

Exploration Strategies for Frontier Hydrocarbon Plays in the Western basins of South Asia in low price environment

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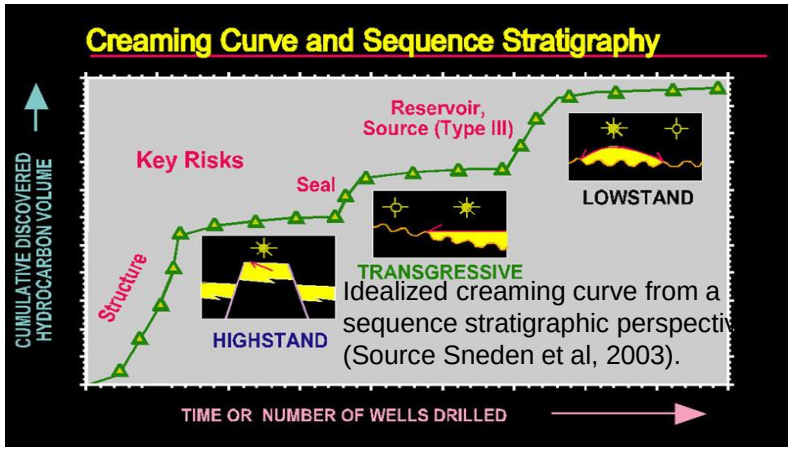
THINK. CREATE. MOVE.

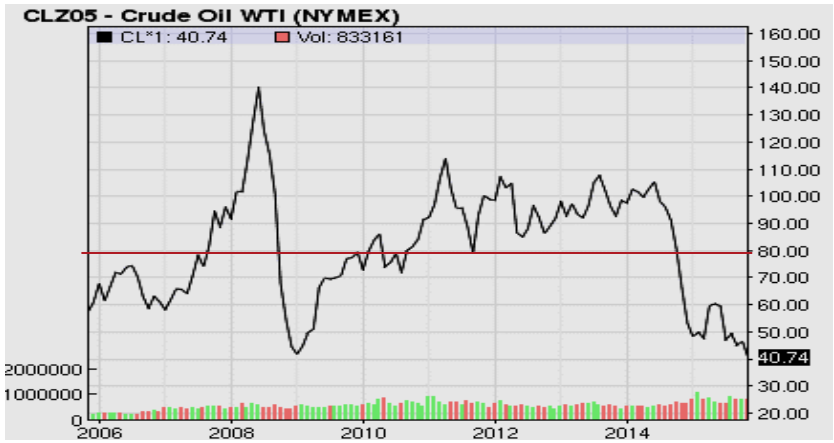
New Millennium's Exploration Paradigm and Performance

Exploration Performance: Success/Failure History and Lessons Learnt

- Seven long years of $80-100/bbl oil price -> lucrative economics of prospects/ projects,
- Exploration ventures in geologically complex, environmentally sensitive, technology intensive, and geographically remote & difficult areas at high finding costs ($6 - $15/boe),
- Exploration Performance of the basins significantly improved in last 2 decades. Factors:
  - Early understanding of the Play, its key uncertainties and technologies needed to de-risk/ discover,
  - Deploying key technologies in timely and operationally effective manner.
- Success of Deepwater exploration and North American Tight Oil/Shale Gas Plays increasingly flooded the markets - oil glut of over 3 Billion barrel,
- Predicted time of Hubert's peak passed? New Oil- abundant, waiting to be developed!
  - 350 Billion boe discovered in last decade as compared to 120Bboe in 1991-2001.
  - 200Bboe in 91 Elephants. Mostly in previously inaccessible areas or geological settings.



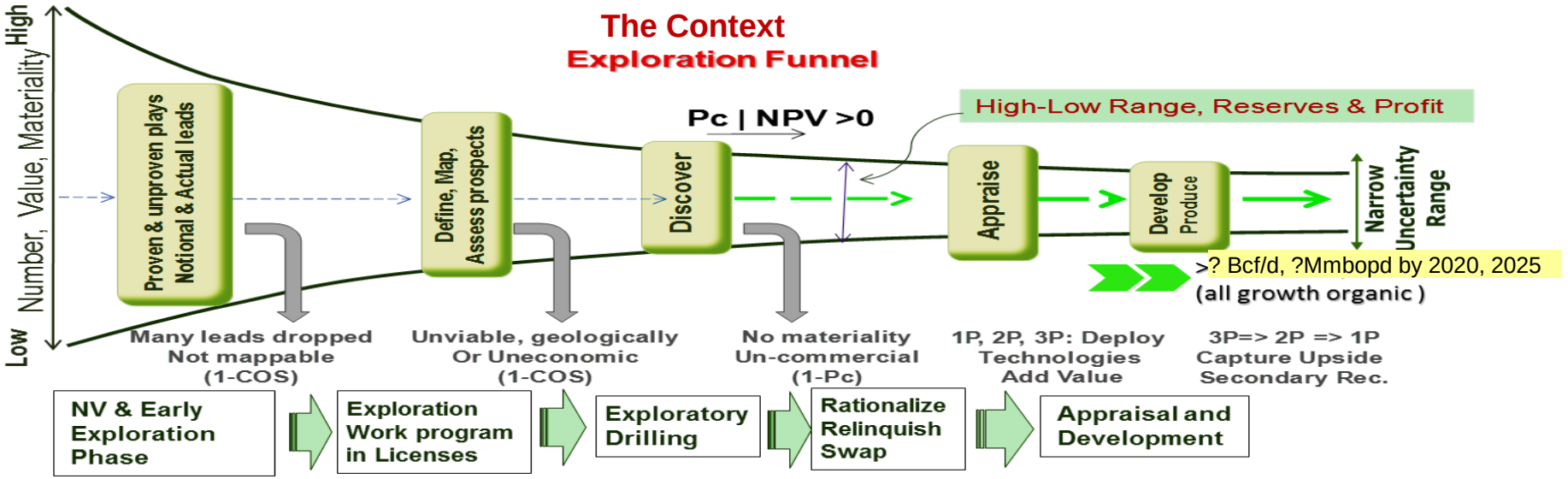
Idealized creaming curve from a sequence stratigraphic perspectiv (Source Sneden et al, 2003).



Modern Exploration History – What it means for Future Exploration Performance & Targets

Modern Exploration History – What it means for Future

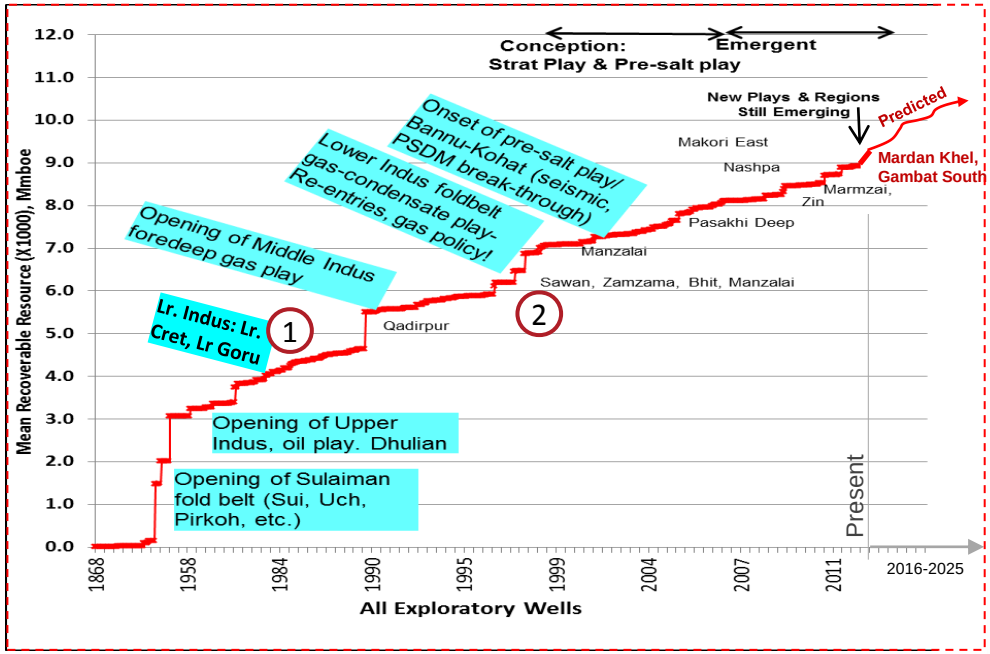
- Implications for the Future, Window of Opportunity:
  - Must redefine efficiency in terms of operating performance, building resilient portfolio and robust economics projects (vis-à-vis neutral cash flows),
  - Like the Unconventionals' exploitation starting in early 2000s (low oil price times), opportunity to exploit **previously less understood Plays** having **smaller Prospect sizes** due to lower operating cost, improved operating efficiency and technologies availability (at lower cost).
- Identify (differentiate) the maturing and emergent Plays & Basins – use wells' statistics and Success-Failure Analysis, Early acreage capture, and periodic relinquishments
- Diversify portfolio, JV Partnerships, Technology Partnerships (IOCs & Service Companies),

