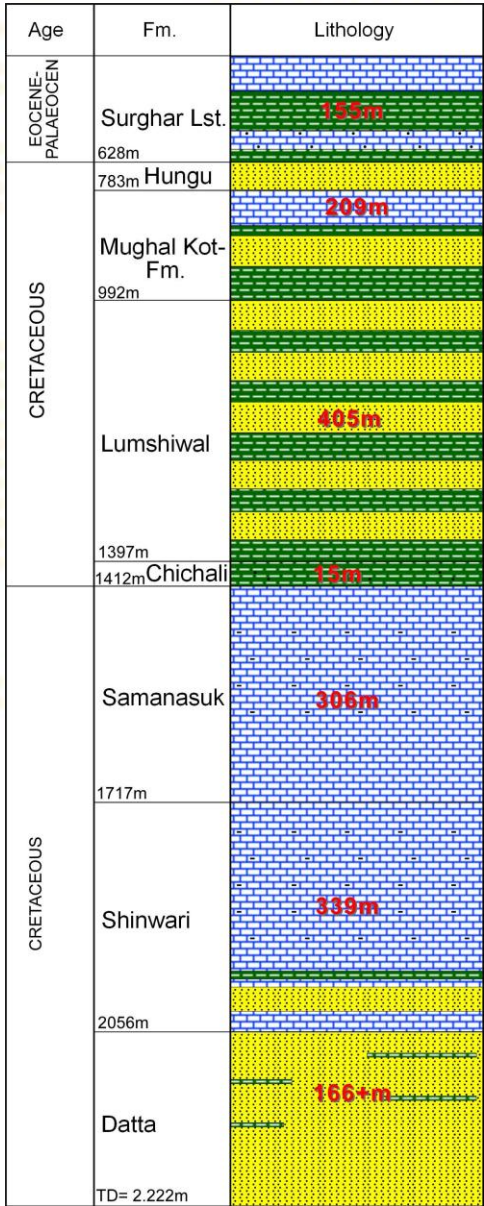
Exploration well – Pezu-1

- Drilled in 1969 based on surface geology
- Drilled down to 2222m in Datta Formation of Jurassic age.
- Drilling results confirmed presence of good quality reservoir seal pairs in clastics of Cretaceous and Jurassic formations which could be charged from adjacent basin

