KUALA LUMPUR 2012 WORLD GAS CONFERENCE

IGU

25th world gas conference

"Gas: Sustaining Future Global Growth"

Recent Advances in Exploration & Production of Natural Gas

WOC-1 Study Group 1.1
2009-2012 Report

Denis Krambeck Dinelli, Petrobras - Brazil

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Convention Center, Room 304/305

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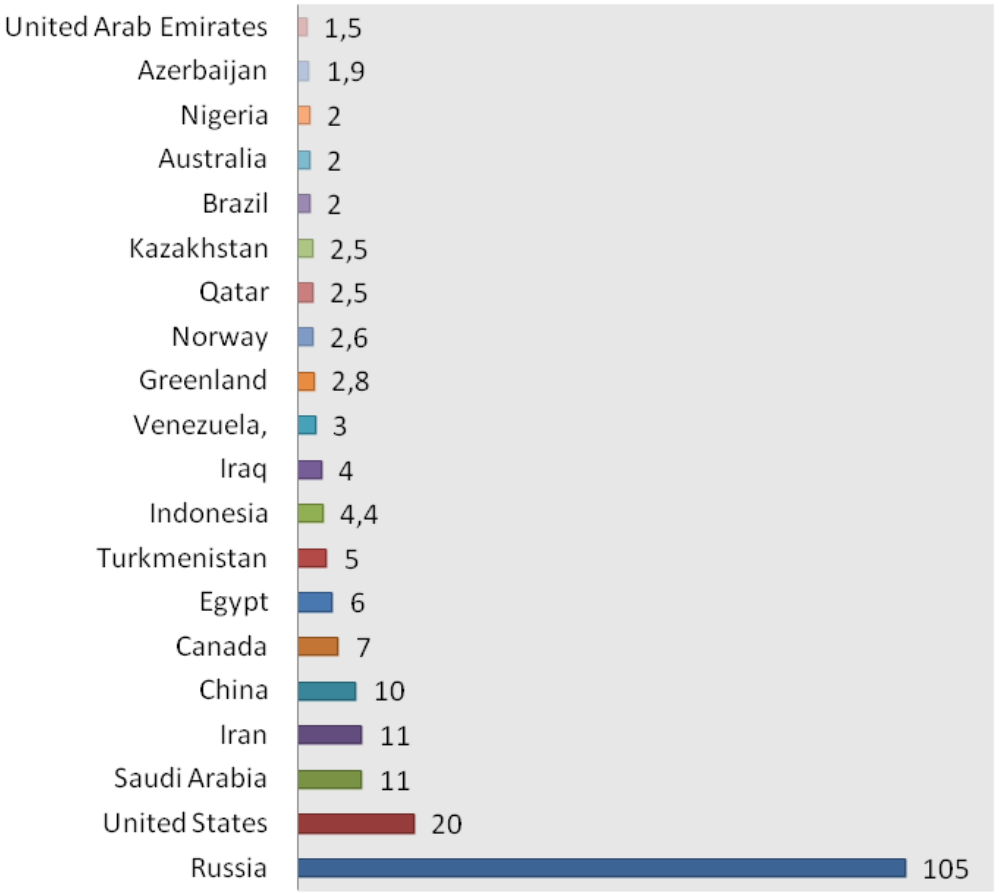
Contents

Worldwide Gas Resources

- Conventional Gas Resources are estimated at **241 TCM**;
- Equivalent to more than **120 years** of current global consumption, according to WEO, 2011;
- Including unconventional, today's production could be sustained for over **250 years**;
- Resources estimates continue to grow as a result of innovations in exploration and extraction techniques.

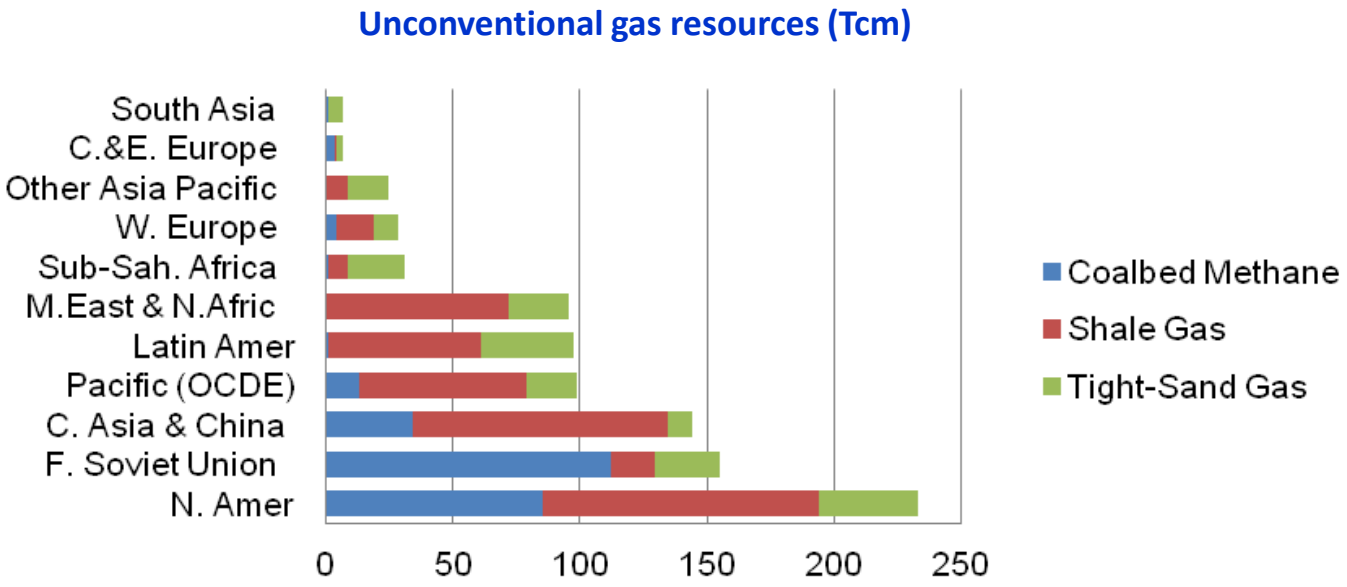
Conventional gas resources (Top 20 countries, Tcm)