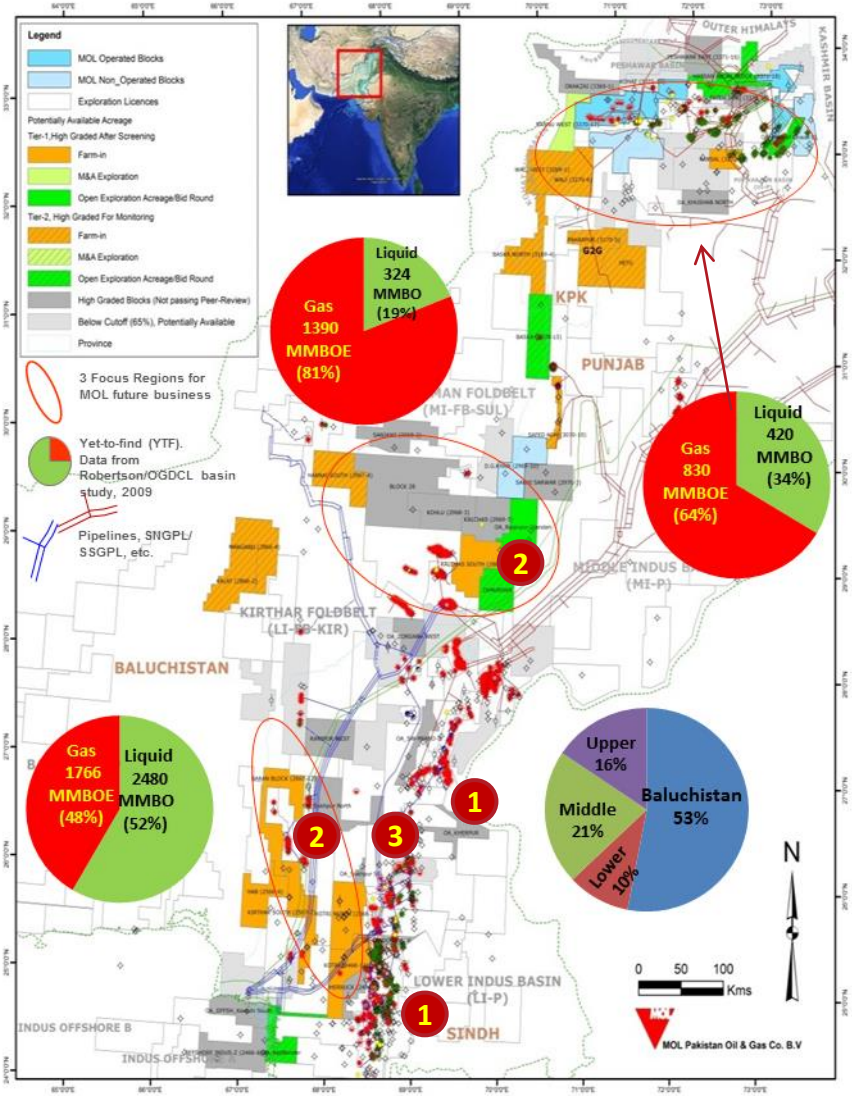


Basins and Plays of Interest with Creaming Curve and Yet-to-find (YTF)

1. Lr. Cretaceous, Lr. Goru Play (Detached shoreface regressive sands (proven)
2. Upper Cretaceous – Lr. Paleocene Progradational Deltas and Turbidite Lobes (proven)
3. Lr. Eocene Lowstand Carbonate wedges (unproven)

- Significant Yet-to-find, (Map)
- North: mainly oil & gas-condensate, Mid: mainly gas, South: oil & gas with condensate

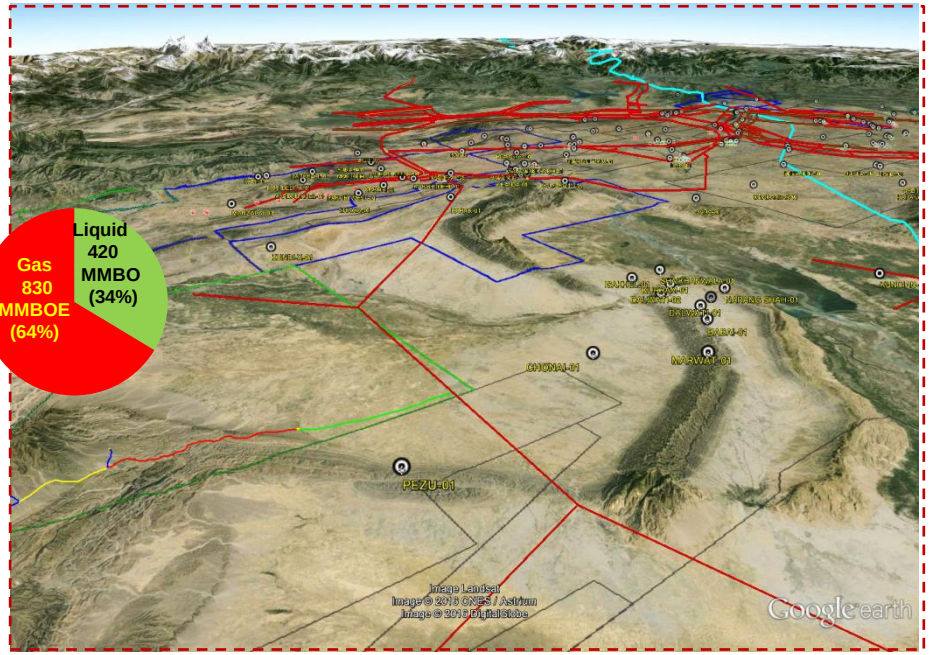


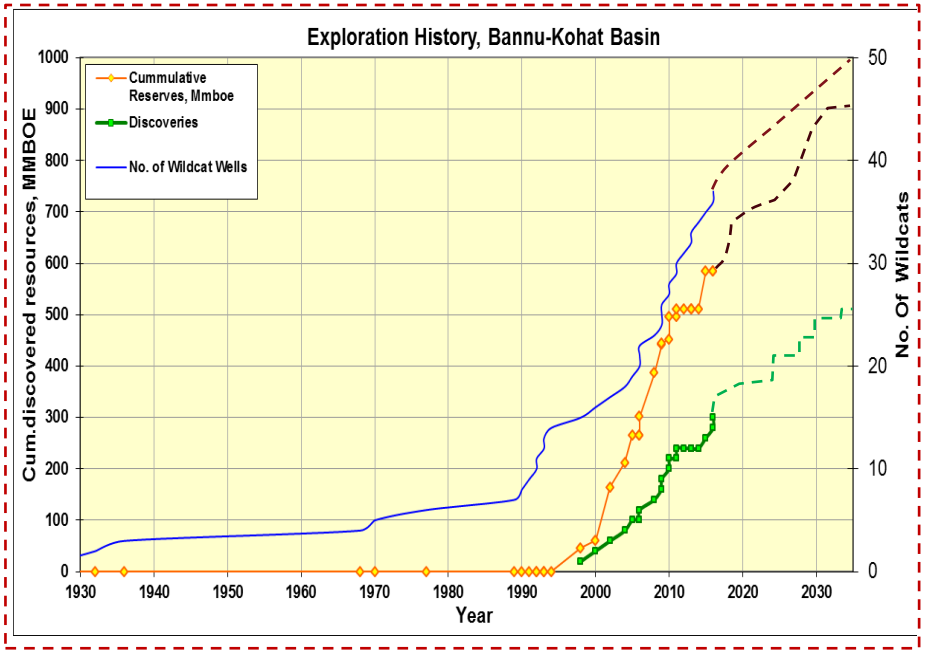


Upper Indus: Bannu-Kohat Basin

Opening of a New Basin, New Play: Cream of the Crop

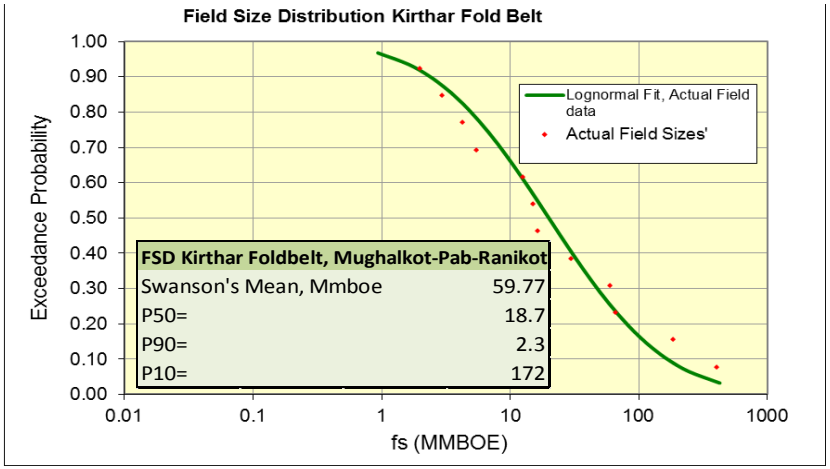
- A story of perseverance! First well: Dalwati-1 in 1937, First discovery in 1999 in the 15th well!
- 1957-1980: 2 seismic surveys, 3 wells, all dry. First generation seismic used- Karak-1 (1977).
- 1980-1990: > 10 seismic surveys, 3 wells, all dry,
- 1990-1998: > 5 seismic surveys, 5 wells, all dry. AMOCO deployed 2nd Generation seismic with PreSTM processing and workstation based workflows,
- First discovery at Chanda-1, followed by Manzala!
- PSDM, imaging below thick salt /diapiric mudstones!