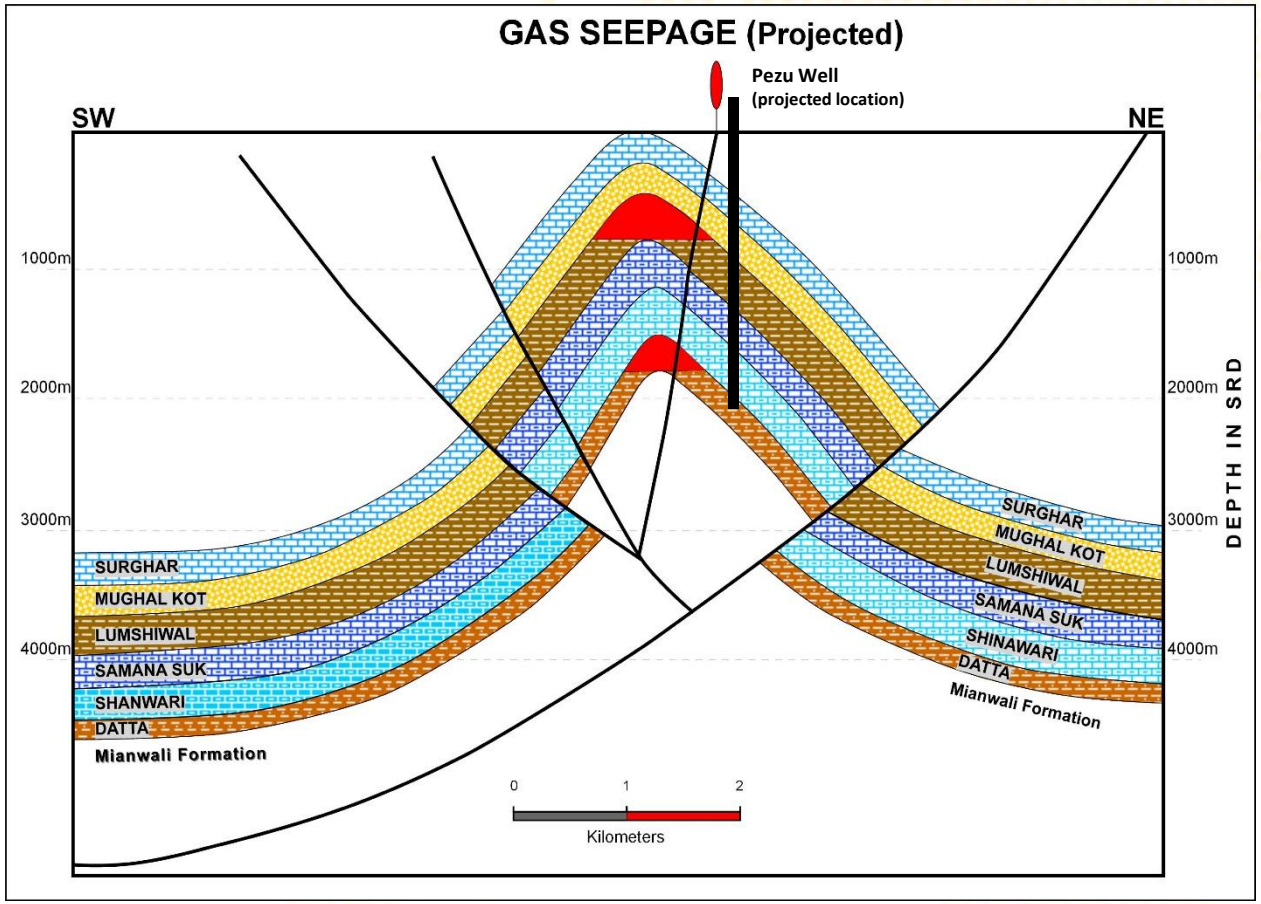
DST Results		
Perforated intervals (m)	2062 - 2065	2014 - 2016
		2017 - 2021
Formation	Datta	Samanasuk
Fluid	Water with surging solution gas (combustible)	

