Hydrocarbon Prospectivity

Indian Sedimentary Basins

MINISTRY OF PETROLEUM AND NATURAL GAS

GOVERNMENT OF INDIA

DGH

Directorate General of Hydrocarbons

Presentation outline

- Sedimentary Basins
  - Global reference
  - Geological set-up
  - Basin categorization
- Hydrocarbon Resources
  - Recent studies
  - Emerging facts
- Subsurface Insights
  - E&P Data
  - Basin prospectivity
  - Opportunities
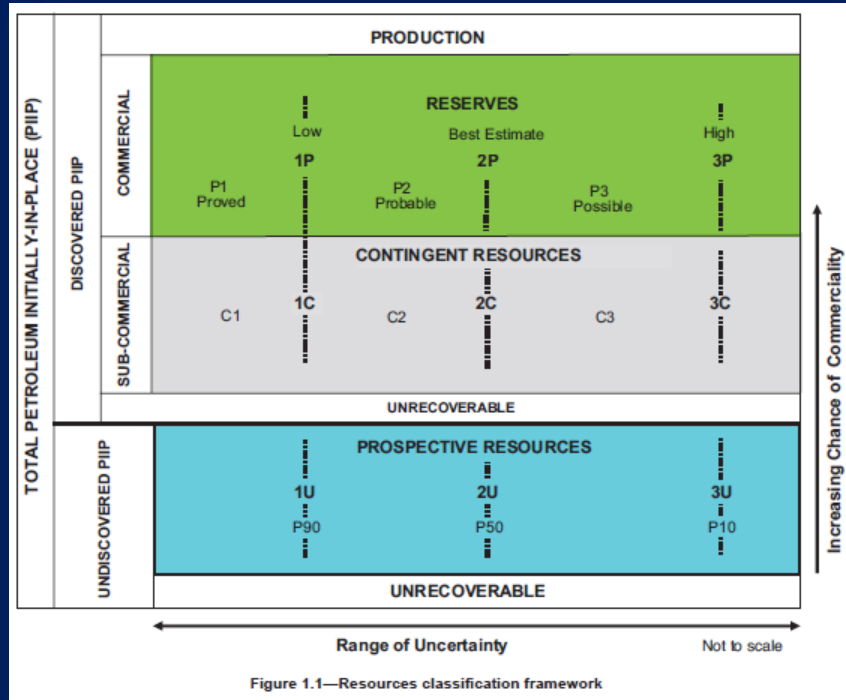
Global Reference: PRMS terms
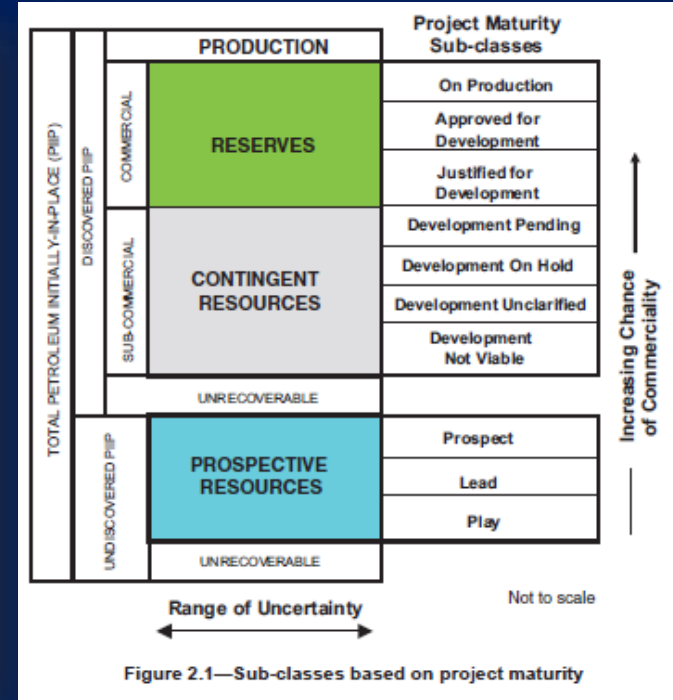

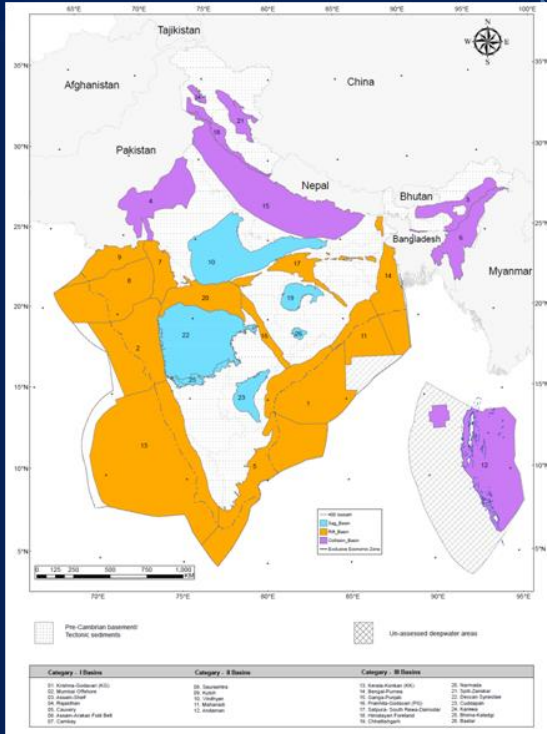Figure 1.1—Resources classification framework

Figure 2.1—Sub-classes based on project maturity

Geological Set-up: Basin type

Rifting
- Rajasthan (Barmer), Cambay, Kutch, Saurashtra, Mumbai Offshore, Kerala-Konkan
- Cauvery, Krishna-Godavari(KG), Mahanadi, Bengal-Purnea,
- Pranhita-Godavari(PG), Satpura-South Rewa-Damodar, Narmada

> Pericratonic Rift Basin
> Intracratonic Rift Basin

Sag
- Vindhyan, Deccan Syneclise, Bhima-Kaladgi, Chattisgarh, Cuddapah, and Bastar

> Intracratonic Sag Basin

Collision
- Assam-Arakan Fold Belt, Andaman,
- Karewa, Spiti-Zanskar, Himalyan Foreland,
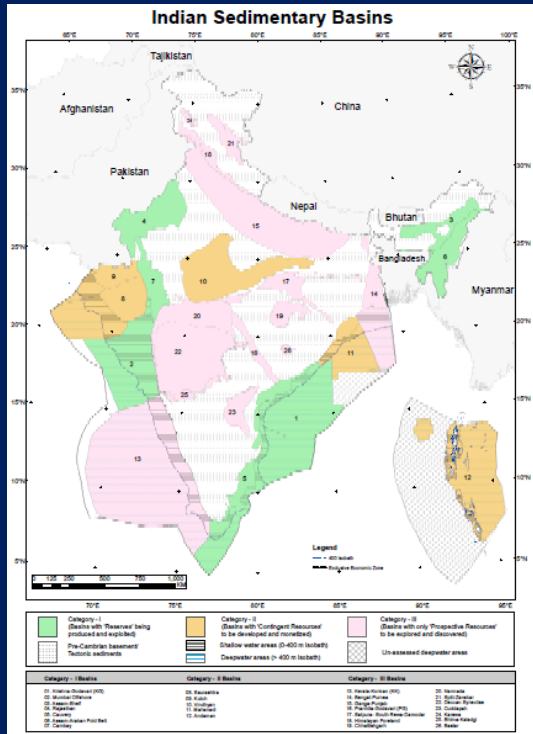- Ganga-Punjab, Rajasthan(Bikaner-Nagaur), Rajasthan (Jaisalmer)
- Assam Shelf

> Forearc Collision Basin
> Foreland
> Peripheral Foreland Basin
> Interorogenic Foreland Basin

Basin Categorization: 26 basins

Indian Sedimentary Basins

Category I (7)
- Krishna-Godavari(KG), Mumbai Offshore, Assam Shelf, Rajasthan, Cauvery, Assam-Arakan Fold Belt and Cambay

Category II (5)
- Saurashtra, Kutch, Vindhyan, Mahanadi and Andaman

Category III (14)
- Kerala-Konkan, Bengal-Purnea, Ganga-Punjab, Pranhita-Godavari(PG), Satpura-South Rewa-Damodar, Himalyan Foreland, Chattisgarh, Narmada, Spiti-Zanskar, Deccan Syneclise, Cuddapah, Karewa, Bhima-Kaladgi, and Bastar

✓ *Basins are shown in decreasing order of undiscovered inplace*
✓ *Saurashtra, Kutch and Bengal-Purnea are under upgrade*