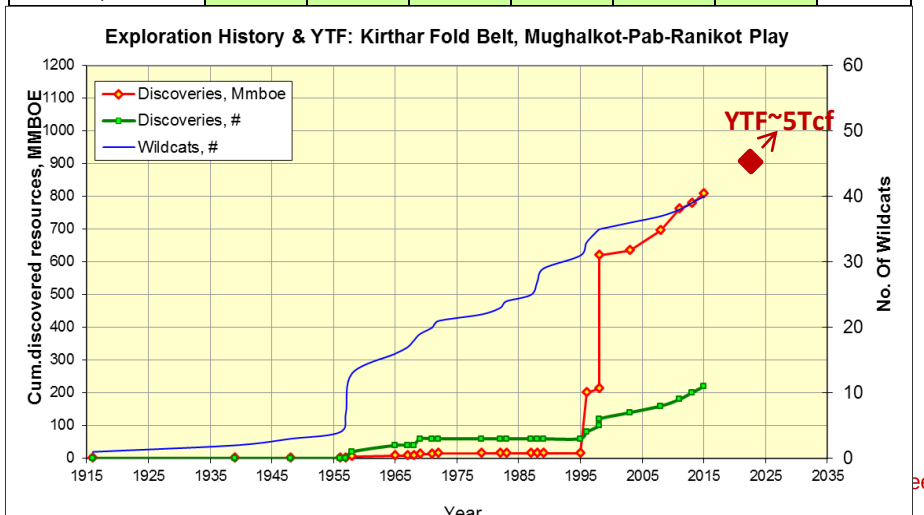


Play Statistics, Yet-to-find (YTF)

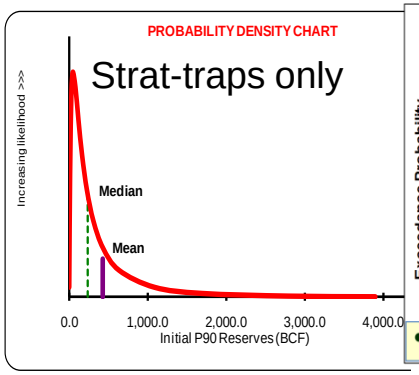
U. Cretaceous/Paleocene Play

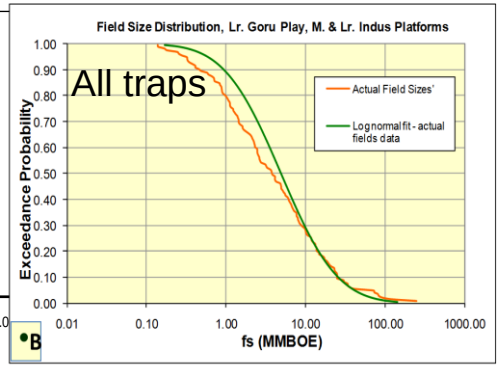


Classes/ range	1 - 5	5 - 10	10 - 50	50 - 100	100 - 200	200 - 300	
Modelled volumes	16.58578	29.86316	307.9125	211.5772	404.5675	672.9374	
Actual volumes discovered	9.27	5.53	74.10	126.70	186.50	406.58	
YTF, Mmboe	7.32	24.33	233.81	84.88	218.07	266.36	**834.77**
Modelled discoveri.	6	4	12	3	3	2	
YTF fields, #	2.648334	3.258841	9.112167	1.203493	1.617042	0.791626	**18.63**



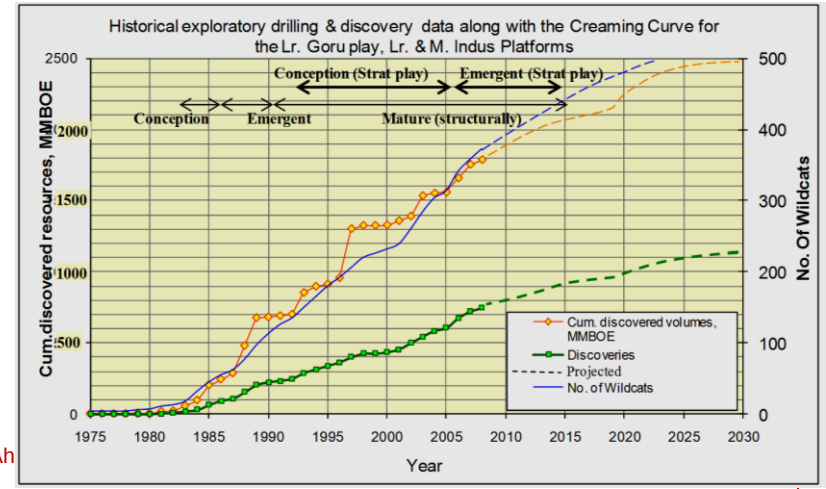
Lr. Cretaceous, Lr Goru Play. YTF in Comb. & Strat traps