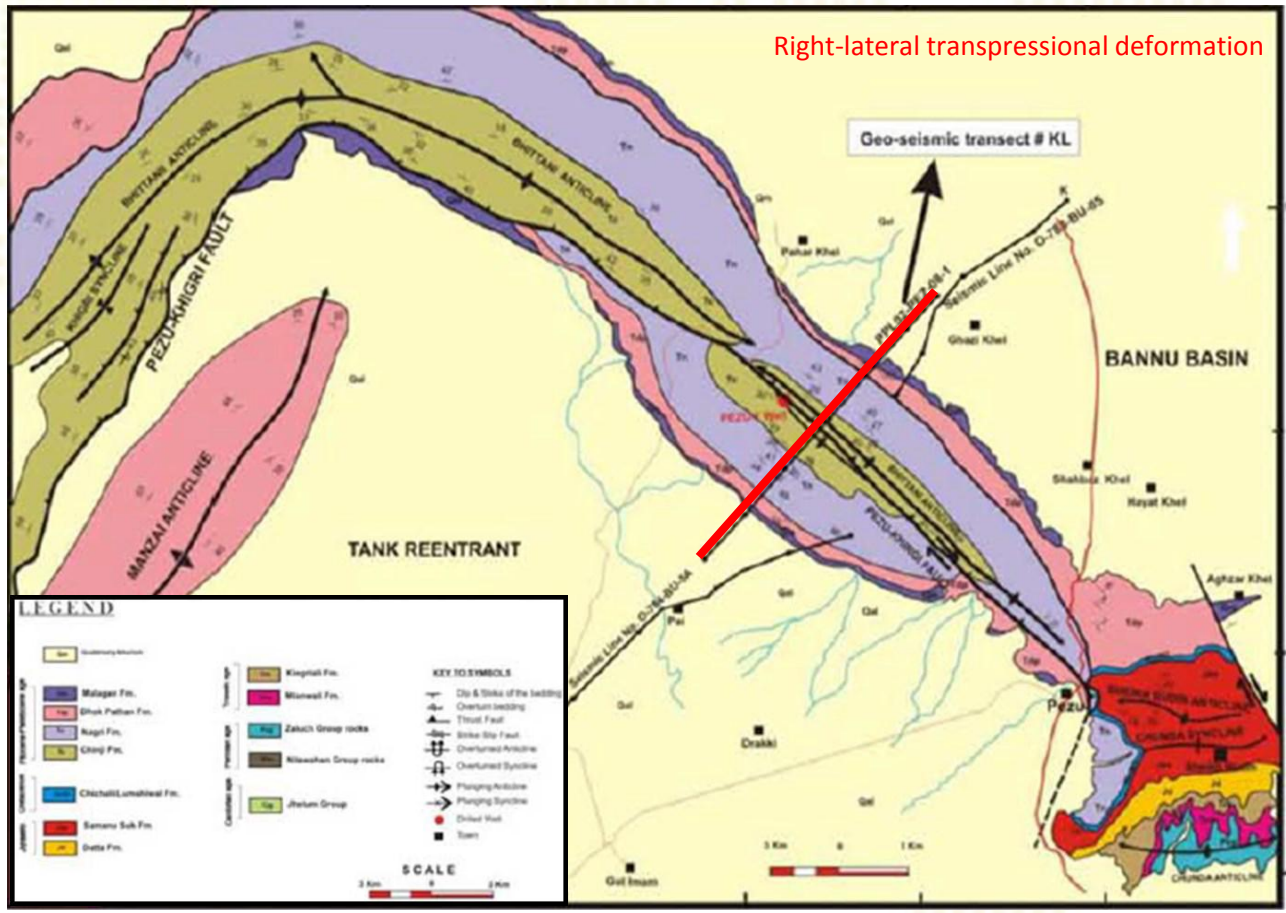


Pezu – 1 (1969)



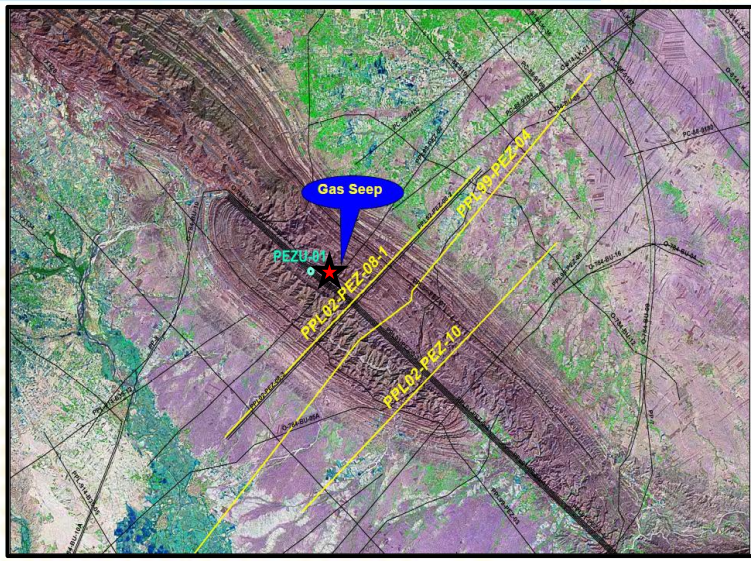
Generalized Structural Models based on surface geology