Recent Studies: Assessment approach


Indian Sedimentary Basins
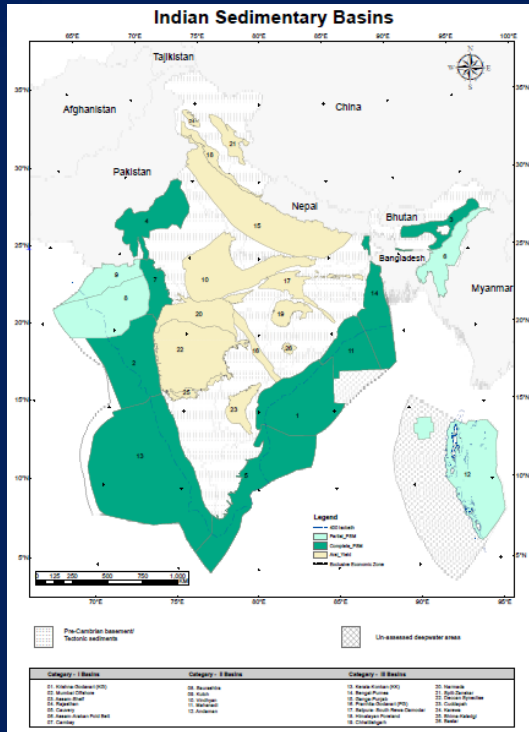
- Petroleum system elements were assessed using latest modeling tools for data-intensive basins and areas
  - 9 basins were completely modeled and 4 basins partly
- Aerial Yield method was used for remaining basins where data were sparse and limited
- 2D-3D seismic, well logs, wells and laboratory data formed the basic datasets
- Models were run through integration of geological and geochemical interpretations
- International domain experts and Indian basin specialists were engaged to check the procedures and assure the results
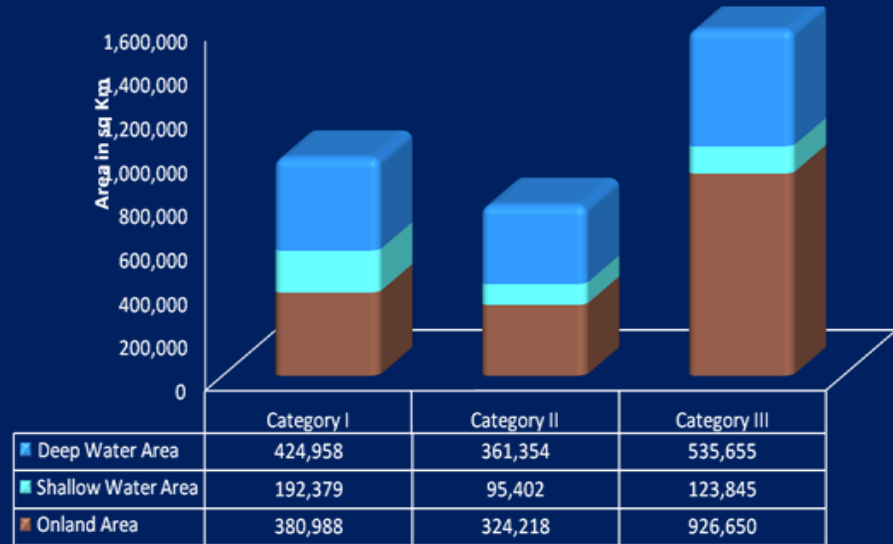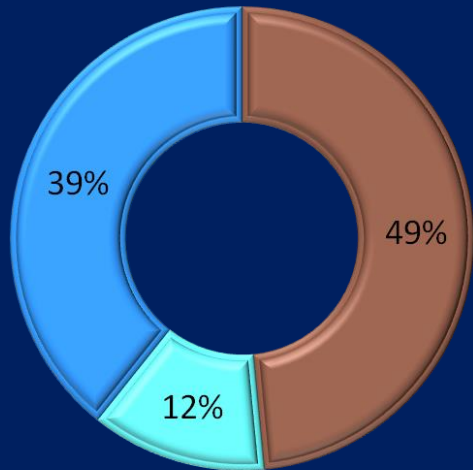
Recent Studies: Basin area

Indian Sedimentary Basins

Category I · Category II · Category III

30% · 23% · 47%
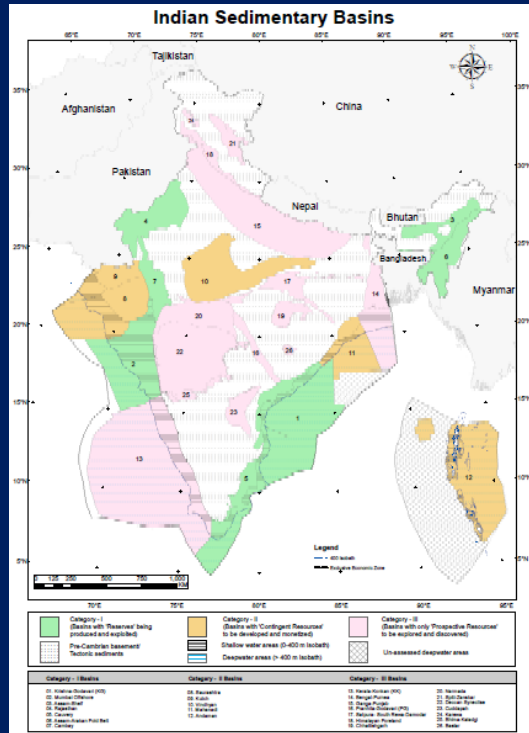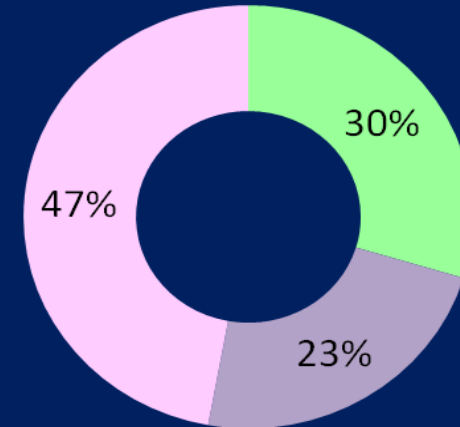
- Majority of the area are under Category III without a discovery and subject to intense exploration

Recent Studies: Basin area

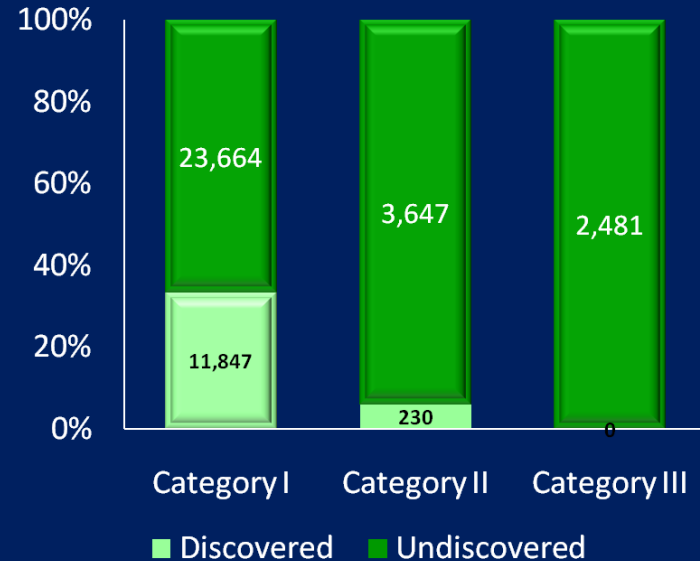■ Onland Area ■ Shallow water Area ■ Deep water Area

39%

49%

12%

	Category I	Category II	Category III
■ Deep Water Area	424,958	361,354	535,655
■ Shallow Water Area	192,379	95,402	123,845
■ Onland Area	380,988	324,218	926,650

Area in sq Km

1,600,000
1,400,000
1,200,000
1,000,000
800,000
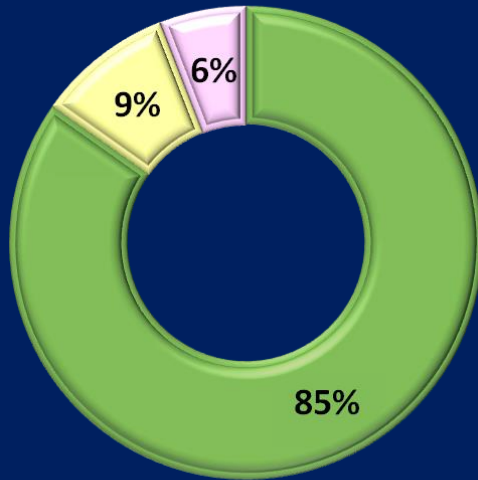600,000
400,000
200,000
0

- Nearly half of the area falls in Onland, which further occupies 58% of Category III area
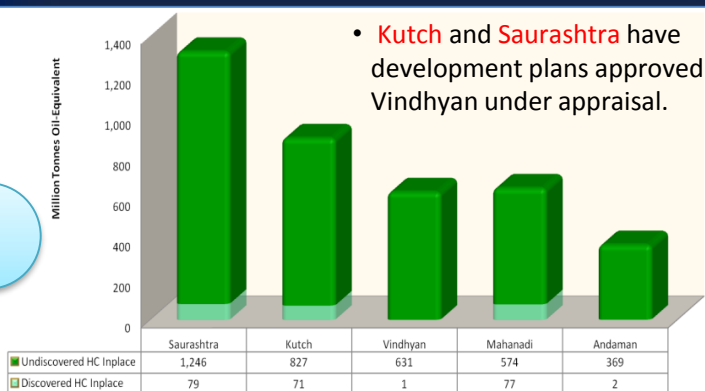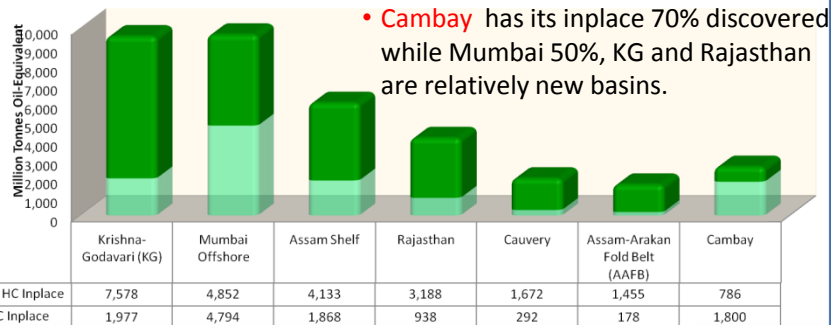
Recent Studies: Hydrocarbon resources

- Category I basins have 85% of total hydrocarbons assessed and 98% of total discovered inplace.

