Hydrocarbon Prospectivity

Indian Sedimentary Basins
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
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

Sag:
- Vindhyan, Deccan Syncline, Bhima-Kaladgi, Chattisgarh, Cuddapah, and Bastar

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

Basin Types:
- Pericratonic Rift Basin
- Intracratonic Rift Basin
- Intracratonic Sag Basin
- Forearc Collision Basin
- Foreland
- Peripheral Foreland Basin
- Interorogenic Foreland Basin
Basin Categorization: 26 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

- 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

- Majority of the area are under Category III without a discovery and subject to intense exploration.
Recent Studies: Basin area

- 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.
Recent Studies: Resources in basins

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

- **Kutch and Saurashtra** have development plans approved. Vindhyan under appraisal.

- **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).
Emerging facts: Resources profile

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

<table>
<thead>
<tr>
<th>Era</th>
<th>Total Hydrocarbon Inplace</th>
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</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>31,655</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>8,594</td>
</tr>
<tr>
<td>Proterozoic</td>
<td>1,265</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>221</td>
</tr>
<tr>
<td>Archean</td>
<td>131</td>
</tr>
<tr>
<td>Quarternary</td>
<td>2</td>
</tr>
</tbody>
</table>

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- 177 plays mapped
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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
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

- 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)

- 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
Basin Prospectivity: Assam & Assam-Arakan

- 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.
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 stratigraphic entrapment

Proximal area to hinge zone remains the exploration target
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)

- 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

- 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

- 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
Basin Prospectivity: Cambay

- 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

- 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
Basin Prospectivity: Vindhyan

- 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

<table>
<thead>
<tr>
<th>Basin category</th>
<th>Total area (million sq km)</th>
<th>Appraised area (million sq km)</th>
<th>Active area (million sq km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>30% (1.01)</td>
<td>47% (0.78)</td>
<td>65% (0.17)</td>
</tr>
<tr>
<td>II</td>
<td>23% (0.77)</td>
<td>22% (0.36)</td>
<td>26% (0.07)</td>
</tr>
<tr>
<td>III</td>
<td>47% (1.58)</td>
<td>31% (0.50)</td>
<td>9% (0.02)</td>
</tr>
</tbody>
</table>
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 ..