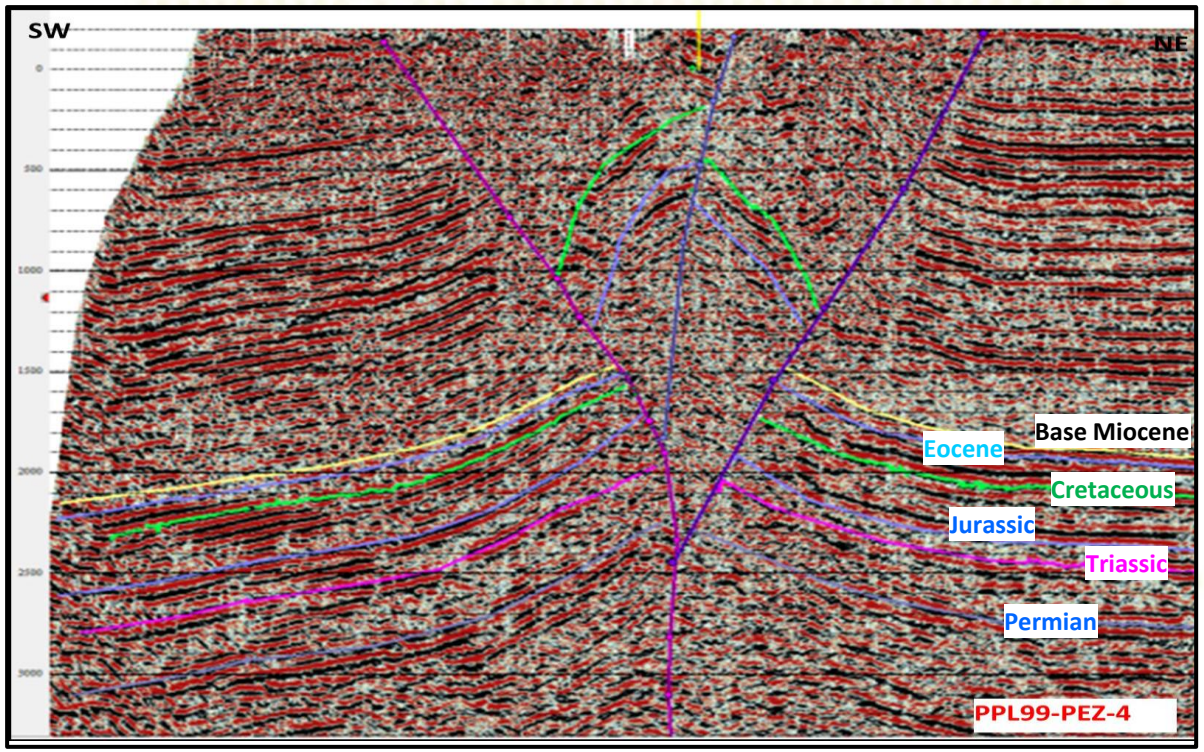


Trap Complexity and Challenges

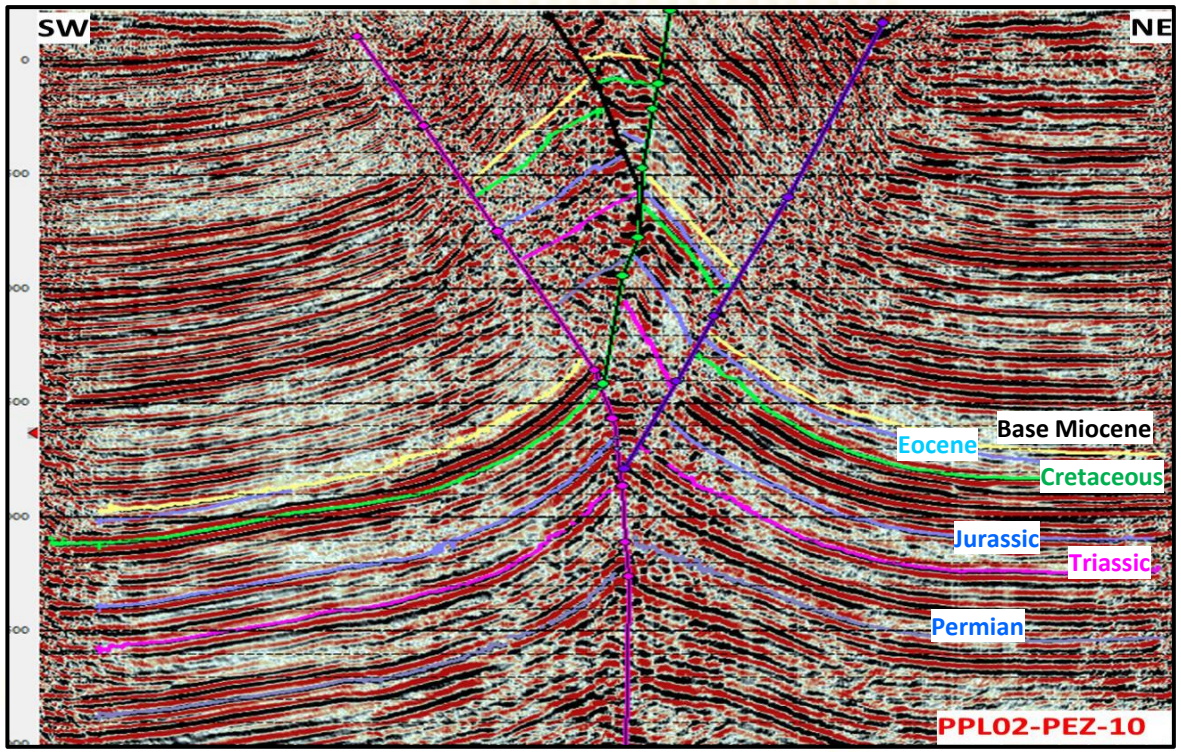
- Post drill seismic reveal steeply dipping reverse faults that pop-up central part
- Quality of vintage seismic may lead to over simplification of a complex structure which may lead to inapt understanding



Vintage seismic (1999)