I

• Cambay has its inplace 70% discovered while Mumbai 50%, KG and Rajasthan are relatively new basins.

Million Tonnes Oil-Equivalent	Krishna-Godavari (KG)	Mumbai Offshore	Assam Shelf	Rajasthan	Cauvery	Assam-Arakan Fold Belt (AAFB)	Cambay
Undiscovered HC Inplace	7,578	4,852	4,133	3,188	1,672	1,455	786
Discovered HC Inplace	1,977	4,794	1,868	938	292	178	1,800

II

• Kutch and Saurashtra have development plans approved. Vindhyan under appraisal.

Million Tonnes Oil-Equivalent	Saurashtra	Kutch	Vindhyan	Mahanadi	Andaman
Undiscovered HC Inplace	1,246	827	631	574	369
Discovered HC Inplace	79	71	1	77	2

III

• Bengal sub-basin recently made a significant discovery, currently under appraisal. Kerala-Konkan has excellent sub-surface data with Mesozoic potential. Most basins have sparse data, which are now covered under National Seismic Campaign (NSP).

Million Tonnes Oil-Equivalent	Kerala-Konkan (KK)	Bengal-Purnea	Ganga-Punjab	Pranhita-Godavari (PG)	Satpura-South Rewa-Damodar	Himalayan Foreland	Chhattisgarh	Narmada	Spiti-Zankskar	Deccan Syneclise	Cuddapah	Karewa	Bhima-Kaladgi	Bastar
Undiscovered HC Inplace	1,245	828	128	95	63	44	25	18	11	11	5	4	3	1
Discovered HC Inplace	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Emerging facts: Resources profile

Total hydrocarbon inplace

Period	Value
Tertiary	31655
Mesozoic	8594
Proterozoic	1265
Paleozoic	221
Archean	131
Quarternary	2

Pie chart:
- Quarternary 0%
- Archean 0%
- Paleozoic 1%
- Proterozoic 3%
- Mesozoic 20%
- Tertiary 76%

- Total estimated conventional hydrocarbons: 41,868 MMTOE
- 177 plays mapped
- 87 in Tertiary, 53 in Mesozoic and 37 Pre-Mesozoic
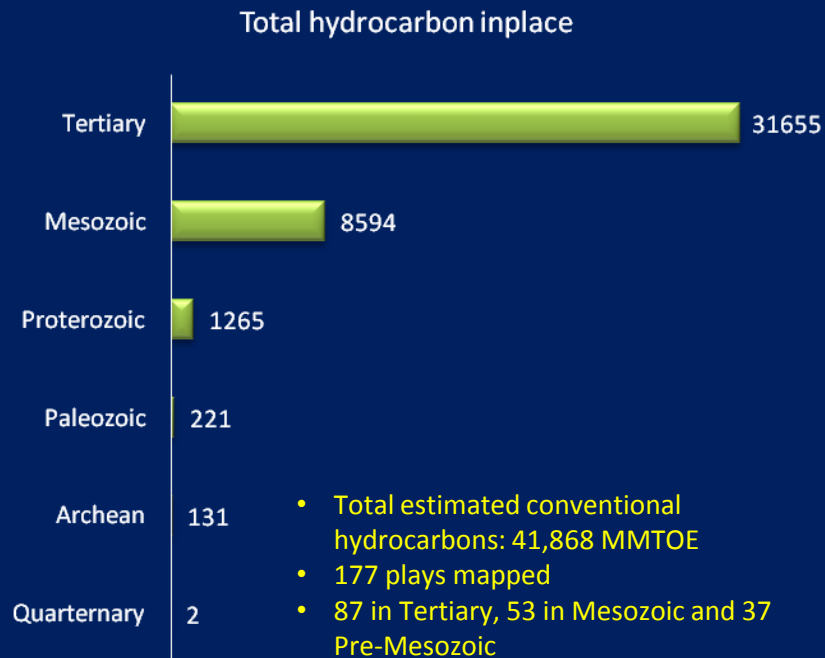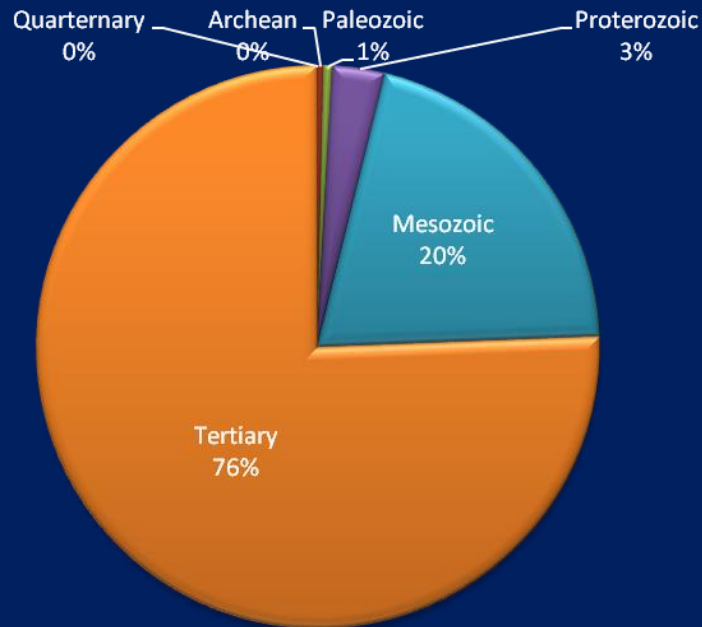
Emerging facts: CBM & Shales

Coal Bed Methane (CBM)

- India's inplace: 2,600 BCM
- 11 active CBM blocks
- Spread across 11 States
- 4 blocks under production
- Reserves: 295 BCM
- Commercial production since July 2007
- Well drilled (March 2020): 980
- Cumulative production (March 2020): 3.7 BCM
- Production: 1.8 MMSCMD
- Operational area: 4,503.5 sq. km.

Shale Oil & Gas

- Exploration efforts carried out so far by NOCs under Shale Gas & Oil Policy, 2013
- A total of 22 wells drilled by ONGC in Cambay, KG, Cauvery, Assam Shelf and Assam- Arakan Fold Belt
- 1 well drilled by OIL in Jaisalmer Sub-basin
- No established shale Gas/Oil reserves yet
- Resource estimates by 3 agencies in different basins
- ONGC (August 2013): 5,309 BCM for 5 basins- Cambay, KG, Cauvery, Ganga, Assam
- CMPDI (July 2013): 1,297 BCM for Gondwana basins
- USGS (January 2011): 173 BCM for 3 basins: Cambay, KG & Cauvery

Emerging facts: Gas hydrate

- Natural Gas Hydrate Program Expedition (NGHP) in place to explore and develop the gas hydrate resources of Indian subcontinent in 3 stages.
- During the 1st stage , the presence of gas hydrate deposits were identified
- During the 2nd stage, sand-rich suitable locations with gas hydrate stability zone were identified for production testing. 42 gas hydrate wells at 25 sites were completed in deep water areas of KG and Mahanadi Basins .
- The 3rd stage will be to carry out production testing

- ONGC during 2016 reported Gas Inplace of 255 BCM in KG basin
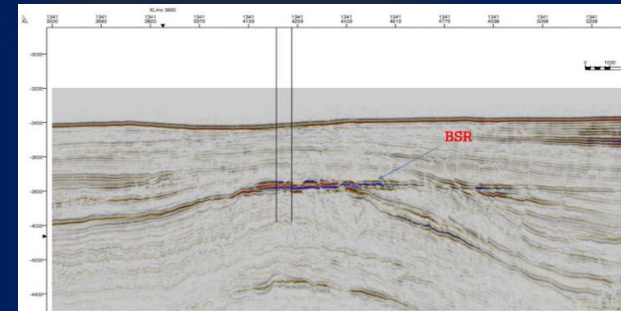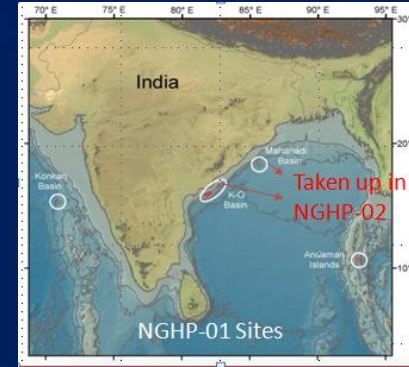
Emerging facts: Resources maturation

Inplace 41.9 BTOE	Risked 25.0 BTOE	Discovered 12.1 BTOE	Recoverable 4.3 BTOE	Produced 2.4 BTOE	Reserve 1.9 BTOE