Source: BGR Annual Report, 2010

Worldwide Gas Resources

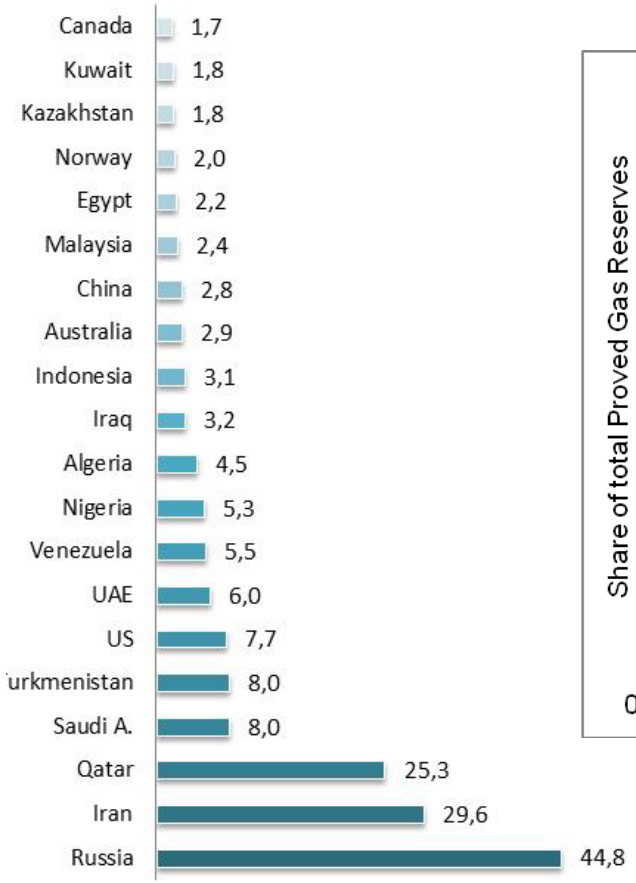
- Worldwide Unconventional Gas Resources Estimates are **922 TCM**:
  - Coalbed Methane: **256,3 TCM**;
  - Shale Gas: **456,2 TCM**;
  - Tight-Sand Gas: **209,7 TCM**.



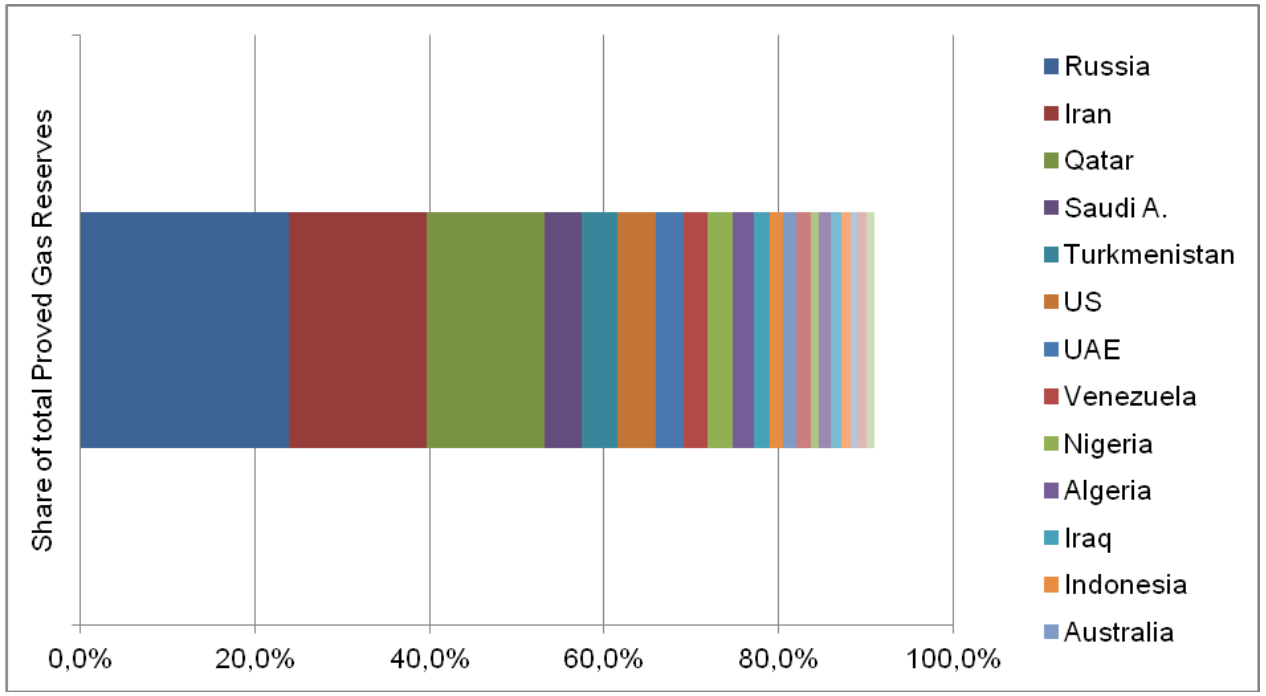
- Gas hydrates are widely distributed on the continental shelves and in Polar Regions. Total worldwide resources are estimated to be between **991 and 5012 TCM**.

Worldwide Gas Reserves

- As of end 2010, proved world natural gas reserves, were estimated at **187.1 Tcm**, about **0.56 Tcm** higher than the estimate for 2009. World's ratio of proven natural gas reserves to production at current levels is between **60 and 70 years** (BP Statistical review, 2011).



Major Proven Gas Reserves (TCM)

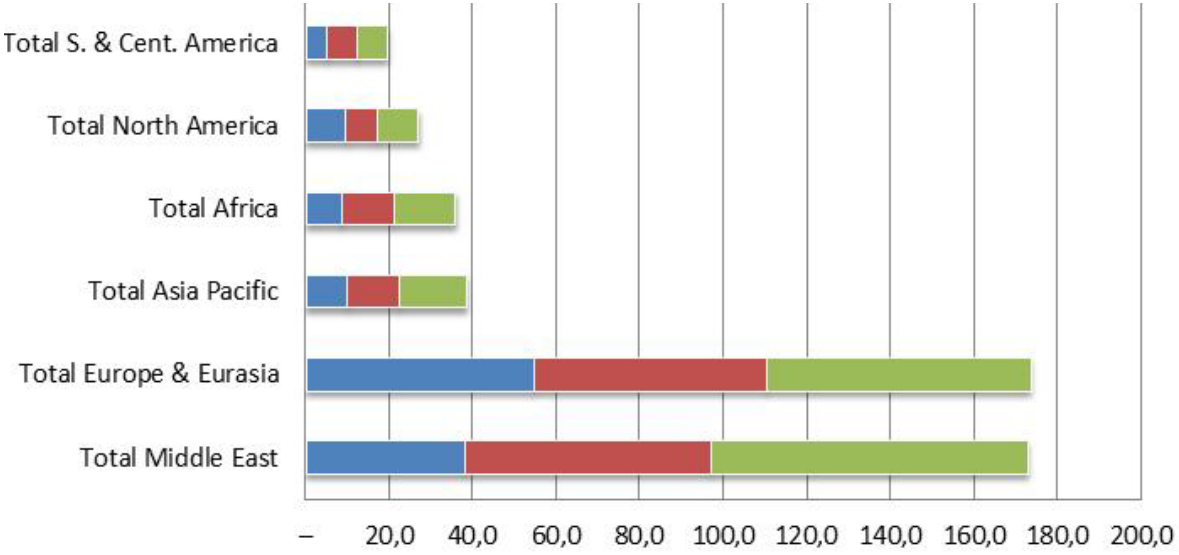


Top 20 countries share of total 2010 proved gas reserves

Source: BP, 2011

Worldwide Gas Reserves

- World natural gas reserves have increased since the 1990's by an average of 3.1 % each year.