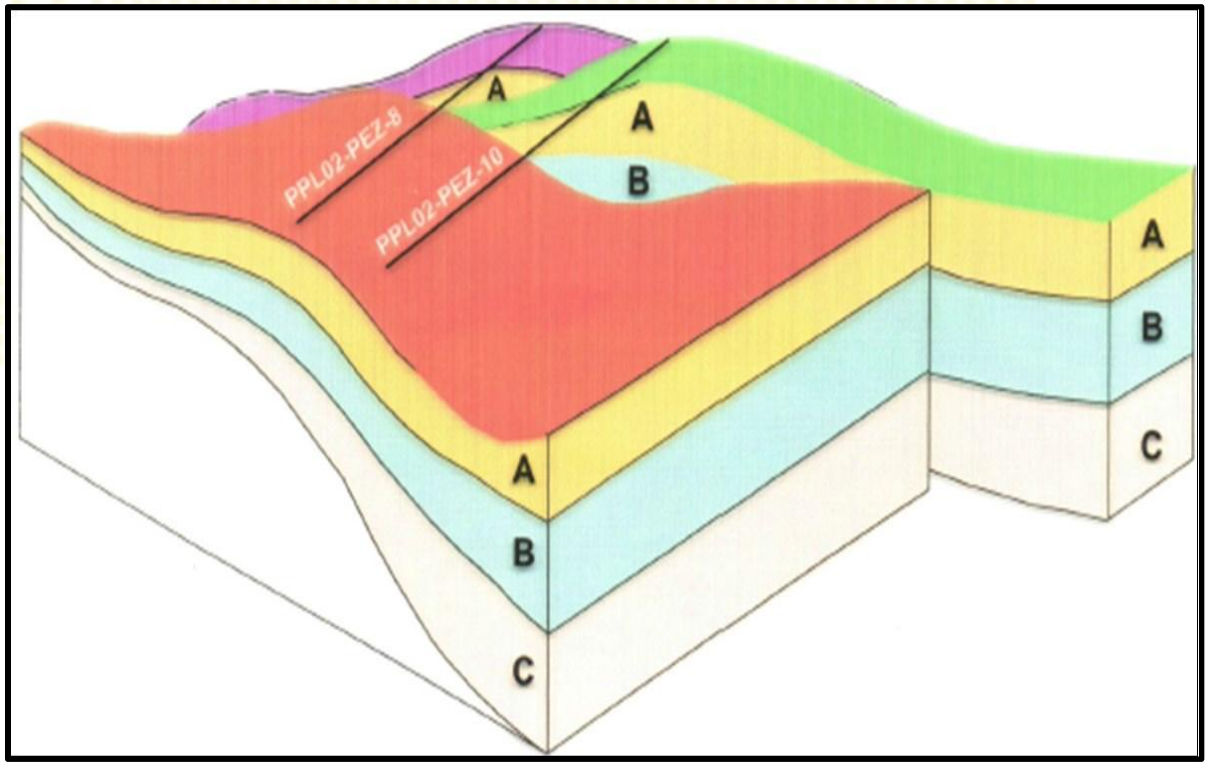


New seismic (2002)