Geological Risking | Exploration Success | Recovery Maximization | Production Acceleration
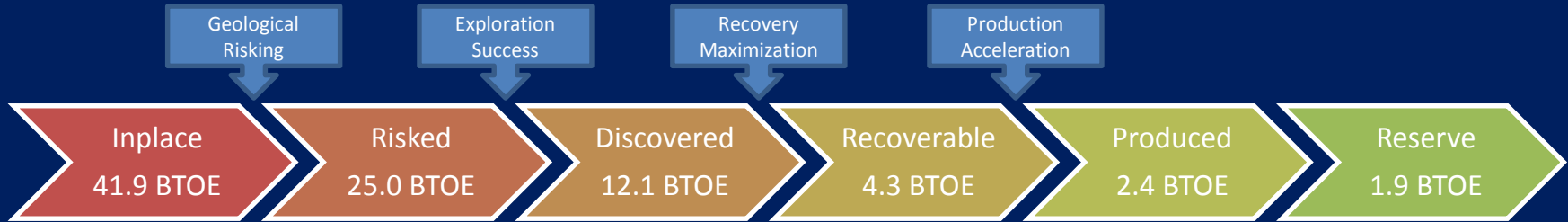
E&P Data: National Data Repository (NDR)
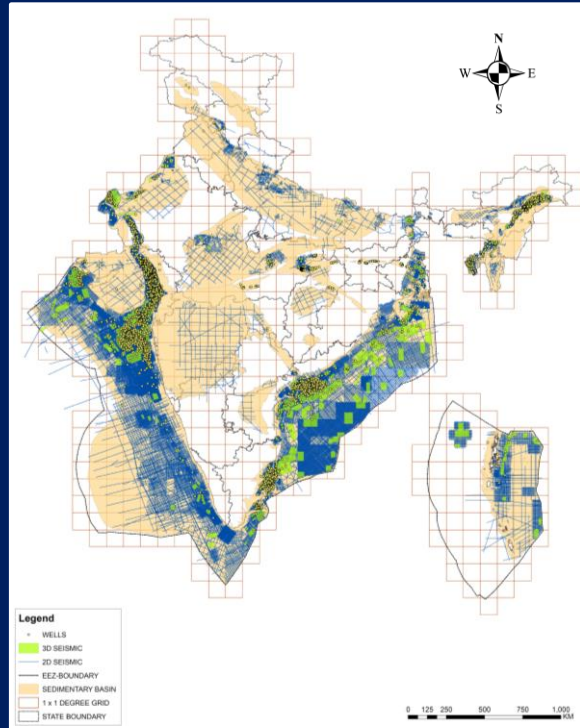
- Set up in 2017 in DGH premises, NDR hosts the country's complete and a centralized E&P database of all sedimentary basins.

- All bidding of acreages under HELP and DSF Policy are now through NDR. It hosts Physical Data Rooms for data viewing and evaluation of acreages/blocks

- Companies can connect through Portal, can view, analyze and buy data at a nominal cost

- Data uploaded on NDR as of Sep, 2020:

  - 2.50 million LKM of 2D seismic data
  - 0.85 million SKM of 3D seismic data
  - 18,686 wells and well logs
  - 15,294 seismic reports
  - 38,072 well reports
  - 27 hydrocarbon resource reports

E&P Data: Data shared by NDR

Data Type	Evaluation of Acreages/ Blocks (Since July 2017)	OALP/DSF Bid Rounds (Since July 2017)
Processed 2D (LKM)	1,276,599	129,990
Processed 3D (SKM)	304,717	19,450
Wells	3832	511
Reports	4,784	
Raw Seismic Data	3D − 11,949 SKM	
	2D − 4,290 LKM	

- 256 registered companies
  - 89 foreign companies,
  - 167 Indian companies/Institutes)
- More than 800 Users
- Delivered orders (408 nos.):
  - 37 Indian E&P companies, including 2 Indian Government Institutes
  - 16 foreign E&P companies
  - 9 academic institutes

E&P Data: National Seismic Programme (NSP)

National Seismic Program
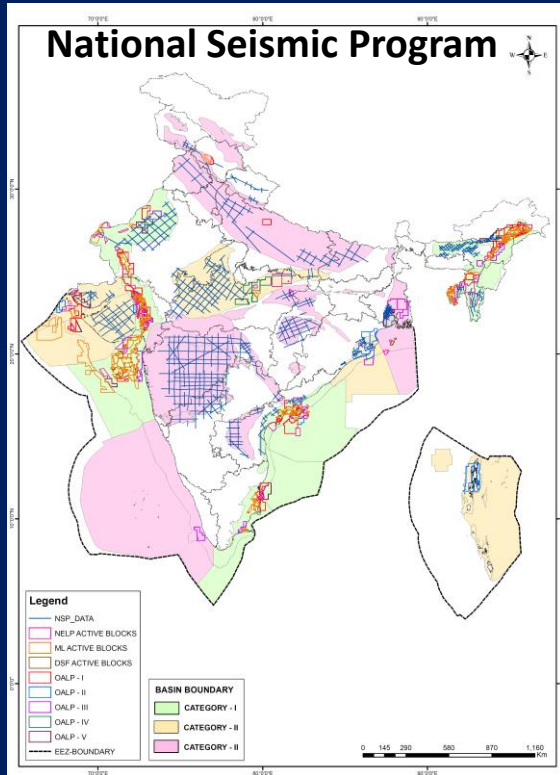
- 2D seismic data acquisition program in onland sedimentary basins where scanty or little data were available

- Campaign started in October 2016

- Target   : 48,243 Line Kilometer (LKM)