	Total Middle East	Total Europe & Eurasia	Total Asia Pacific	Total Africa	Total North America	Total S. & Cent. America
At end 1990	38,0	54,5	9,9	8,6	9,5	5,2
At end 2000	59,1	55,9	12,3	12,5	7,5	6,9
At end 2010	75,8	63,1	16,2	14,7	9,9	7,4

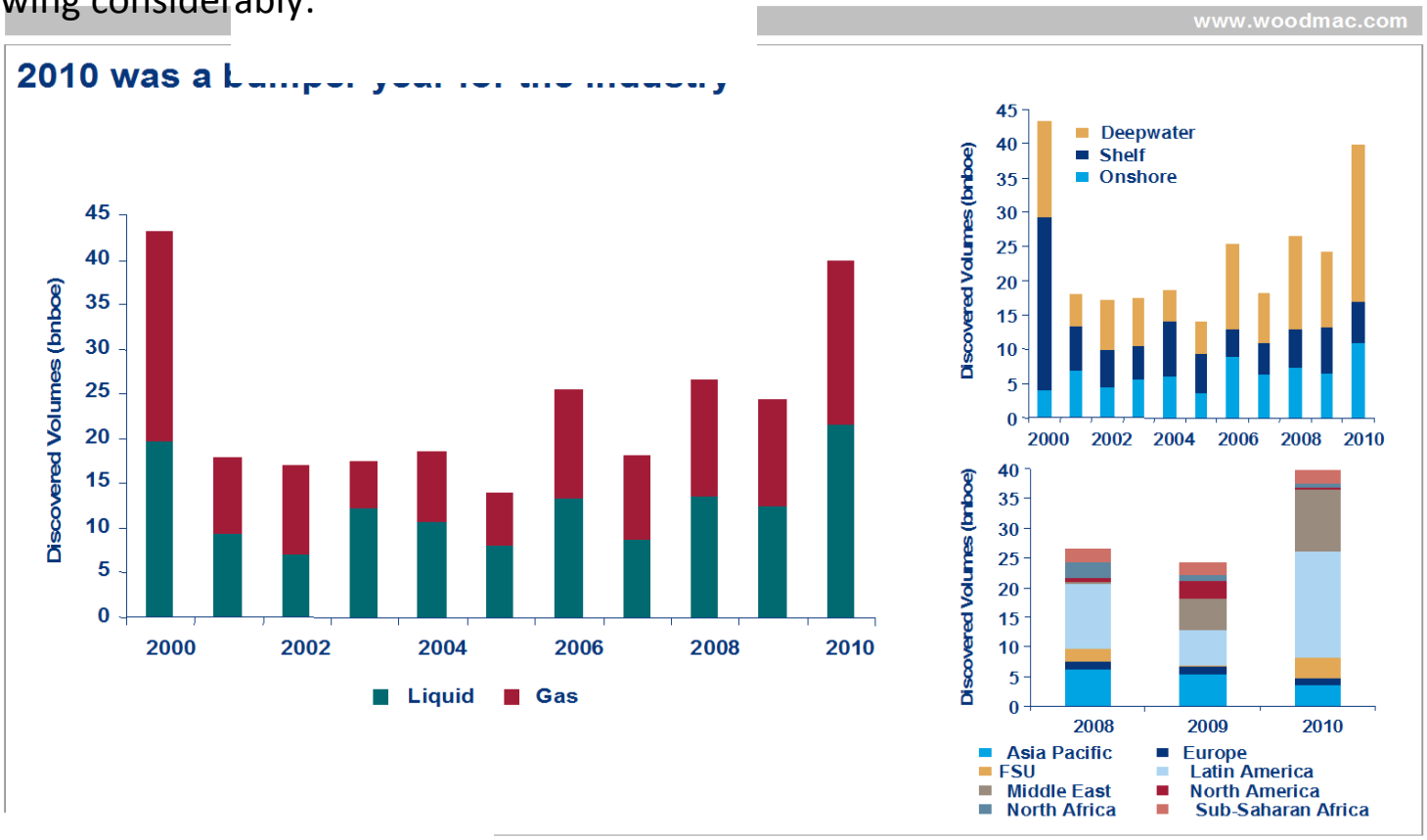
Last 20 years Regional proved gas reserves (TCM)