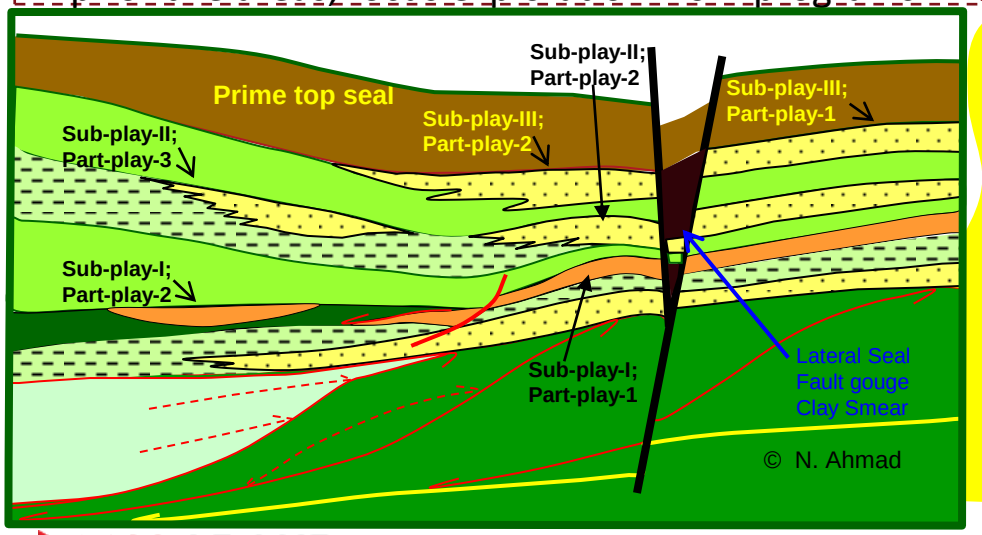
Strat-traps only

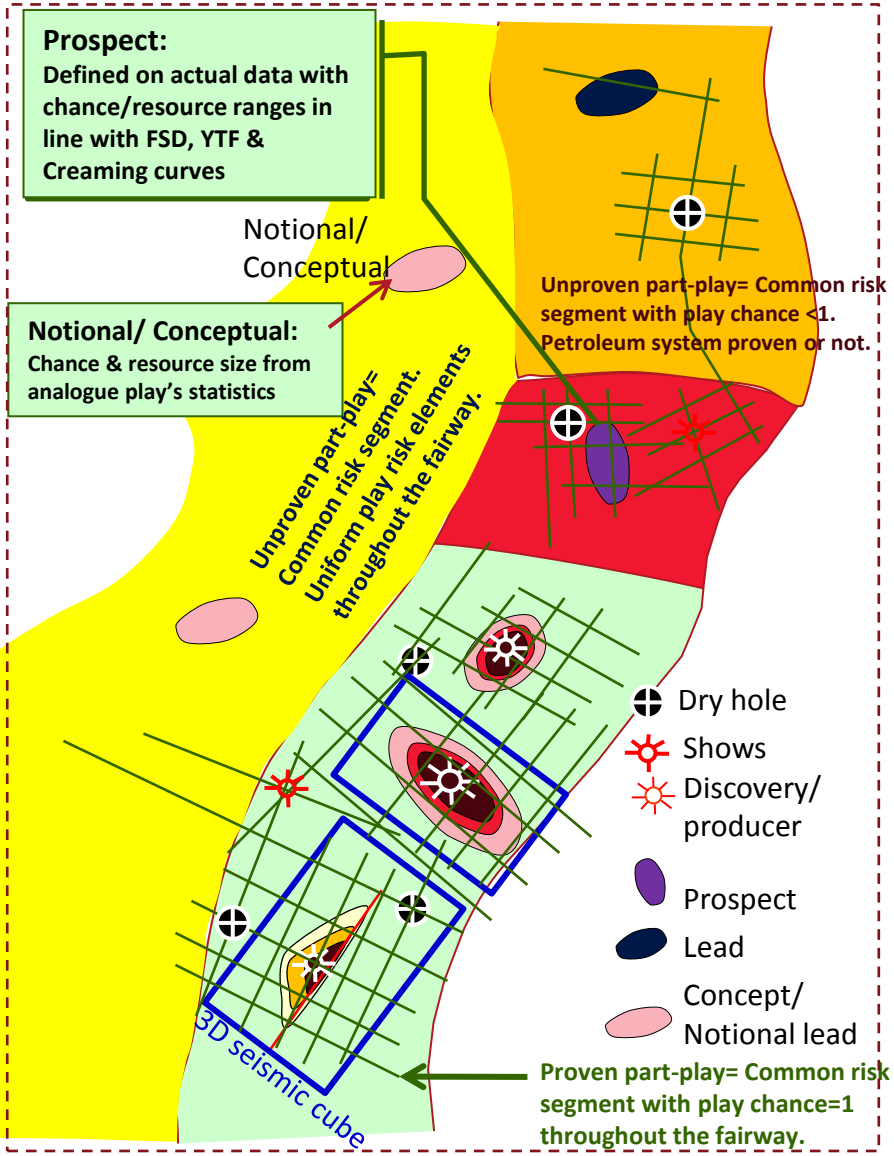
Classes, MMBOE	1 - 10	10 - 50	50 - 100	100 - 200
Actual found	0	57.25	159.80	250.00
Modelled, MMBOE	7.22	280.18	283.00	575.59
# of Finds, actual	0	3	2	1
# of Finds, Modelled	1	10	4	4
YTF, MMBOE		222.93	123.20	325.59
New Pot. Finds	1	7	2	3



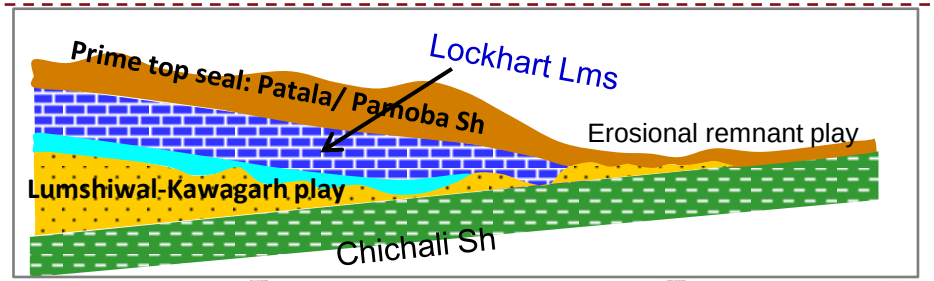
Play and Play Fairway for Portfolio based Exploration: Definitions, Workflow

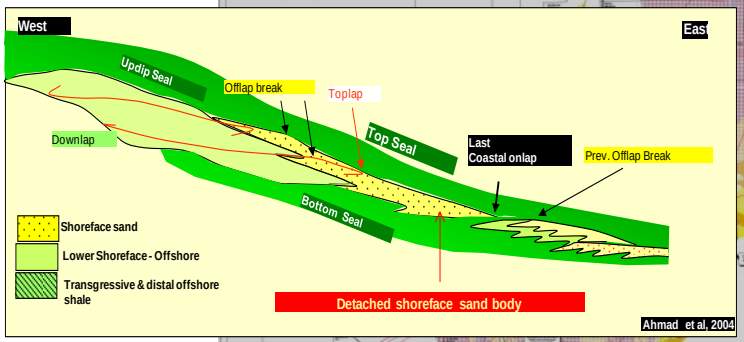
- Play, conventional approach – Reservoir focus
- In hierarchical framework of petroleum system
- Play: a **reservoir-seal Pair**, stretched over basin:
  - Pair of Reservoir and its genetically associated top seal in hierarchical sequence stratigraphic framework
  - Specific spatial and temporal arrangement
  - Prospects have a shared mechanism/ arrangement of migration pathways, Containment
  - **Part-play:** Proven & Unproven
  - **Sub-play:** Proven & Unproven
- Common Risk Segment (CRS) maps of each element
- Composite CRS (CCRS) map of a Play Fairway, to prioritize areas, focus exploration work programs.



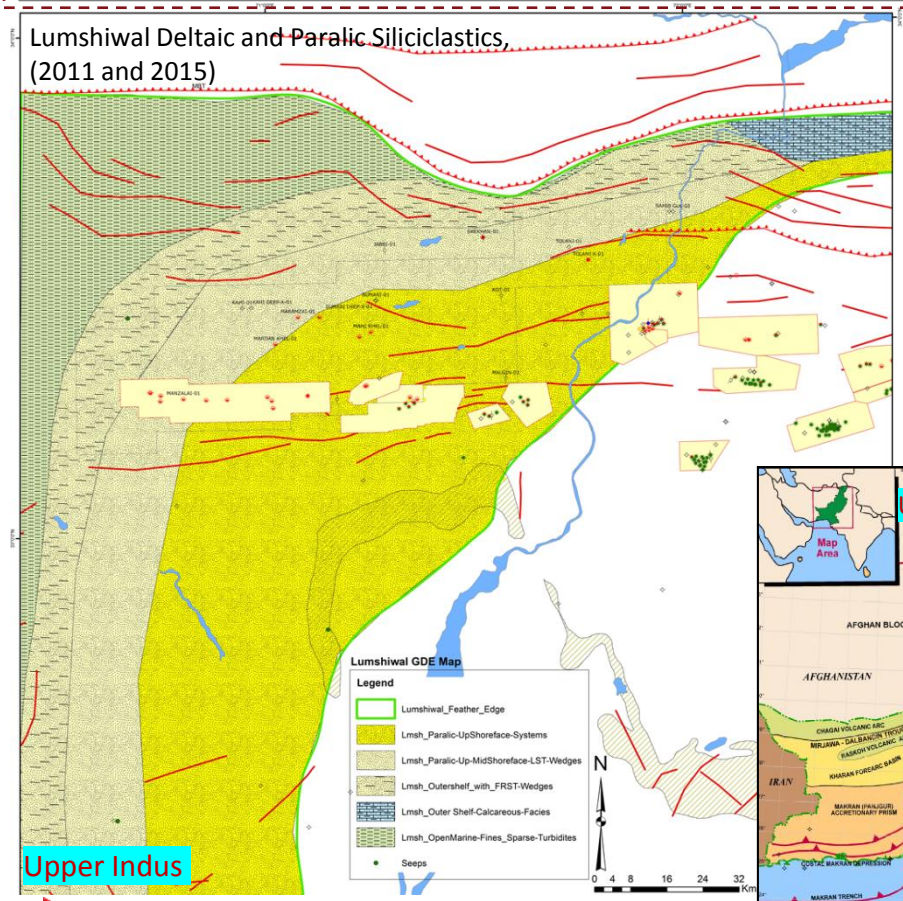


1 PFA – Mapping, Extending from the same age analogue Play Fairway in South: Lr. Goru and Lumshiwal Reservoir CRS, Upper Goru marls and Kawagarth Marl-Limestone Seal CRS





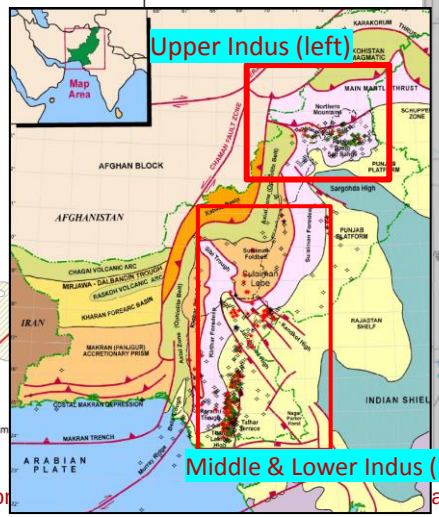
Lumshiwal Deltaic and Paralic Siliciclastics, (2011 and 2015)