- As of Sept. 2020, Acquired 93%, Processed 91% and Interpreted 62%

- Data generated are processed and continuously uploaded in NDR

- 42,394 LKM of NSP Data are loaded in NDR as of August 2020

E&P Data: Speculative leads on NSP data
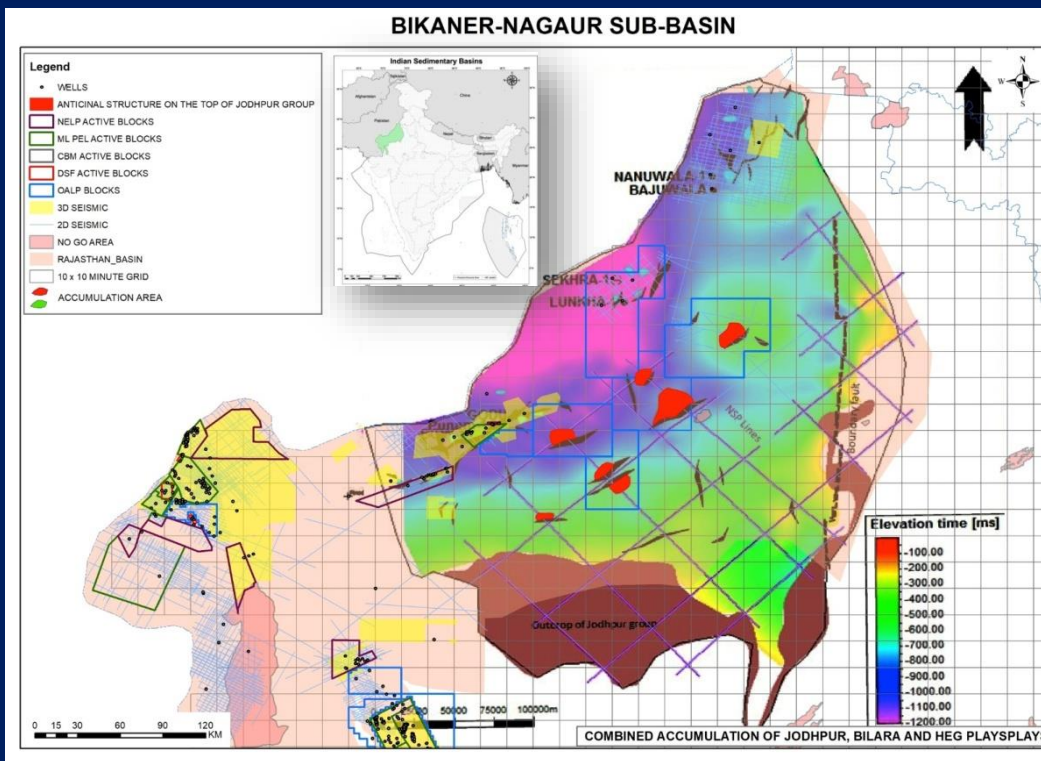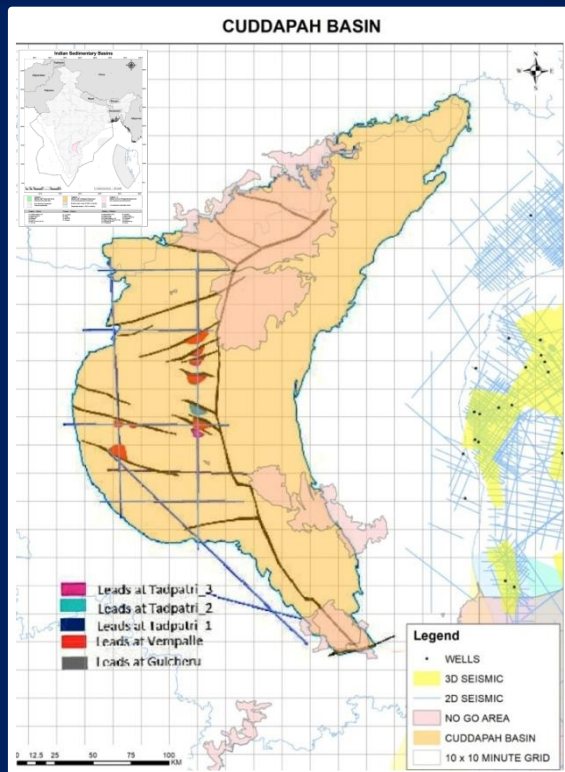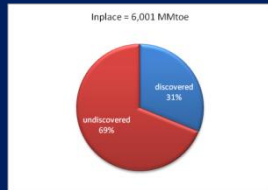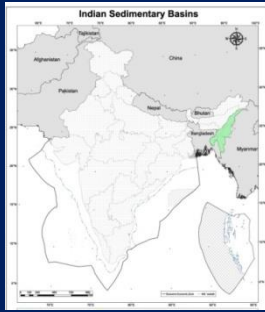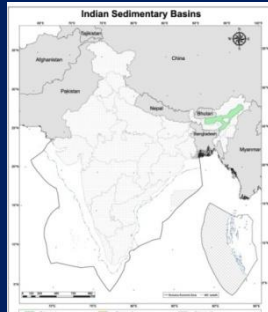
- 56,000 sq km area with 58% appraised.
- Mature source rocks lie under Naga Thrust with potential shallow plays. Good number of oil fields are located
- 8 plays all proven with clastic reservoirs with occurrence basement fractures
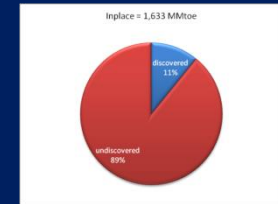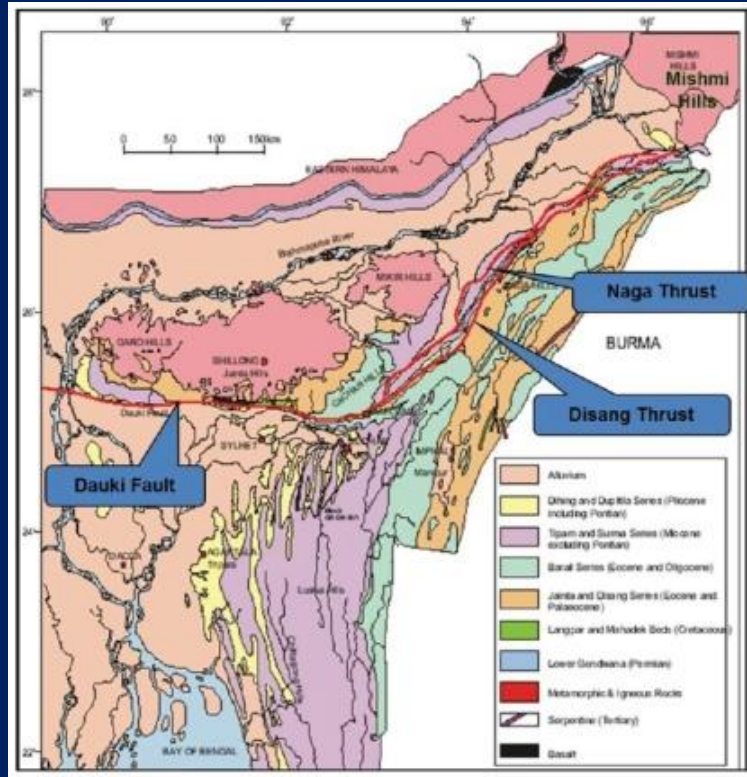
- 80,825 sq km area with 35% appraised
- 7 plays with Oligocene being prominent
- Restoration of complex structure is the key
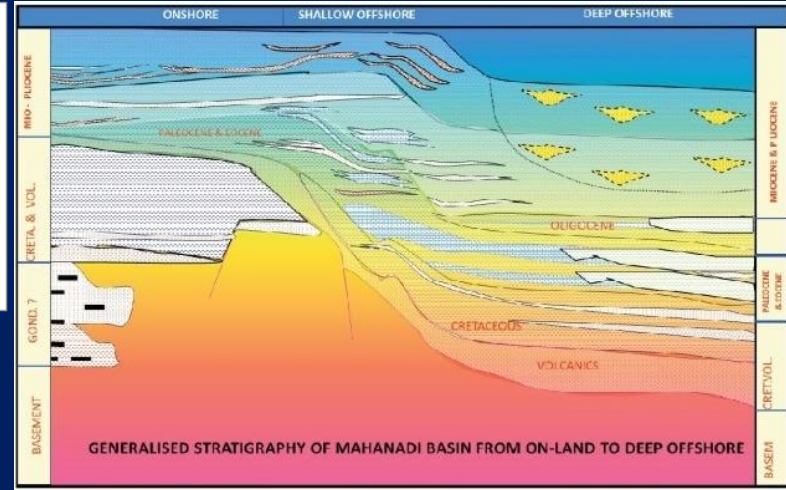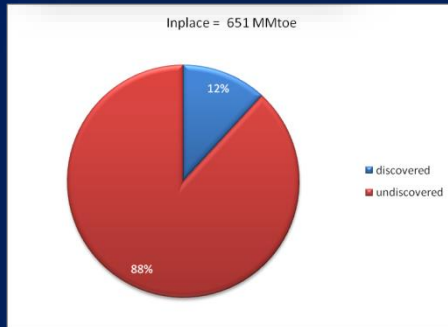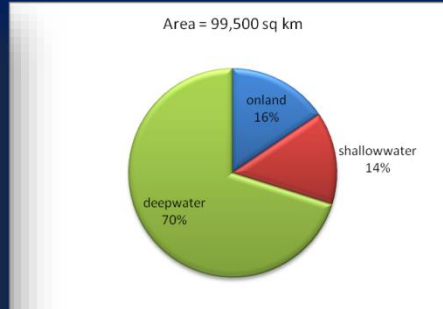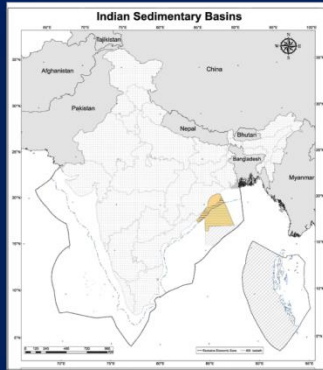- New gas discoveries in the fold areas

Basin Prospectivity: Bengal-Purnea
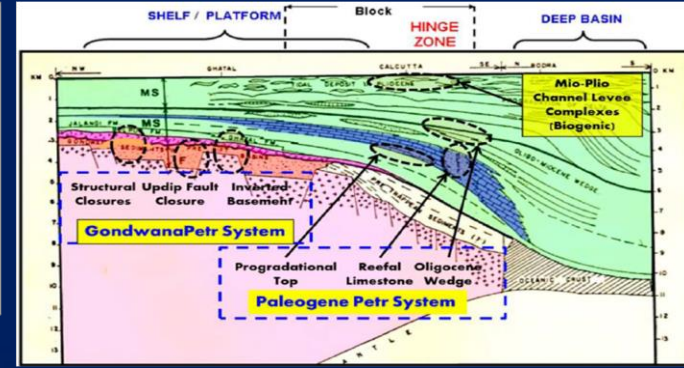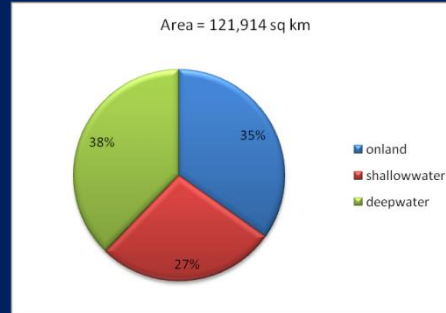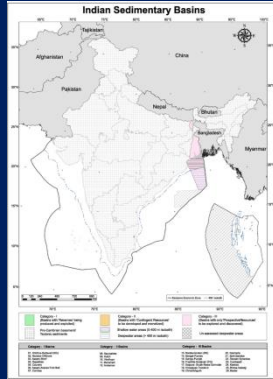
- ✓ Estimated inplace 828 MMTOE
- ✓ The basin is appraised to the extent of 76%
- ✓ 16 plays, recent discovery of gas and oil in Miocene and Pliocene sequences
- ✓ Significant potential in Pliocene play.
- ✓ Biogenic gas expected in shallow stratistructural entrapment
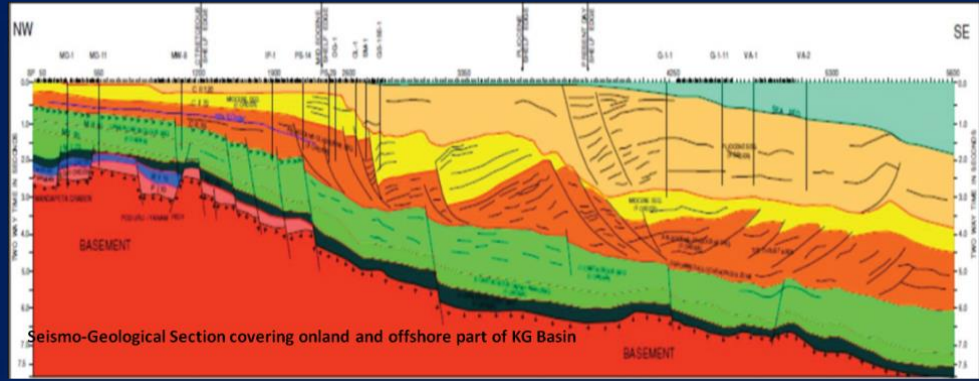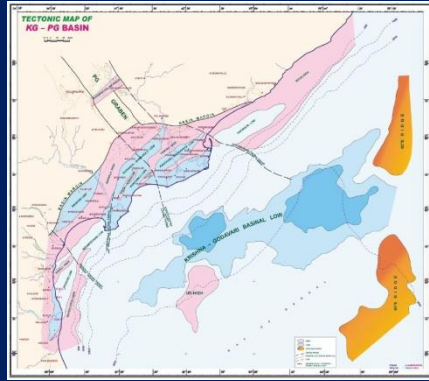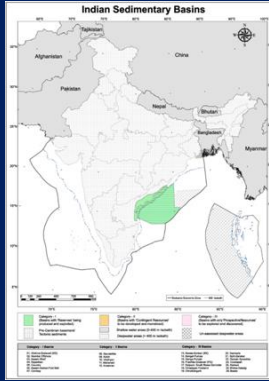- ✓ Proximal area to hinge zone remains the exploration target
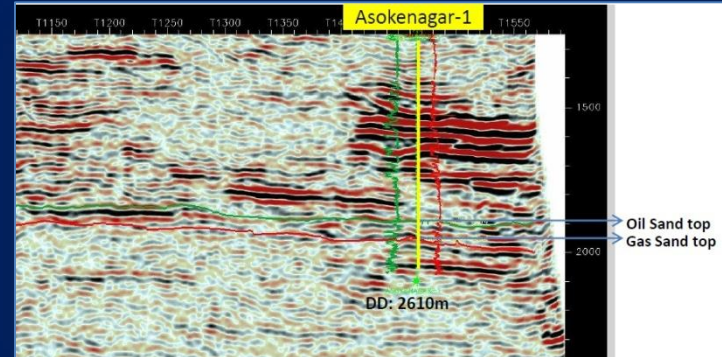
Basin Prospectivity: Mahanadi