Source: BP, 2011

Contents

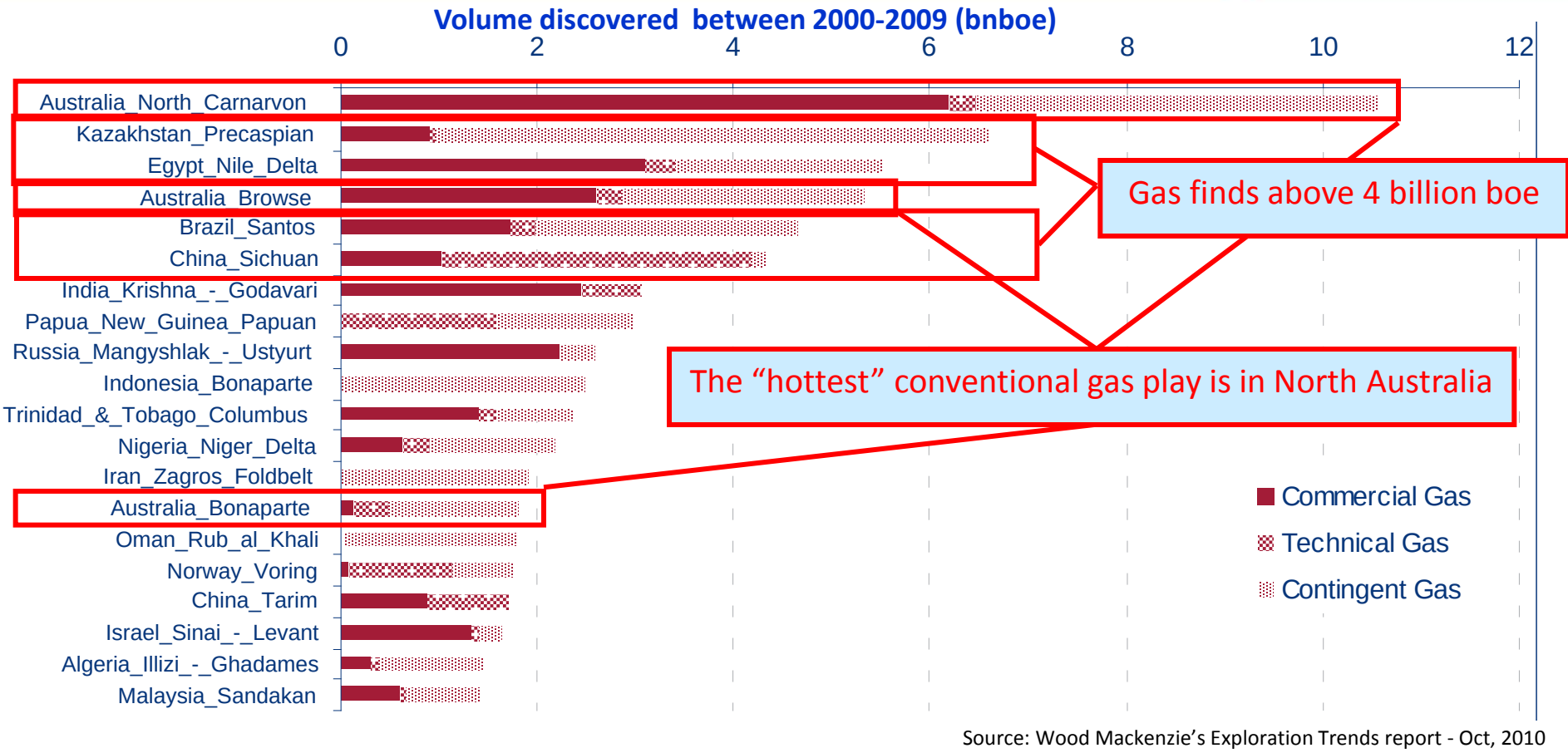
Exploration and Discovery Trends

- Global exploration is focusing on frontier exploration (<20%), emerging and mature exploration (one third each) and unconventional exploration (<20%);
- After a stagnation phase from 2001 to 2005, the annual discovered volumes of oil and gas have been growing considerably:



Source: Wood Mackenzie Exploration Service

Exploration and Discovery Trends



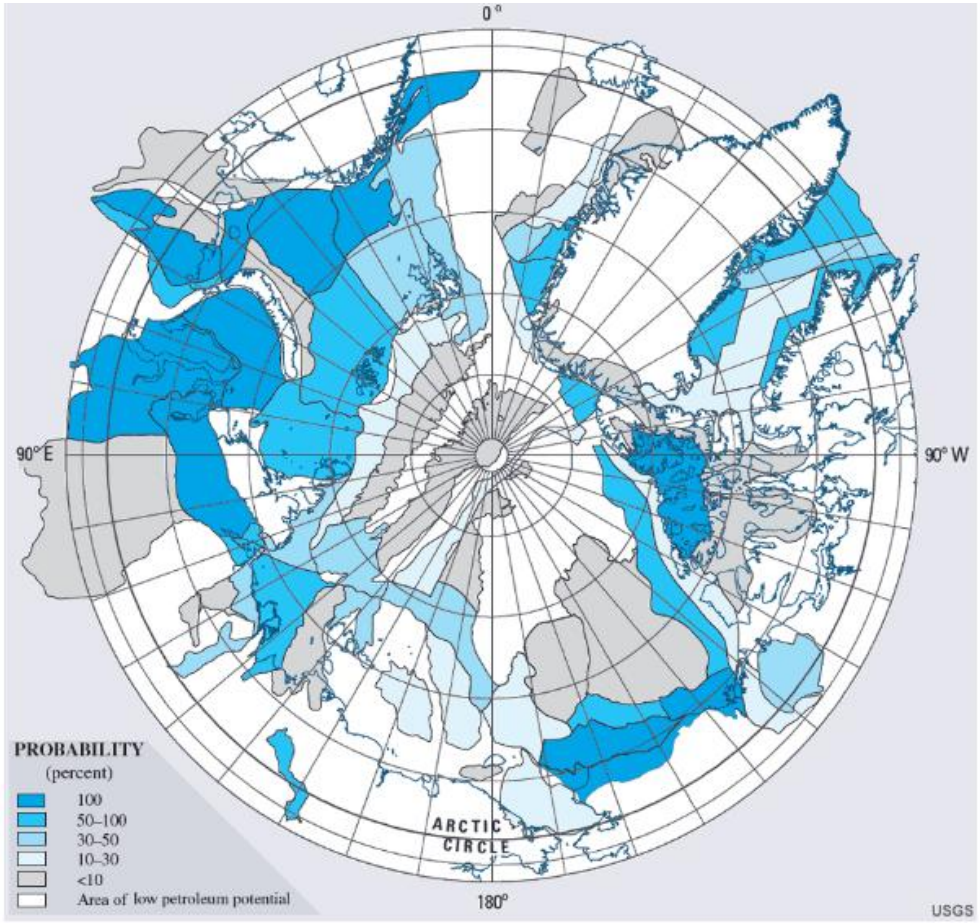
Source: Wood Mackenzie's Exploration Trends report - Oct, 2010

- These gas exploration areas are not necessarily coinciding with the areas of largest existing gas reserves, what indicates that there are new gas areas dawning to develop and providing the future gas supply above and beyond the existing gas reserves areas.