Upper Indus

Middle & Lower Indus (Right)

Upper Indus (left)

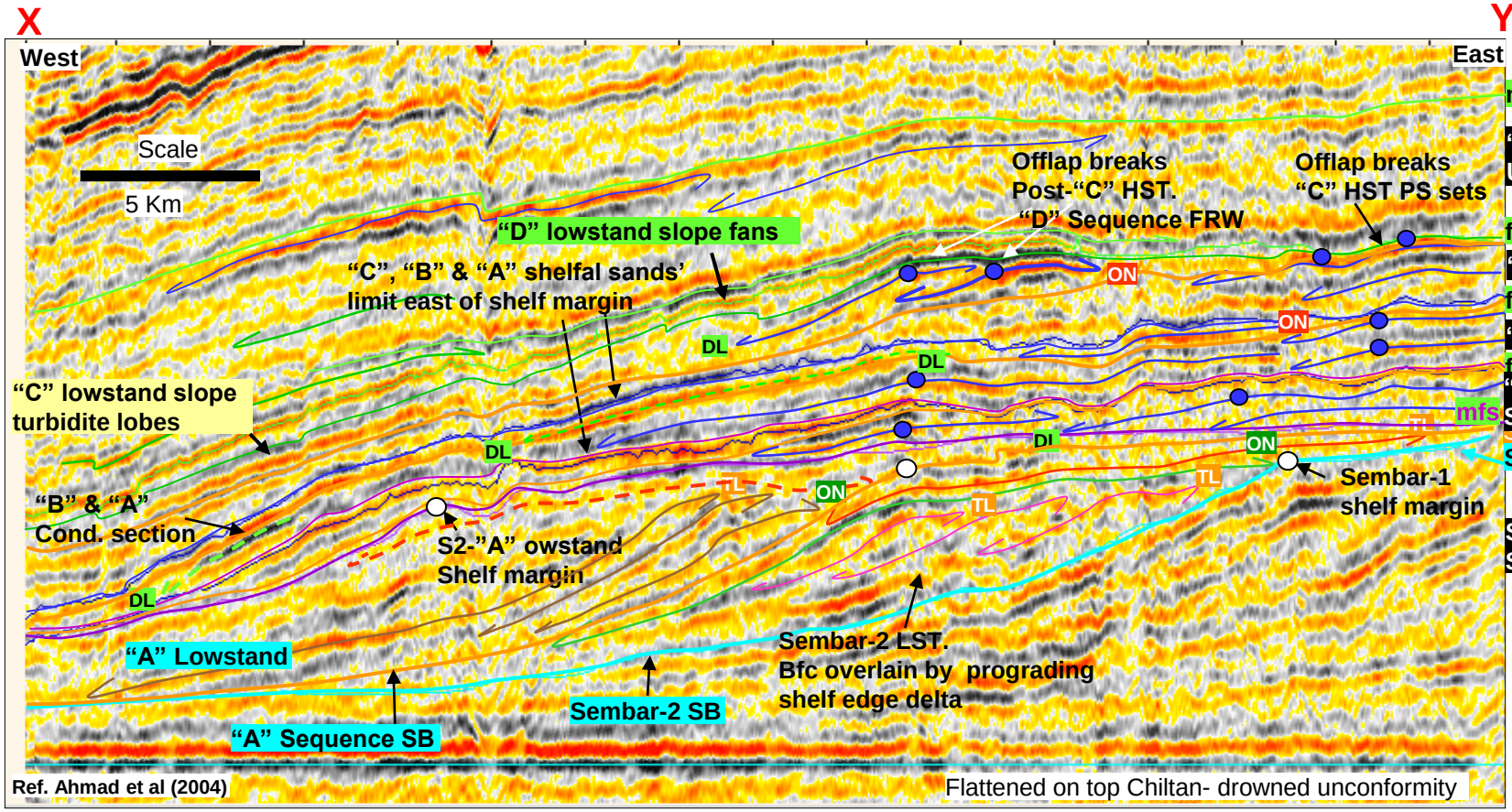


Middle & Lower Indus (Right)

Distribution of Lr. Cretaceous Deltaic and Paralic Siliciclastic Systems, IEDS Study, 1995

1 Middle & South: PFA – Mapping, Extending from the same age analogue Play Fairway in south Lr. Goru-Lumshiwal Reservoir, Upper Goru marls - Kawagarth Marl-Limestone Seal

- Seismic stratigraphic interpretation of E-W regional seismic line from across the Sawan area
- Subtle seismic reflection geometries, truncation patterns and dimming & brightening of amplitudes help infer coastal onlaps and offlap breaks -> sand bodies' proximal and distal extents



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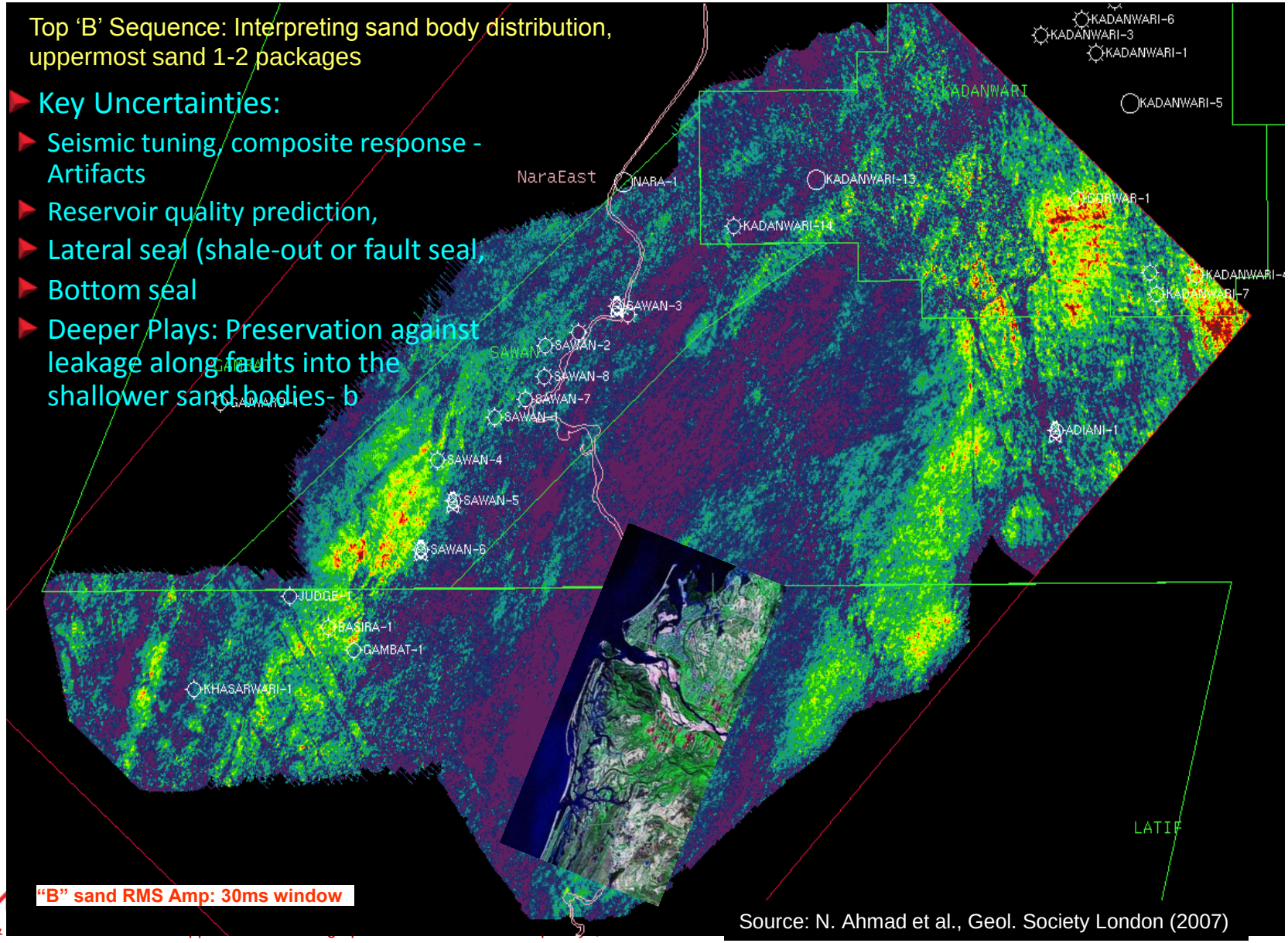
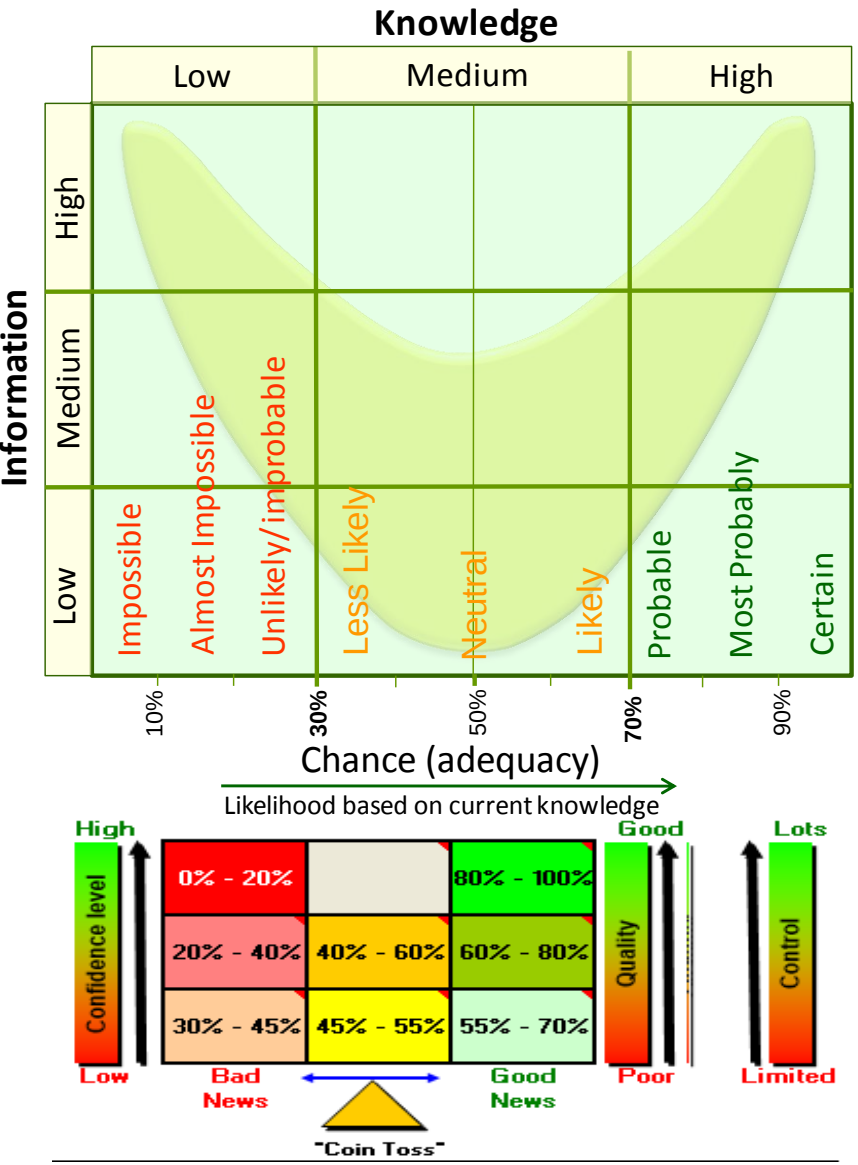