Indian Sedimentary Basins

Area = 99,500 sq km

onland 16%
shallowwater 14%
deepwater 70%

Inplace = 651 MMtoe

12% discovered
88% undiscovered

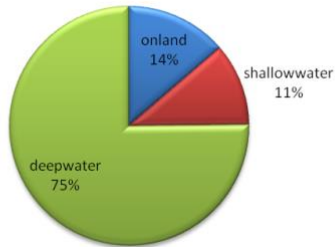GENERALISED STRATIGRAPHY OF MAHANADI BASIN FROM ON-LAND TO DEEP OFFSHORE

- ✓ The basin is appraised to the extent of 89%.
- ✓ 10 geologic plays with 5 proven
- ✓ Potential in the north-eastern part of offshore adjoining Bengal offshore.
- ✓ Good close-grid 2D seismic data were newly acquired under National Seismic Programme
- ✓ 7 offshore gas discoveries are now appraised and developed under DSF bid round II

Basin Prospectivity: Krishna-Godavari (KG)

Indian Sedimentary Basins

TECTONIC MAP OF KG – PG BASIN

Seismo-Geological Section covering onland and offshore part of KG Basin

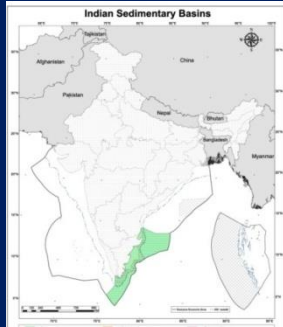Area = 230,000 sq km

- onland 14%
- shallowwater 11%
- deepwater 75%

✓ Most prospective (7,578 MMTOE undiscovered inplace)

✓ Highest accretion (8,425 MMTOE) of inplace than last estimate

✓ Dual-rift province with older NW-SE trending Gondwana Pranhita-Godavari basin, superimposed by younger Late Jurassic rift-associated NE-SW trending passive margin basin

✓ Sediments range from Permian to Pliocene sequence into 12 plays

✓ Deepwater completely appraised, shallow water 99% and onland 63%, at basin level 95%

✓ Large unexplored areas in proven plays

✓ Biogenic plays are charged from within Miocene and Pliocene sequence

✓ Potential unconventional resources (CBM, Shale, Gas Hydrate) , Fractured, Tight and HP-HT plays
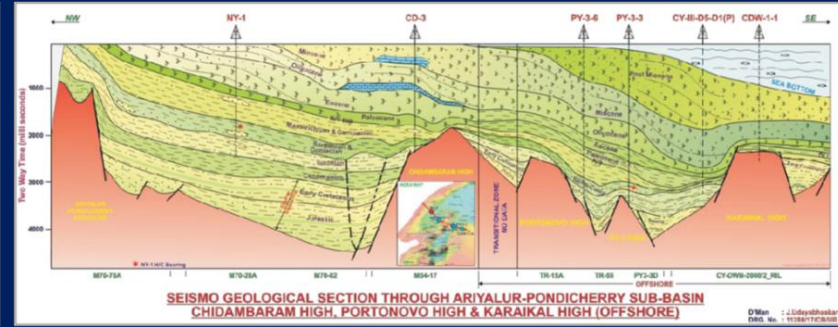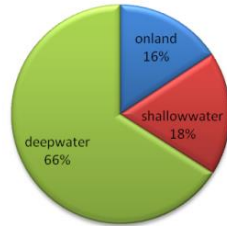
Basin Prospectivity: Andaman
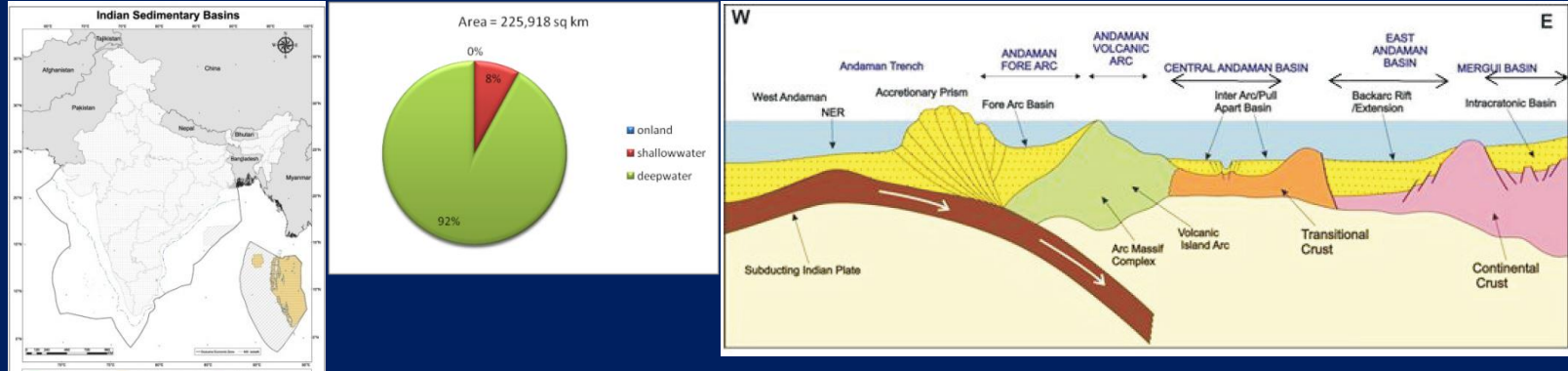
- ✓ The basin is appraised to the extent of 42%
- ✓ 6 geological play with 1 proven through discovery
- ✓ Estimated inplace of 371 MMTOE
- ✓ Better source rock maturity in the south-eastern part of the East Andaman basin promises good potential
- ✓ High resolution seismic data acquisition can better image the structural complexity
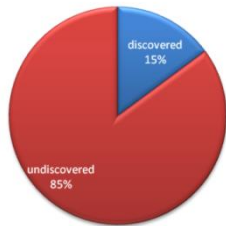
Basin Prospectivity: Cauvery

Indian Sedimentary Basins

Area = 240,000 sq km

- onland 16%
- shallowwater 18%
- deepwater 66%

SEISMO GEOLOGICAL SECTION THROUGH ARIYALUR-PONDICHERRY SUB-BASIN
CHIDAMBARAM HIGH, PORTONOVO HIGH & KARAIKAL HIGH (OFFSHORE)


Inplace = 1,964 MMtoe

- discovered 15%
- undiscovered 85%

- ✓ The basin is appraised to the extent of 92%
- ✓ 9 plays within Basement, Jurassic, Cretaceous, Paleocene-Miocene
- ✓ Reservoirs: sandstones and unconventional fractured basement

- ✓ Cretaceous and Basement plays are focus area
- ✓ Seismic acquisition in transitional areas would improve reservoir mapping, sub-basalt imaging in Gulf of Mannar

Basin Prospectivity: Kerala-Konkan
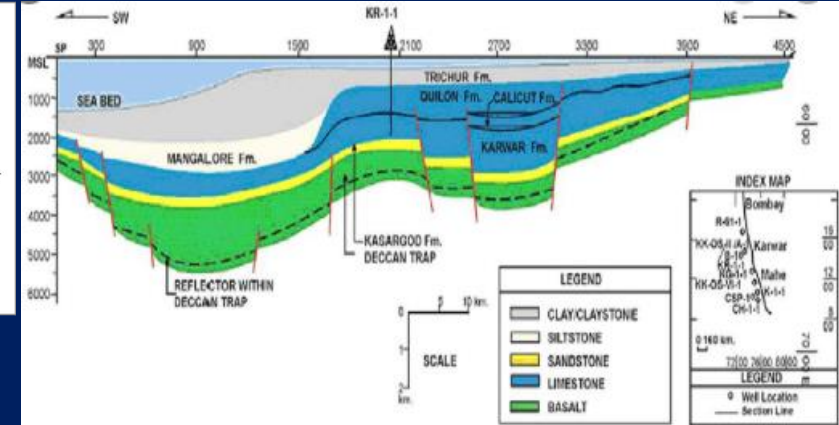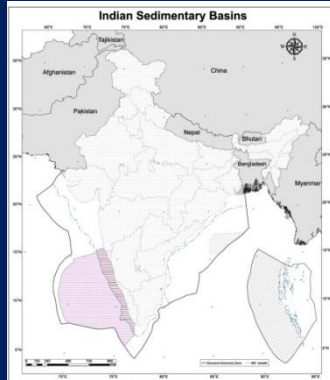
- ✓ The total inplace 1,245 MMTOE with 56% area appraised
- ✓ Broad-grid seismic data available
- ✓ 5 geological play, all conceptual
- ✓ Shelfal area around Cochin low is the focus area
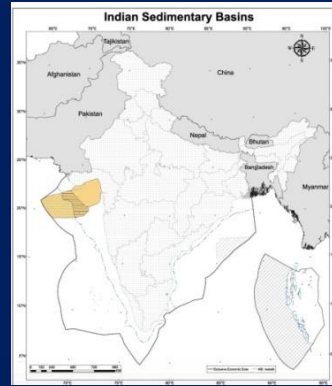- ✓ Improving sub-basalt imaging is the key factor
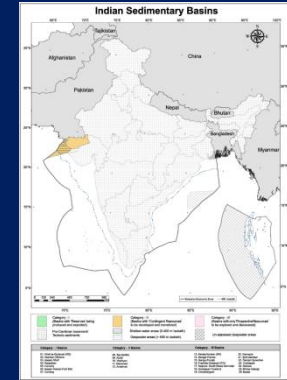
Basin Prospectivity: Mumbai offshore