Contents

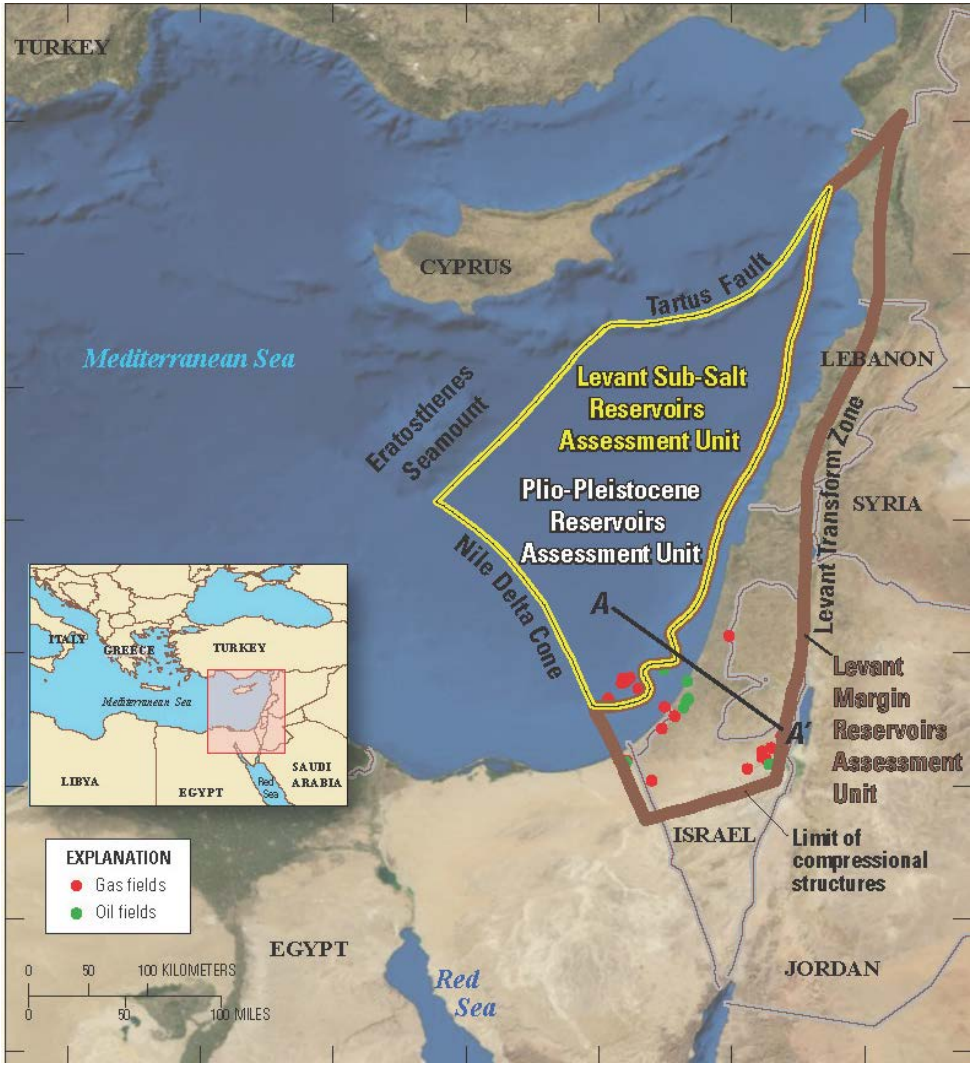
The Arctic Circle

- Covers more than 21 Million Km² (6 % of the Earth's surface);
- Belongs to 5 countries: Norway, Russia, USA, Canada and Denmark;
- 13 main basins outlined, and over 400 Oil and Gas fields already discovered, containing about 10% of the conventional Oil and Gas resources (~240 bboe);
- Contains 22% of the yet-to-find potential (USGS study, 2008);
- Exploration depends not only on the potential, but also on the difficulties of operating under harsh conditions and on national incentives.



The Levantine Basin

- Situated in the eastern Mediterranean area, with approximately 83.000 km²;
- Emerged as a prominent target after the decision to drill through the salt layer;
- The main discoveries are Leviathan (0.5 TCM) and Tamar (0.3 TCM);
- Success of exploration will largely be dependent on:
  - the Political situation in the area;
  - the development costs due to the water depth, targets depths and lack of export infrastructure .

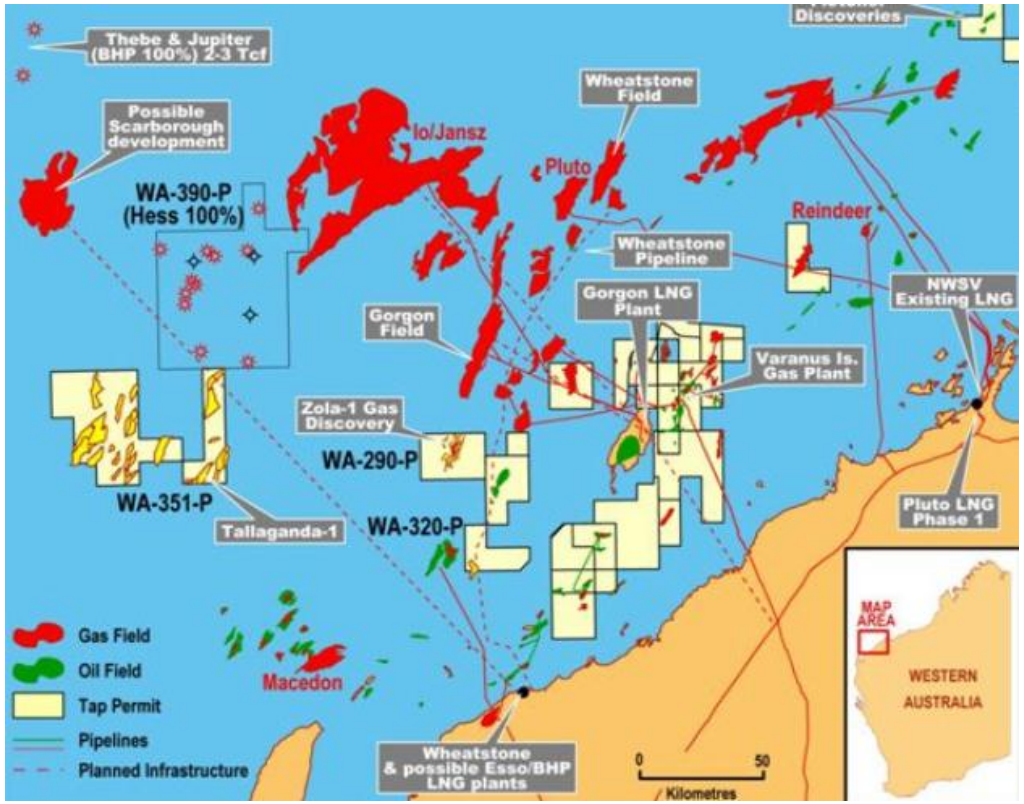


The Middle East

- Still considered the second most important region for gas after former soviet Union;
- The gas undiscovered resources are situated in the deeper Paleozoic levels, accounting for more than 22 TCM, according to the USGS evaluations;
- The discovery of new plays and large reserves will, however, be strongly linked to the local policies and international environment.