Source: N. Ahmad et al., Geol. Society London (2007)

1 Quantification of Uncertainties, Risk Models



- Chance adequacy matrix
  - Information: Data, observations
  - Knowledge is interpretation in the form of evaluations
- Elements plotting in top left corner & mid bottom area have large room for de-risking.

EXPLORATION PROSPECT Chance Success	PLAY SEGMENT	PROSPECT	TOTAL
SOURCE COMPONENTS	Confidence of P99 Resources: 61.00 MMBO		
Quantity/Volume (include Monetizable Product)		89.0%	
Quality/Richness			
Maturation			
MINIMUM FACTOR	100.0%	89.0%	89.0%
TIMING/ MIGRATION COMPONENTS	Confidence of P99 Resources: 61.00 MMBO		
Timing of Closure / Trap		90.0%	
Timing of Expulsion			
Effective Migration Pathway			
MINIMUM FACTOR	100.0%	90.0%	90.0%
RESERVOIR COMPONENTS	Confidence of P90 NetPay: 22.39 Metres		
Presence		90.0%	
Quality			
Reservoir Performance			
MINIMUM FACTOR	100.0%	90.0%	90.0%
CLOSURE COMPONENTS	Confidence of P90 Area: 3.50 SqKm		
Map Reliability & Control		80.0%	
Presence			
Data Quality			
MINIMUM FACTOR	100.0%	80.0%	80.0%
CONTAINMENT COMPONENTS	Confidence of P99 Resources: 61.00 MMBO		
Top / Base Seal Effectiveness		90.0%	
Lateral Seal Effectiveness			
Preservation from Spillage or Depletion			
Preservation from Degradation			
MINIMUM FACTOR	100.0%	90.0%	90.0%
EXPLORATION PROSPECT Chance of Success (calculated)	100.0%	51.9%	51.9%
EXPLORATION PROSPECT Chance of Success OVERRIDE			
FINAL Chance of Success (Shared, Local, Total Pg)	100.0%	51.9%	51.9%

1 Quantification of Uncertainties, Play level Risking

- Quantify uncertainty, Establish classes/bins
- Draw risk segment polygons on top of GDE maps.

Classes for CRS	mid-point
0.7 -1.0	0.85
0.4 - 0.7	0.55
0.1 -0.4	0.3
0 - 0.1	0

Scenarios	CCRS
0.85x0.85x0.85 equals	0.614
0.85 x 0.85 x 0.55equals	0.40
0.85 x 0.85 x 0.3 equals	0.217
0.85 x 0.55 x 0.55 equals	0.26
0.85 x 0.55 x 0.3 equals	0.140

CCRS Classes as use based on the binning scenarios	
0.05 - 0.125	
0.125 - 0.25	
0.25 - 0.4	
> 0.4	

Proven Part-play:
Play chance = P(R) x P(S-e) x P(C-e)
Where, R = **R**eservoir presence, S-e = top **S**eal effectiveness, C-e = **C**harge **E**ffectiveness

Unproven part-play

Play chance = P(R) x P(S-e) x P(C-e) x P(model)

Where, **P(model)** is Probability of the model given alternate possibilities and available data & knowledge in the un-drilled part of the Play (part play).

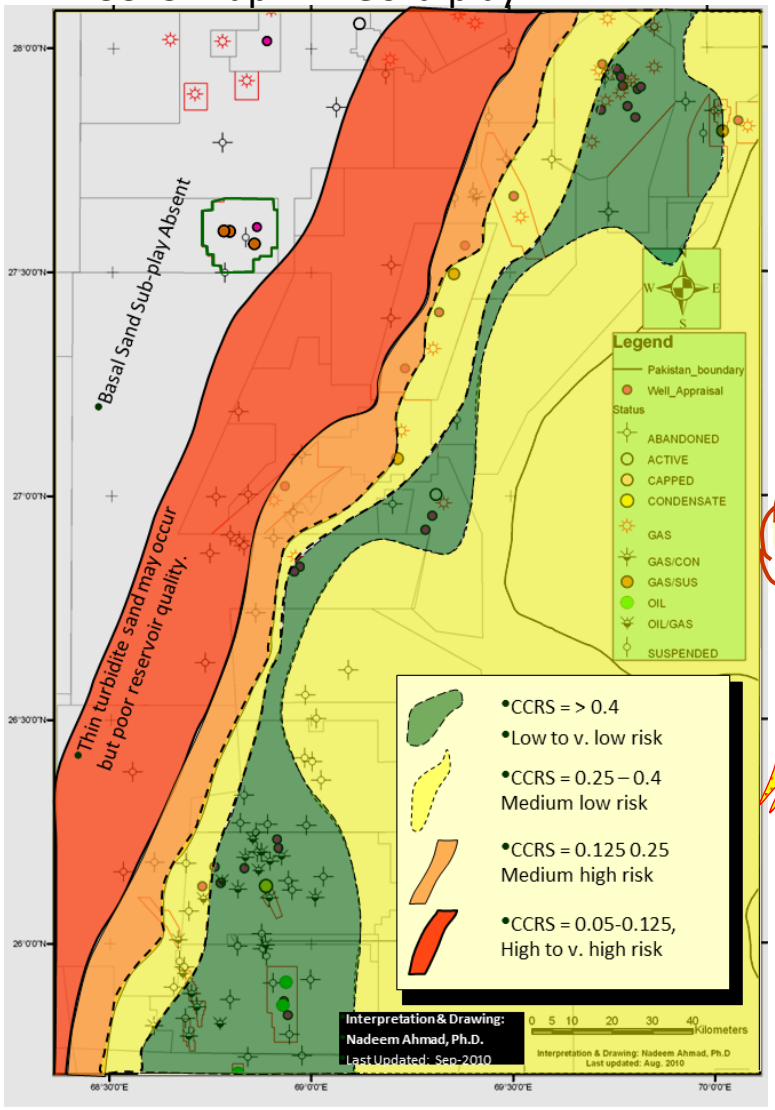
Unconventional Traps (e.g., strat trap) in proven part-play:

Prospect COS = P(play) x P(seal) x P(trap) x P(cont) x P(Model-U-Sh)

Whereas, **COS**= chance of success, **P(seal)** is the chance for local top seal and fault seal but excluding the bottom-seal and lateral shale-out seal, **P(Model-U-Sh)** is probability of model (e.g., detached shoreface, lateral shale-out, structural setup, etc).