Indian Sedimentary Basins

Area = 212,000 sq km

- deepwater 44%
- shallowwater 56%
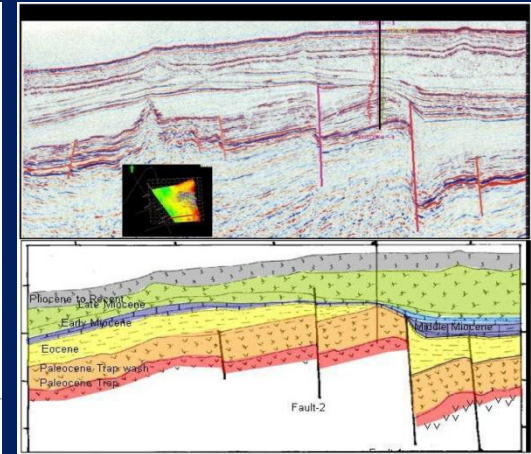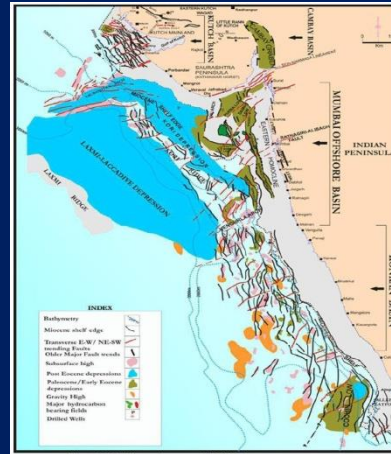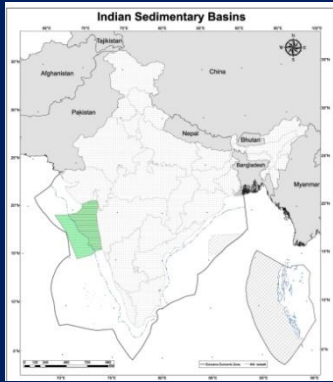
✓ Maximum discovered inplace (4,794 MMtoe), 50% of estimated total inplace

✓ Proven basin with producing fields, contributing 1/2 of total oil and 2/3rd of total gas production by Operator

✓ Shallow water has 96% area appraised while deepwater 75%

✓ 10 plays including 3 biogenic. Largely carbonate deposits with occurrence of clastic in deeper plays.

✓ Potential thrust area in Paleocene and Eocene plays including deeper plays in Tapti-Daman area

✓ The deepest sequence encountered is Basal clastic over Deccan Trap basalts. Mesozoic potential is still elusive.

✓ Discovery in shallower plays off deep continental shelf is new phenomenon
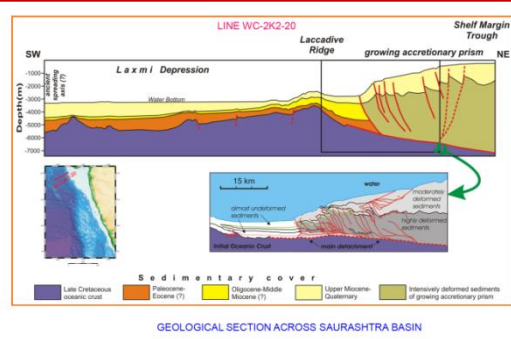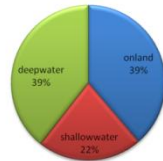
Basin Prospectivity: Saurashtra & Kutch

✓ The basin is appraised to the extent of 57%.

✓ There are 16 geologic plays with 13 reasonably assessed

✓ Sub-basalt imaging and low frequency 2D seismic are the key factors to explore the Mesozoic.

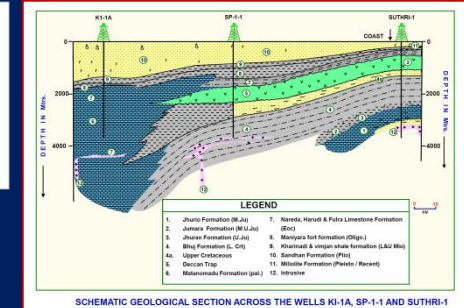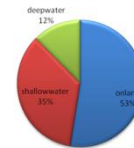✓ 1 offshore gas discovery in Cretaceous age is contemplated for development

✓ The basin is appraised to the extent of 45%.

✓ There are 17 geologic plays with 14 reasonably assessed

✓ Sub-basalt imaging is the key factor to explore the Mesozoic.

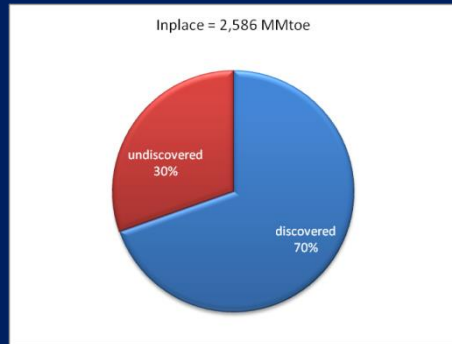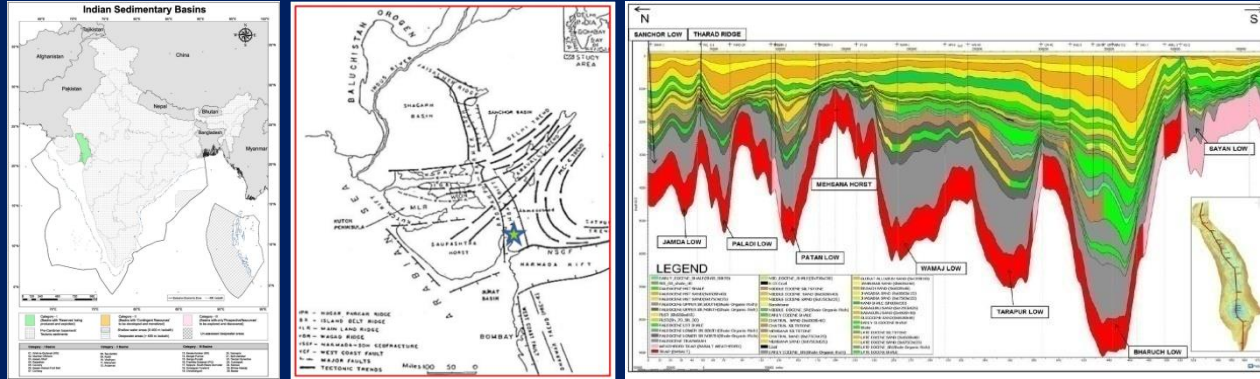✓ 2 offshore gas discoveries in Mesozoic are contemplated for development

Indian Sedimentary Basins

Indian Sedimentary Basins

Area = 194,114 sq km

onland 39%
deepwater 39%
shallowwater 22%

GEOLOGICAL SECTION ACROSS SAURASHTRA BASIN

Area = 58,554 sq km

deepwater 12%
onland 53%
shallowwater 35%


SCHEMATIC GEOLOGICAL SECTION ACROSS THE WELLS KI-1A, SP-1-1 AND SUTHRI-1

Basin Prospectivity: Cambay

Inplace = 2,586 MMtoe


- ✓ Basin area 53,500 sq km including a small part , 4,618 sq km falling offshore
- ✓ The basin is appraised to the extent of 72%
- ✓ Most matured basin with 70% inplace discovered.
- ✓ Potential Miocene and Fractured Basement plays including unconventional shales

Basin Prospectivity: Rajasthan

Indian Sedimentary Basins

Inplace = 4,126 MMtoe
- discovered 23%
- undiscovered 77%

Barmer

Jaisalmer
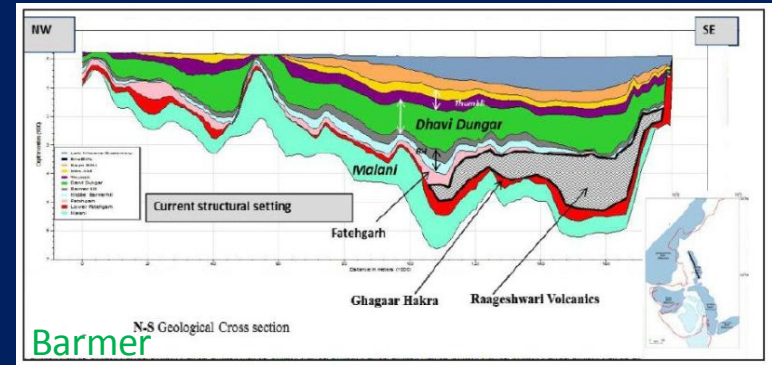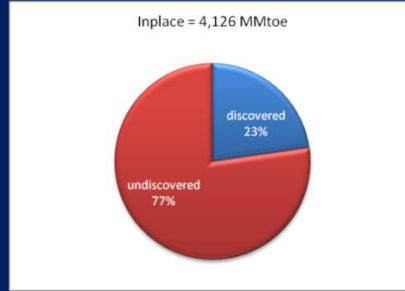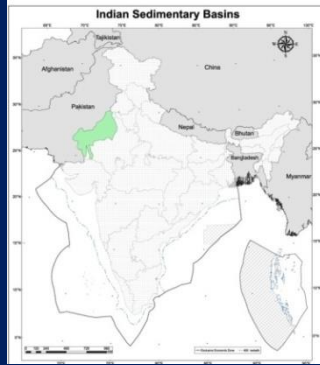
Bikaner-Nagaur