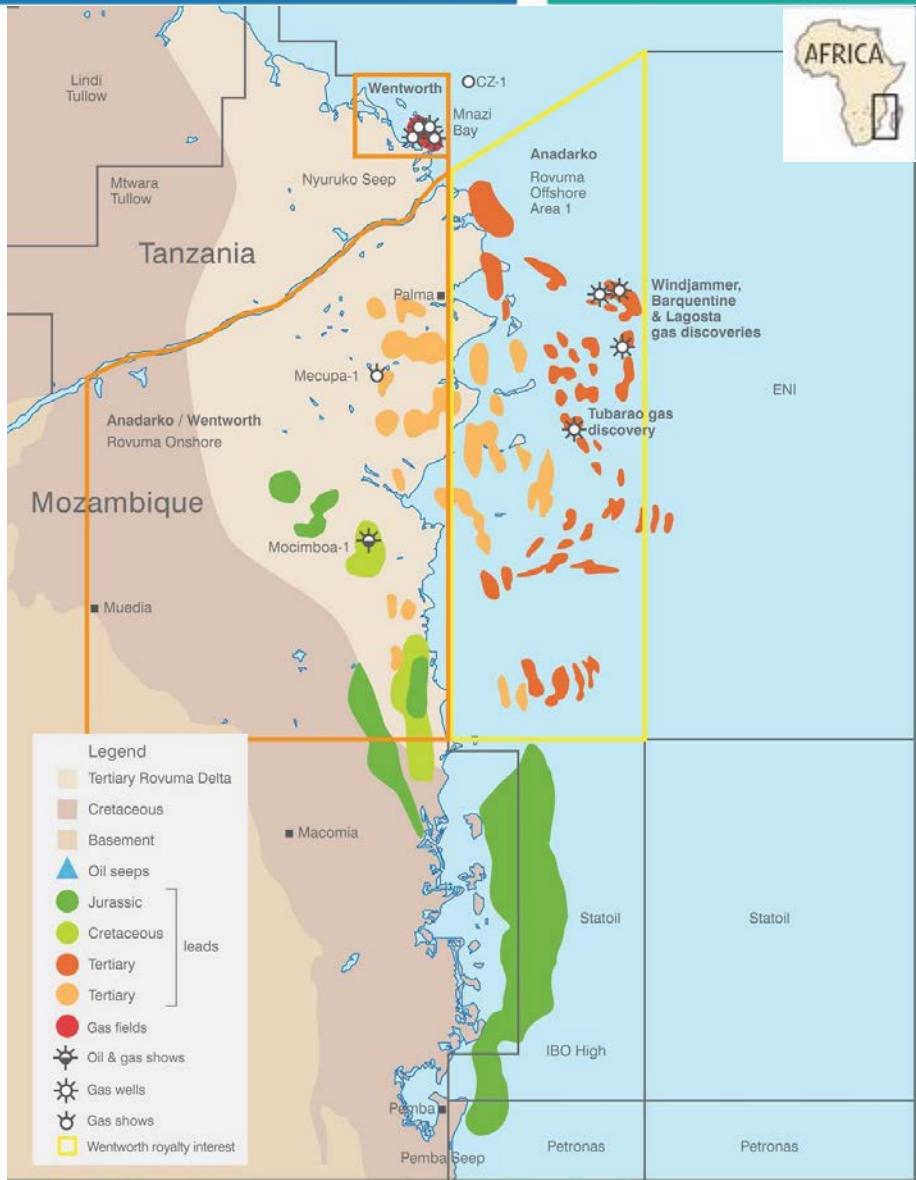
The Australian Offshore

- Proving from the last ten years to be one of the most prolific basin for gas worldwide;
- New giant fields accounted for 1.4 TCM of new reserves in the last decade;
- Offshore exploration identified over 4.5 TCM of gas in the Carnavon, Browse and Bonaparte basins;
- The low political risk and the proximity to Asian markets places it in an ideal position to meet growing expected gas demand.



East Africa

- Has been emerging as a new frontier area for gas exploration in the very recent years;
- Progresses of deep water drilling technologies enabled the operators to tackle basins that were considered too deep to be explored before;
- Recent discoveries in Mozambique created a regional acceleration in exploration. Tanzania and Kenya also have high potential for gas exploration;
- Lack of major export solutions is the main bottleneck.



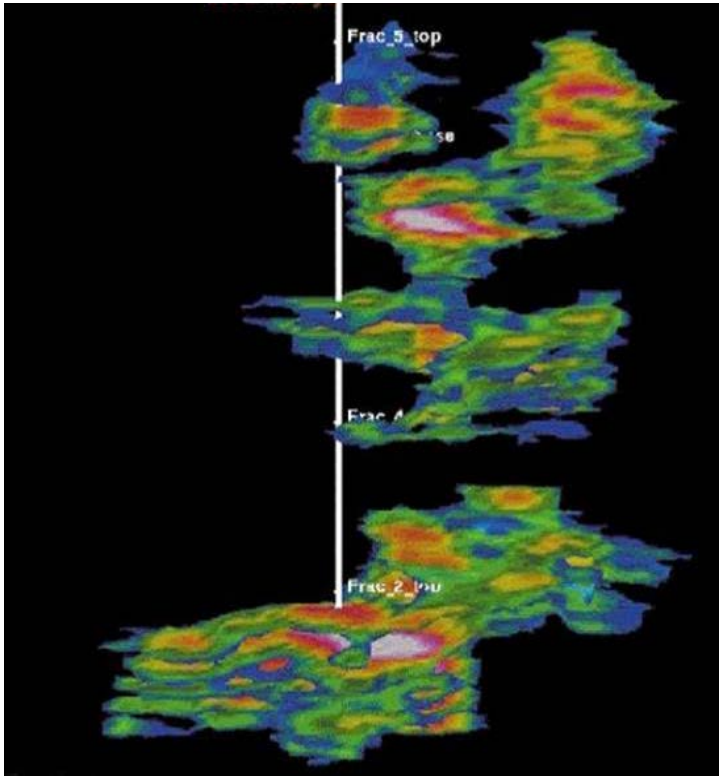
Central Asia

- Although it's perceived as a fantastic area for exploration, situation is quite contrasted in the different countries;
- Kazakhstan is considered rather under-explored, and one of the most promising countries;
- In Azerbaijan, exploration focused on onshore plays, and the remaining undiscovered hydrocarbons should mostly be located offshore, in very challenging environments;
- In Turkmenistan, discovery and reassessment of the giant South Iolotan field allowed the country to jump as one of the world's new gas reserve holder.

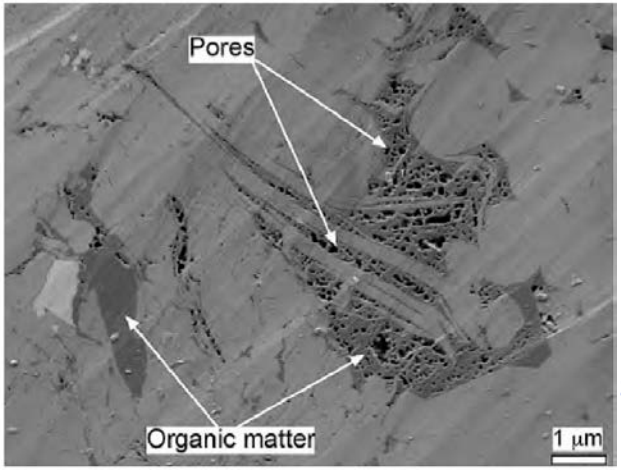
Contents

Advances in Unconventional Gas Technologies

- **Reservoir Characterization Technologies:**
  - ***Depositional models and paleogeographic reconstructions*:** critical to identifying those areas mostly likely to contain thick unconventional accumulations;
  - ***3-D seismic data*:** key to recognizing "sweet-spots" and quantifying structural closures, faults, stratigraphic pinch-outs, porosity/saturation fairways, facies types, mechanical properties and natural fracture swarms.
  - ***Digital rock physics*:** new core-scale imaging technologies that are providing insights into gas storage and deliverability mechanisms in extremely low permeability rocks.