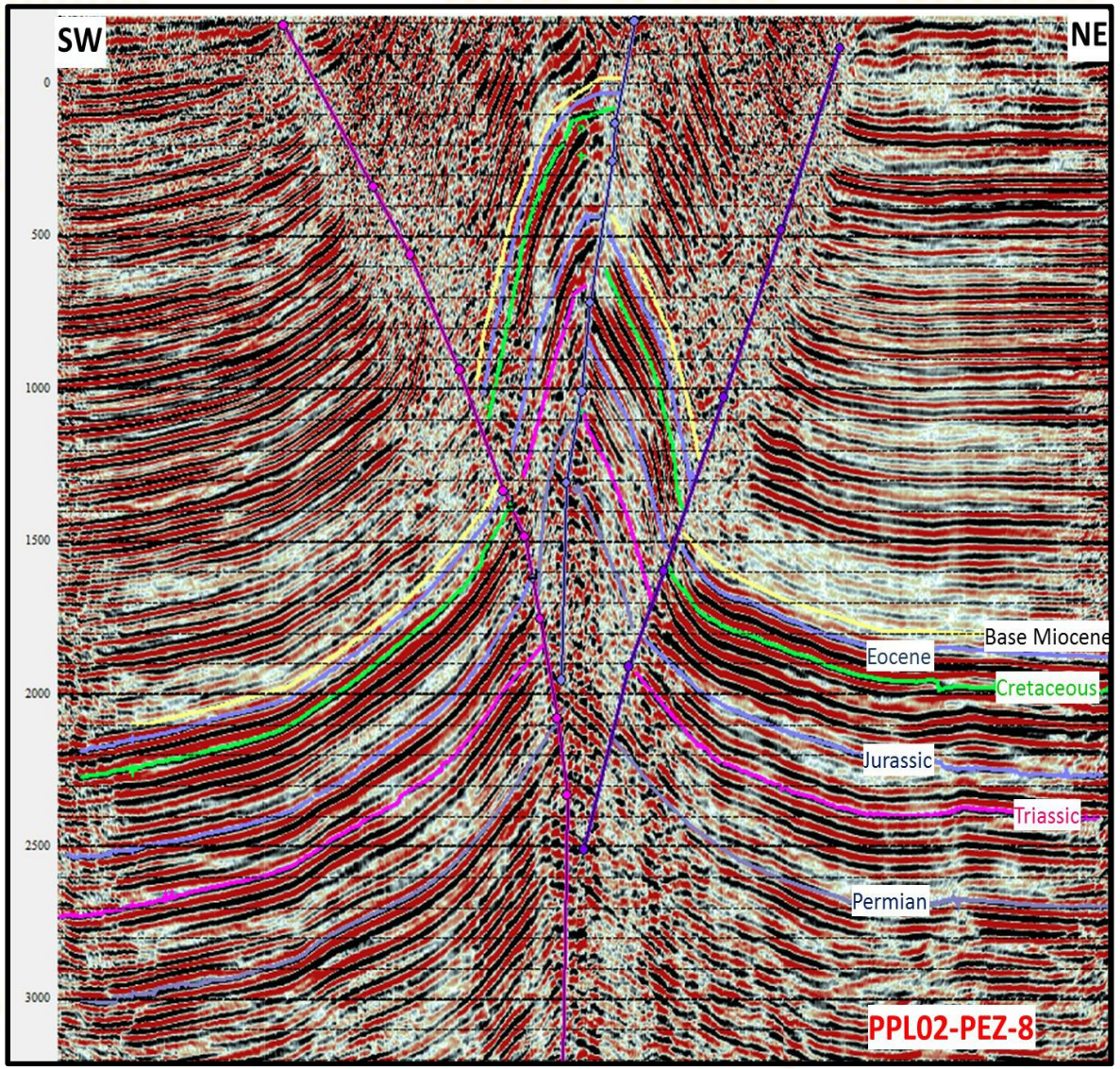


Trap Complexity and Challenges

- New seismic with advanced processing reveals complexity of structure
- The most likely traps of supra-thrust and sub-thrust structural geometry may be much complex as strike-slip fault mapped on surface is not properly imaged by seismic

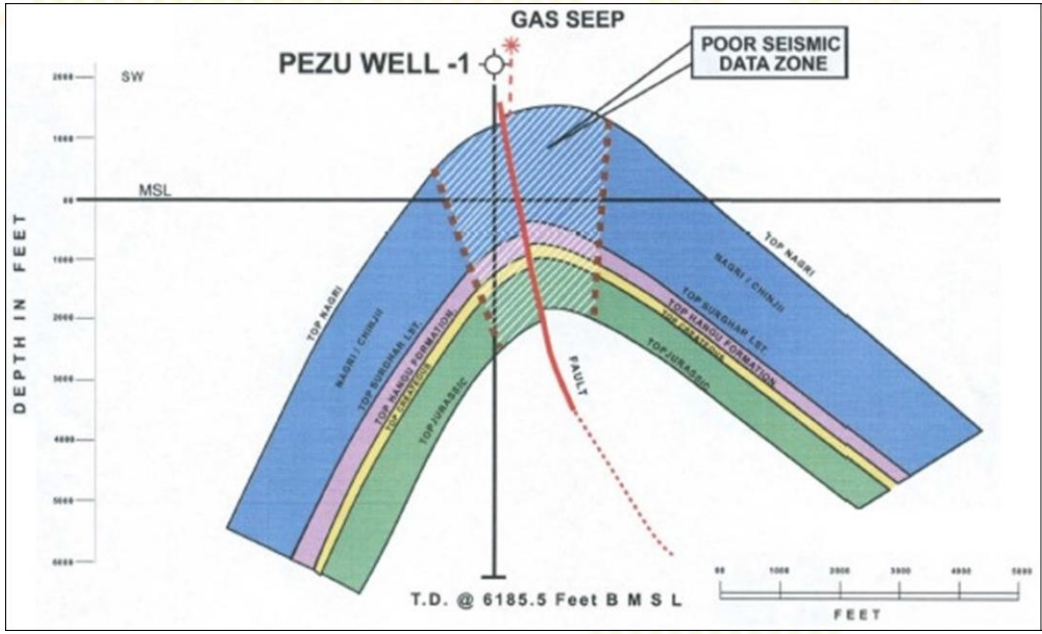


New Seismic (2002)



Conclusions

- Fold and thrust belts are challenging frontiers for hydrocarbon exploration because of complex / uncertain structural geometry
- Structure drilled decades back based on surface geology with lack of quality seismic data; hence region still unexplored / under explored
- This area, with working petroleum system is a promising hydrocarbon exploration target but uncertain trap definition
- Complex structural geometry leads to meager quality of seismic data
- Proper imaging of subsurface is required by advanced geophysical work (including processing) to determining size and location of structures / trap



Acknowledgement

We thank to Management of Pakistan Petroleum Limited for allowing to present this paper

We are also indebted to our co-workers who reviewed this work critically and provided useful input to improve it

THANK YOU