- ✓ Area 126,000 sq km with 43% appraised
- ✓ 3 sub-basins of Pre-Cambrian, Mesozoic and Tertiary
- ✓ Barmer boasts of largest onland crude production, 25% of Indian total.
- ✓ Jaisalmer has producing gas fields in tight plays
- ✓ Bikaner-Nagaur has viscous oils and subject to active exploration
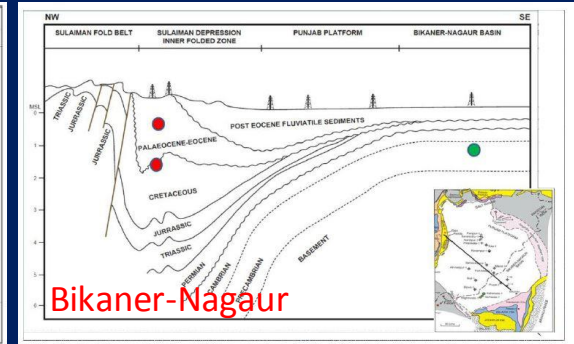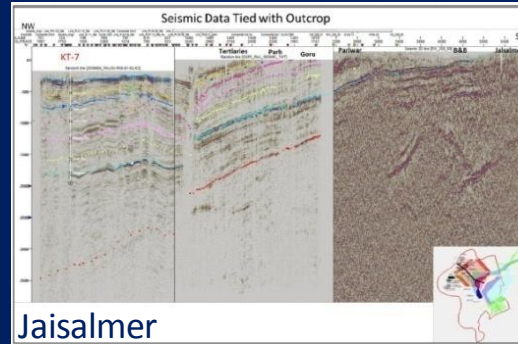
Basic Prospectivity: Vindhyan

4.1: Location and Geological Map of Vindhyan Basin
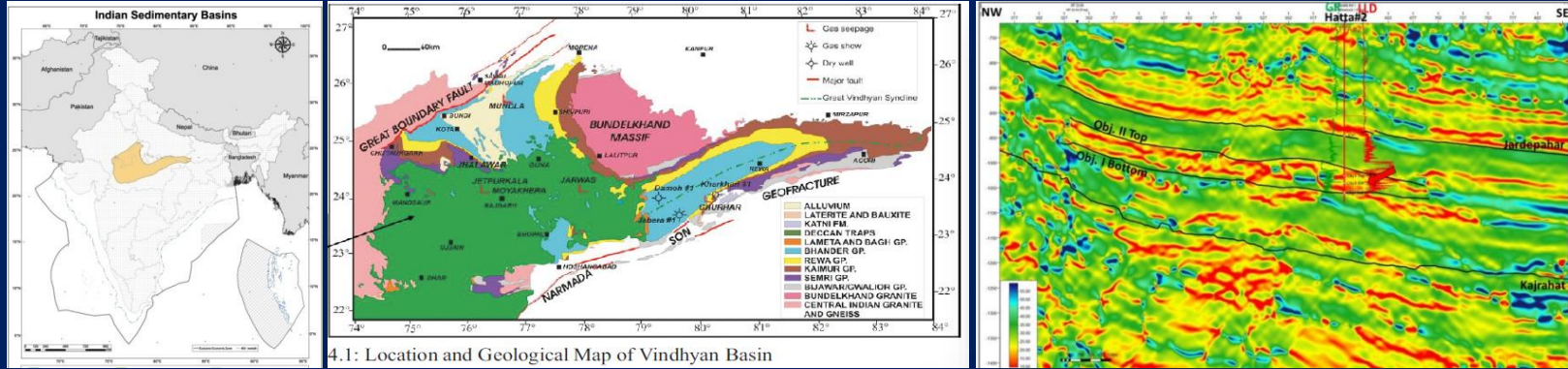

- ✓ Basin area 202,888 sq km, out of which 14% area appraised
- ✓ Estimated risked inplace of 632 MMTOE
- ✓ 3 geologic plays
- ✓ Recent discovery of significant gas potential, influencing all Proterozoic analogue basins
- ✓ Technology intervention for exploration and development of tight plays
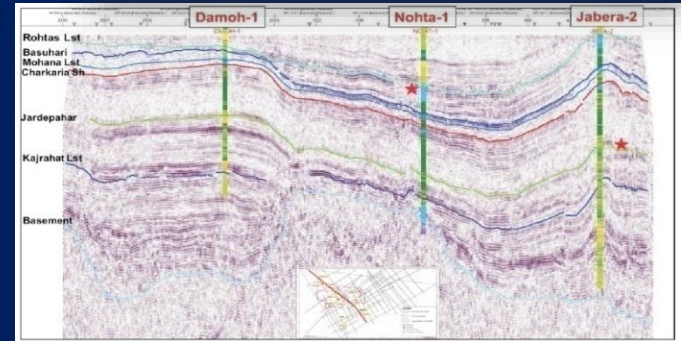
Opportunities: Key facts

SEDIMENTARY BASIN AREAS

Indian Sedimentary Basin Area

total appraised area
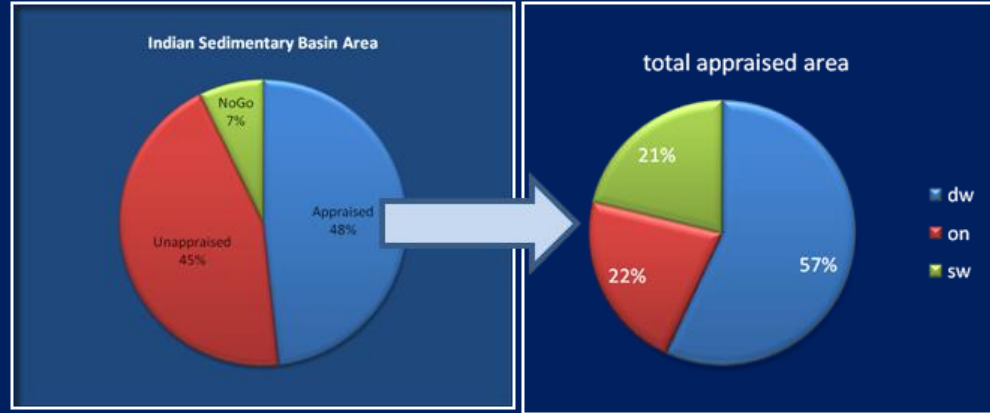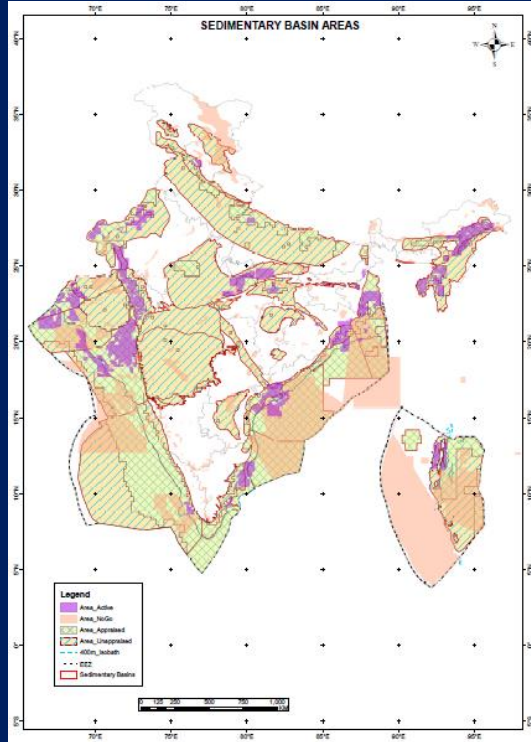
Basin category	Total area (million sq km) **3.36**	Appraised area (million sq km) **1.64**	Active area (million sq km) **0.26**
I	30% (1.01)	47%(0.78)	65%(0.17)
II	23%(0.77)	22%(0.36)	26%(0.07)
III	47%(1.58)	31%(0.50)	9%(0.02)

Opportunities: Sum-up

- Freedom and Facilitation:
    - Investor-carved out acreage to start the bidding process
    - Information on block-level prospectivity at the time of bidding
    - Basin-specific Technical Booklets and Block-specific Presentations
    - Information Dockets and Presentations for fields-on-offer under Discovered Small Field bid rounds
- Access to NDR:
    - Access to Online portal 24x7 with option for Data Request
    - Book for Physical Data Rooms
    - On-the-spot assessment using popular Interpretation Software
- Data enrichment:
    - New discoveries,
    - New/ revised interpretations,
    - New 2D seismic data from NSP with speculative leads,
    - Basin-specific information on Hydrocarbon Resources

THANK YOU ..