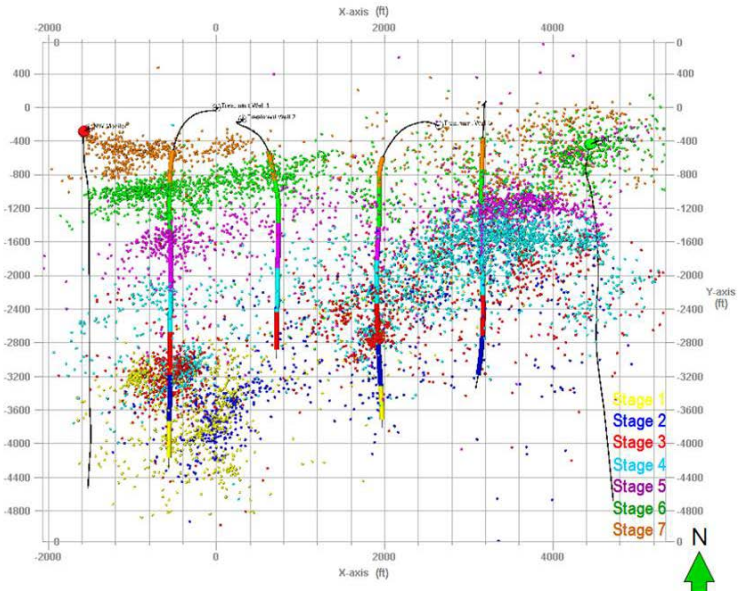
Fracture swarms interpreted from 3-D seismic



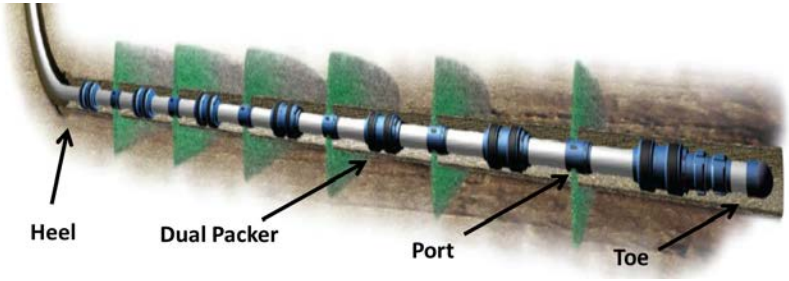
Scanning Electron Microscopy (SEM) photomicrograph of nanoscale pore architecture

Advances in Unconventional Gas Technologies

- **Drilling and Completion Technologies:**
  - ***Customized drilling technologies*:** reduce the time and cos required to drill wells. Some companies design and build their own fit-for-purpose rigs and implement processes tha continuously reduce drilling time and costs;
  - ***Open-hole completions using isolation packers with ball-activated ports*:** reduce time and increase gas production from horizontal wells;
  - ***Microseismic Monitoring*:** used to characterize the reservc volume affected by hydraulic fracture stimulation in unconventional reservoirs. Some of the uses are:
    - Quantifying the height and lateral extent of the stimulated fracture network;
    - Testing the effectiveness of different stimulation techniques and tools;
    - Optimizing the well spacing to ensure that interwell areas are being drained and well interference is minimized.



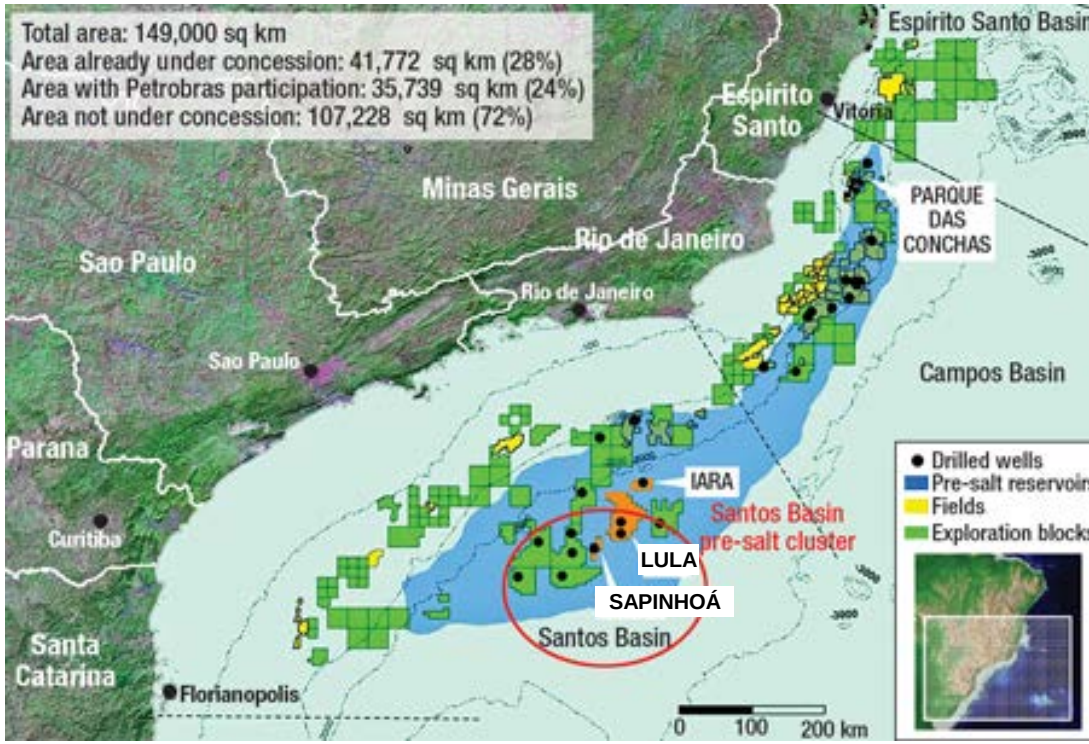
Microseisimic data from hydraulic fracture stimulations



Open-hole completion technique using isolation packers with ball-activated ports in a horizontal well