1 Middle & South: Play Fairway Mapping: Extending from the same Play Fairway - Lr. Goru and Lr. Goru paralic sand Reservoir, Upper Goru marls as prime top Seal

CCRS Map - Lr. Goru play

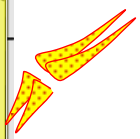


Left: Overlay Analysis of key CRS maps. Multiplication of individual risk polygons.

Removed shattered glass effect. Minimize classes – simplify binning

Feeders: Delta plane distributary channels, mouth bars & heterolithics

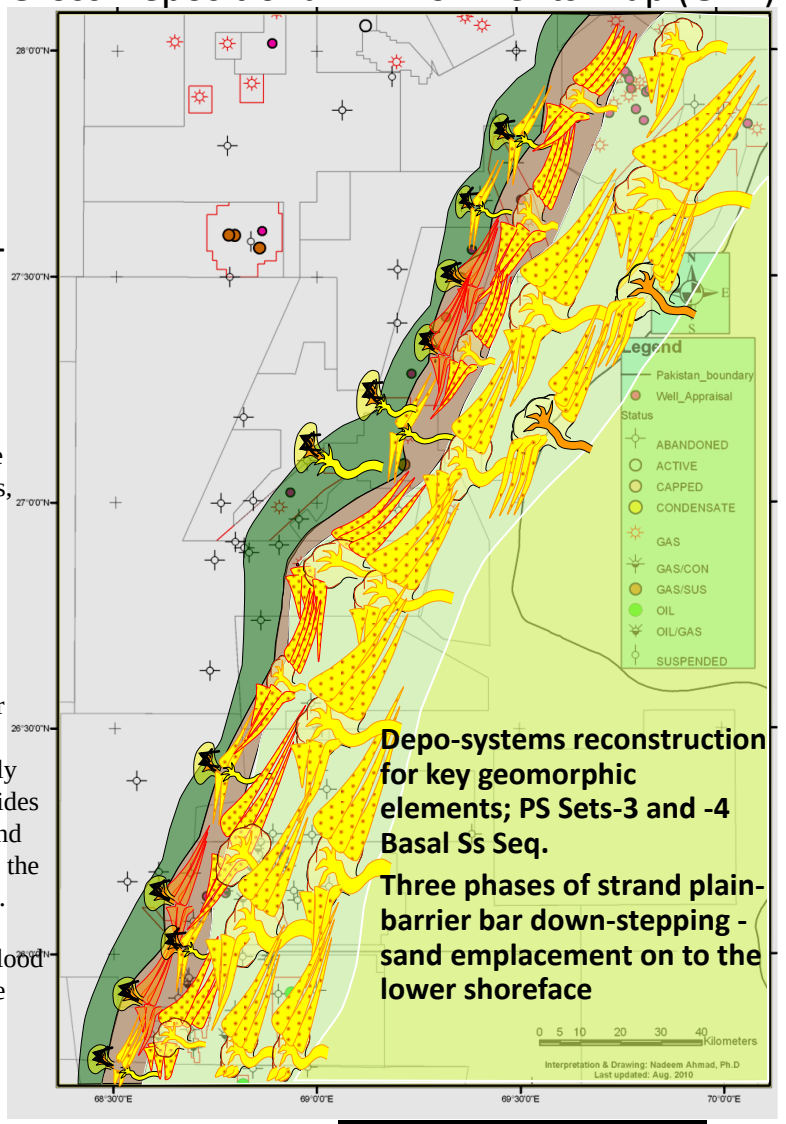
Longshore drift.



Strandplains & Shoreface bars under mixed wave & tide effect. Waves actively back-piling sands. Tides spreading fines around and laying sand onto the back-barrier lagoons.

Rip current or Ebb flood deltas attached to the Tidal inlets cutting across the shoreface bars and even strandplains

Gross Depositional Environments map (GDE)



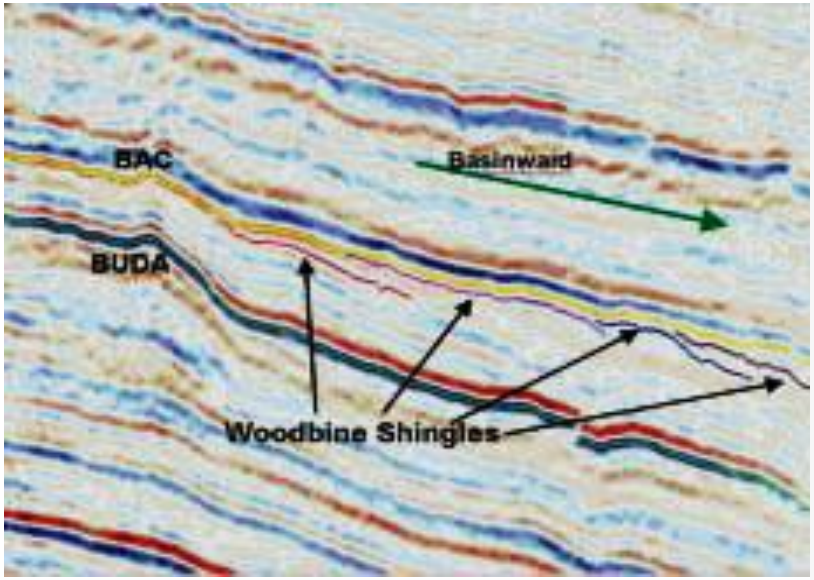
Depo-systems reconstruction for key geomorphic elements; PS Sets-3 and -4 Basal Ss Seq.

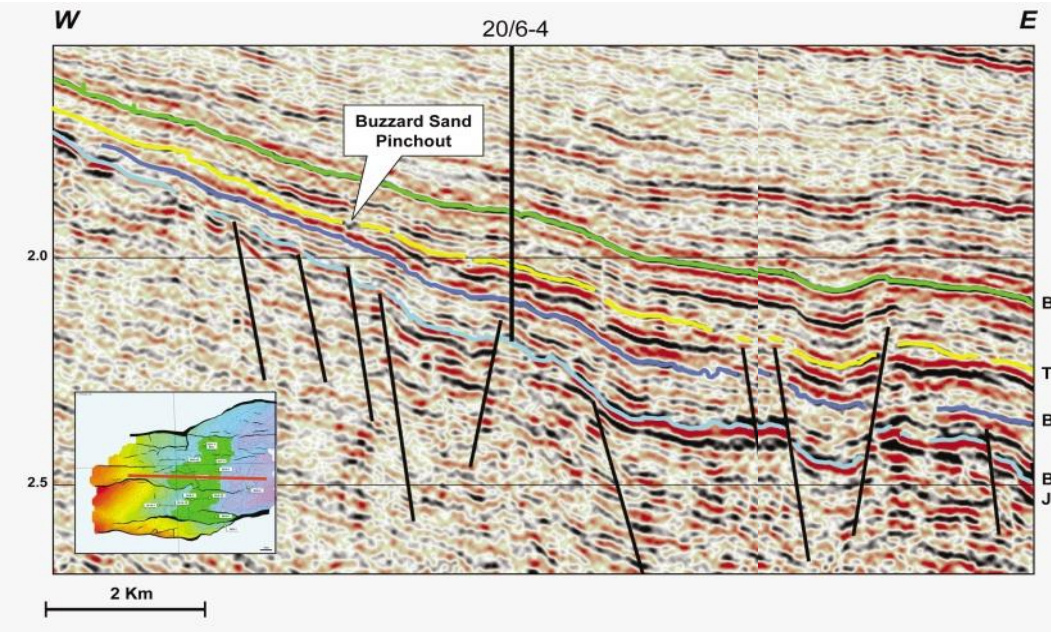
Three phases of strand plain-barrier bar down-stepping - sand emplacement on to the lower shoreface

Interpretation & Drawing: Nadeem Ahmad, Ph.D.

Strat-trap Prospects definition in Cretaceous Play; Risks

- Thief sand risk towards hinterland; success-failure analysis from analogues
- In Cretaceous systems of Lower & Middle Indus, no such success despite multiple wells (Karachi South 1A, Chnoai-1, Lundo-1, etc).
- Fewer examples exist of strat-traps in sandstone pinchouts updip towards hinterland (sand source, fluvial inputs).
  - East Texas, Cretaceous Woodbine sandstone play. Porosity preservation mechanism similar to Lr. Goru with porous-permeabile sand at >6000m in a number of fields. Works with Buda Lms as bottom seal, thick Austin Chalk as updip and top seal.
  - Buzzard Field, Moray Firth Basin, UK North Sea: U. Jurassic Turbidite sandstone reservoir, Thick Cretaceous chalk on top, Tight limestone underneath. Complete detachment of sand (fault escarpments).





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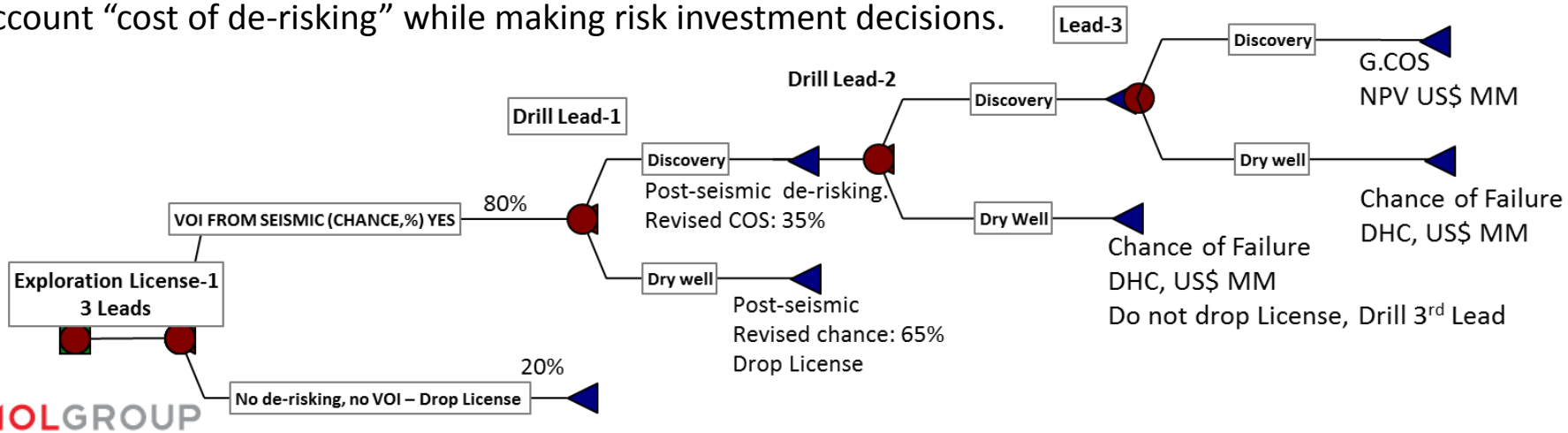
Strat-trap Prospects; Resource & Risk Assessment Strategies

- Exploration work programs to be designed to cover Play Fairways in contiguous blocks using CCRS maps
- Strat-traps/ Combination traps to be added to a Prospect Inventory to diversify & spread risk,
- Play and Portfolio based de-risking means Consistent resource & risk assessment across the blocks, forecasting on the bases of Portfolio instead of individual Leads/Prospects' COS, and achieving matching results at the end of Exploration Effort vis-à-vis initial planning & forecast,
- Due process of successive de-risking to be:
  - Gauge the room for de-risking (COS improvement) through available technologies/ methodology,
  - Select appropriate technology specific to critical uncertainties, pre-assess future risk revision with increased or decreased GCOS,
  - Before ranking / maturing to drill, determine maximum number of high risk elements acceptable (per prospect) and residual risk vis-à-vis ALARP framework of the company; we recommend two (2).
  - Set up accordingly the Decision Tree and back-calculate the expected value (EMV, ENPV) by taking into account "cost of de-risking" while making risk investment decisions.



Future Challenges and Strategies

- Field size and Finding cost ranges: 1-5MM boe (Million Barrels of Oil Equivalent) at an exorbitantly higher finding cost of +$10/boe, others continue to discover larger gas and oil fields (5-50 MMboe) at a cost less than $5/boe,
- Creaming Curve of three (3) proven basins of Pakistan: Rising trend on creaming curve and geological Play Fairway and Common Risk Segment (CRS) maps suggest Basins are still in emergent or yet-to mature stage,
- Significant yet-to-find due to yet-to-mature sub-plays within the already discovered Plays
  - Over 800MMboe (gas) and +400MMboe (oil) in the Upper Indus (Figure 1).
  - Nearly1,400 MMboe gas and Over 300MMboe liquids are expected from the Middle Indus Sulaiman Foldbelt area,
  - Over 600MMboe gas and nearly 170MMboe liquids are expected from the Kirthar fold belt

Table 1. *Status of exploratory and A&D drilling in the country for 2015-16. Source: PPIS Online and Scout Check reports.*

Wells	Exploratory	Completed	App/Dev	Completed
OGDCL	17	2	14	2
PPL	14	2	10	1
Private	23	5	16	4
Total	**54**	**9**	**40**	**7**

Table 2. *Upper Indus Basin, Average costs, US$ Million.*

Seismic cost; 300sq-km 3D, or 400 L.km 2D	**10-14**
Well Cost, 3,000- 35,000m deep	18-25
G&A Cost (1 yr, 1 block)	1.5-2
Typical resource size, MMBOE	10-50
Finding Cost, $/BOE	1.5 – 7.0

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Strategic Options for Pakistan

- Technology selection and timely deployment: 2D and 3D Seismic surveys & Processing
  - Global spending on seismic reached $7 Billion in 2011, and exceeded $12 Billions in 2013. In Pakistan, during last 8 years, over 20,000 sq.Km 3D seismic (~ $0.5 Billion) and over 100,000 L.Km 2D (>$1.5Billion) have been acquired.
  - Potential Field surveys especially Gravity (rather Gravity Gradiometry) and Magnetic mainly for rather frontier basins.
- Brownfield and greenfield infrastructure-led exploration of smaller prospects,
- Explore frontier basins & plays: Public sector companies to engage IOCs to explore remote and unproven basins like interior fold belts, Kharan basin. Must define New play concepts, use innovative approaches.
- Add Unconventional play types to the portfolio,
- IOCs having Giant fields in their portfolios continuously add new countries and basins to their portfolios to access new emergent basins (larger field sizes). Recent examples are: Petrochina, Petronas, ONGC Videsh. Accessing E&P projects in the neighboring oil & gas rich countries: Secure energy at the source

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Private	23	5	16	4
Total	**54**	**9**	**40**	**7**

Table 2. *Upper Indus Basin, Average costs, US$ Million.*

Seismic cost; 300sq-km 3D, or 400 L.km 2D	**10-14**
Well Cost, 3,000- 35,000m deep	18-25
G&A Cost (1 yr, 1 block)	1.5-2
Typical resource size, MMBOE	10-50
Finding Cost, $/BOE	1.5 – 7.0

Table 1. *Status of exploratory and A&D drilling in the country for 2015-16. Source: PPIS Online and Scout Check reports.*

Wells	Exploratory	Completed	App/Dev	Completed
OGDCL	17	2	14	2
PPL	14	2	10	1
Private	23	5	16	4
Total	**54**	**9**	**40**	**7**

Table 2. *Upper Indus Basin, Average costs, US$ Million.*

Seismic cost; 300sq-km 3D, or 400 L.km 2D	**10-14**
Well Cost, 3,000- 3,500m deep	18-25
G&A Cost (1 yr, 1 block)	1.5-2
Typical resource size, MMBOE	10-50
Finding Cost, $/BOE	1.5 – 7.0

Strategies for Times of Low Oil Prices – Closing Remarks

- Basin's exploration performance linked w/ Play characteristics & right techniques/ workflow deployed,
- But also linked with Company's operating performance which is determined by:
  - Portfolio mix (diversity of basins & play types and prospect sizes and their risks),
  - Managing the Operations onset or scheduling risk, contracts management,
  - Stakeholders' management including the local communities and security risks, and
  - Controls and Assurance processes the company runs for prioritizing its capital allocations to the new projects/acquisitions and an agile and disciplined execution of projects.

- A low oil price of $45-$65/bbl is anticipated for next few years -> Companies must redefine efficiency in terms of:
  - Operating performance, Securing sustained financial inflows while maintaining certain debt ratio, building resilient portfolio and robust economics projects in the face of their neutral to slightly negative cash flows,
  - Portfolio mix of diverse Plays and prospect sizes: these low times also offers window of opportunity to capture promising acreage from cash-strapped companies, restructuring and repositioning, and exploiting smaller Prospect sizes based on lower operating cost, improved operating efficiency and technologies developed and learned in last decade.