The Brazilian Pre-Salt

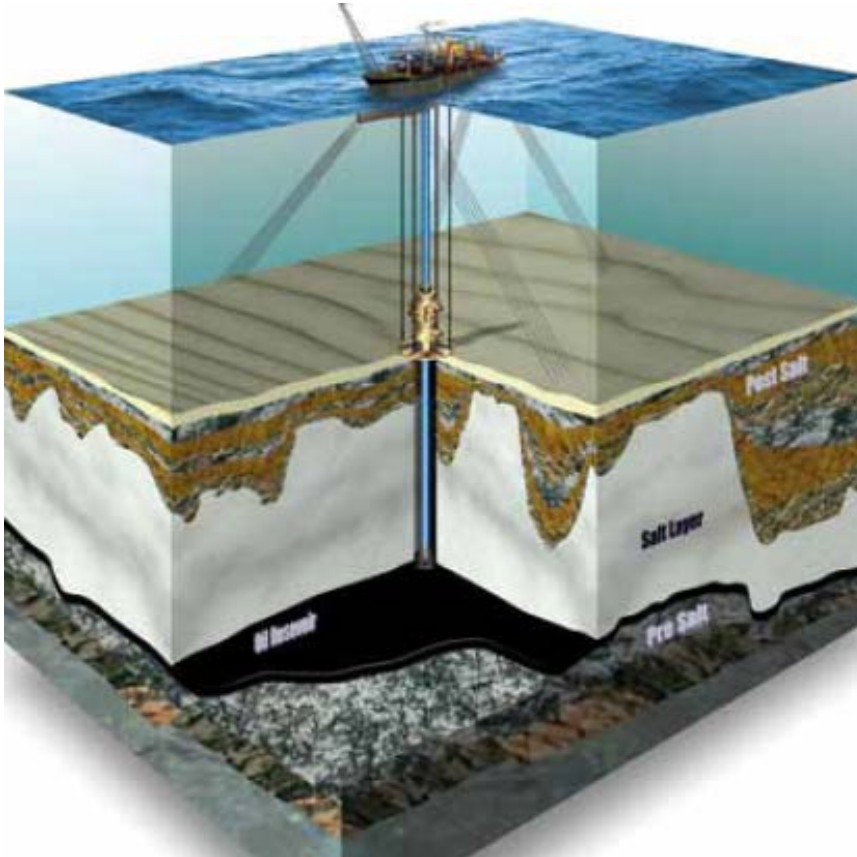
- The Pre-Salt in Brazil was the result of efforts to find new exploratory horizons in the Brazilian sedimentary basins;
- Total area of 149,000 km^2, comprising the Santos and Campos sedimentary basins;
- The Pre-Salt reservoirs are, as is characteristic of carbonate reservoirs, heterogeneous, with highly variable petrophysical properties.
- Basically associated gas, in a gas-oil ratio between 200 and 300 m^3/m^3.



The Brazilian Pre-Salt

- **Challenges:**
  - reservoirs depths between 5,000 and 6,000 m below the sea level;
  - extensive salt layer, with thickness up to 2,000 m;
  - high contents of CO_2 ;
  - H_2S in high concentrations;
  - flow assurance in ultra-deep waters, with low fluid temperature.

- **Technologies:**
  - Ultra-deep waters: hybrid rigid-flexible riser and pipe systems;
  - CO_2: membrane permeation, and compression systems able to cope with different flowrates and different CO_2 concentrations in the gas stream;
  - H_2S: adsorption with metallic oxide;
  - Gas Pipelines: H_2S resistant and with a corrosion allowance thickness suitable to CO_2 contents higher than 5% molar; insulation and heating under analysis to enhance flow assurance.

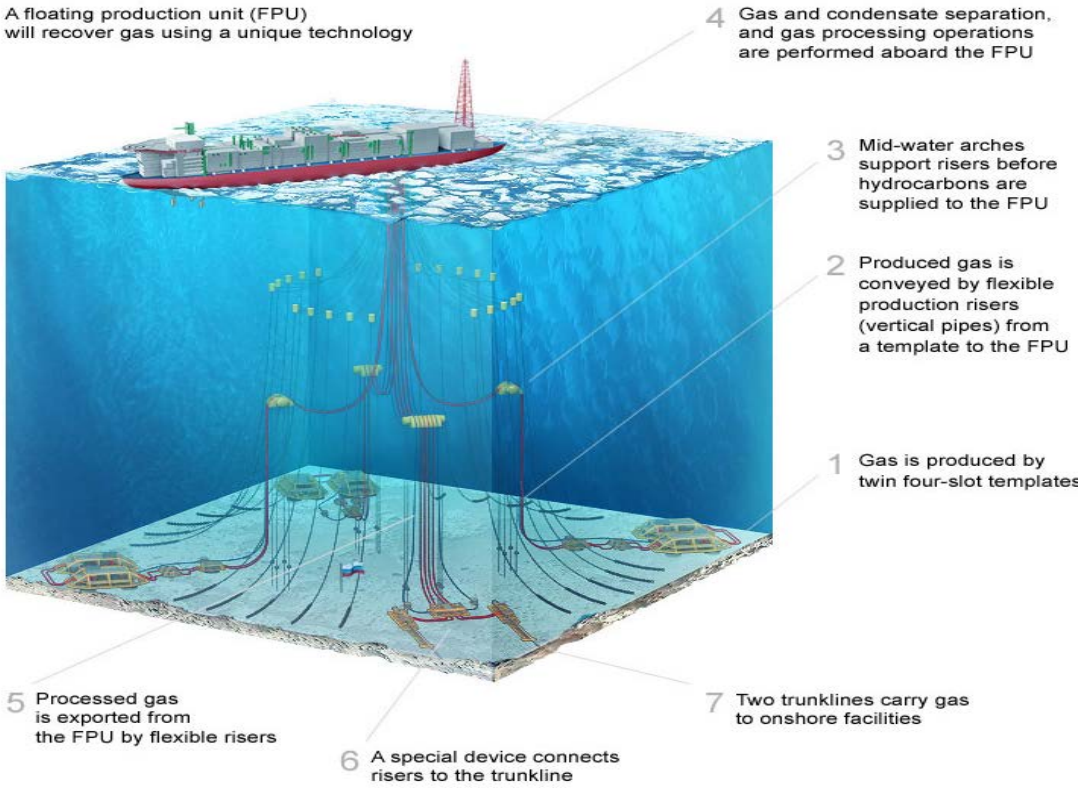


The Russian Arctic

- Enormous hydrocarbon resources associated with extreme environments and harsh climatic conditions, in both its coastal areas and the shelves of the northern seas;
- Presents obvious special physical hurdles – lots of ice, extremely low temperatures, remote locations and long periods of darkness;
- Two main projects under development: Yamal peninsula (resources estimates of 22 TCM) and Shtokman (reserves estimates of 4 TCM).

The Russian Arctic

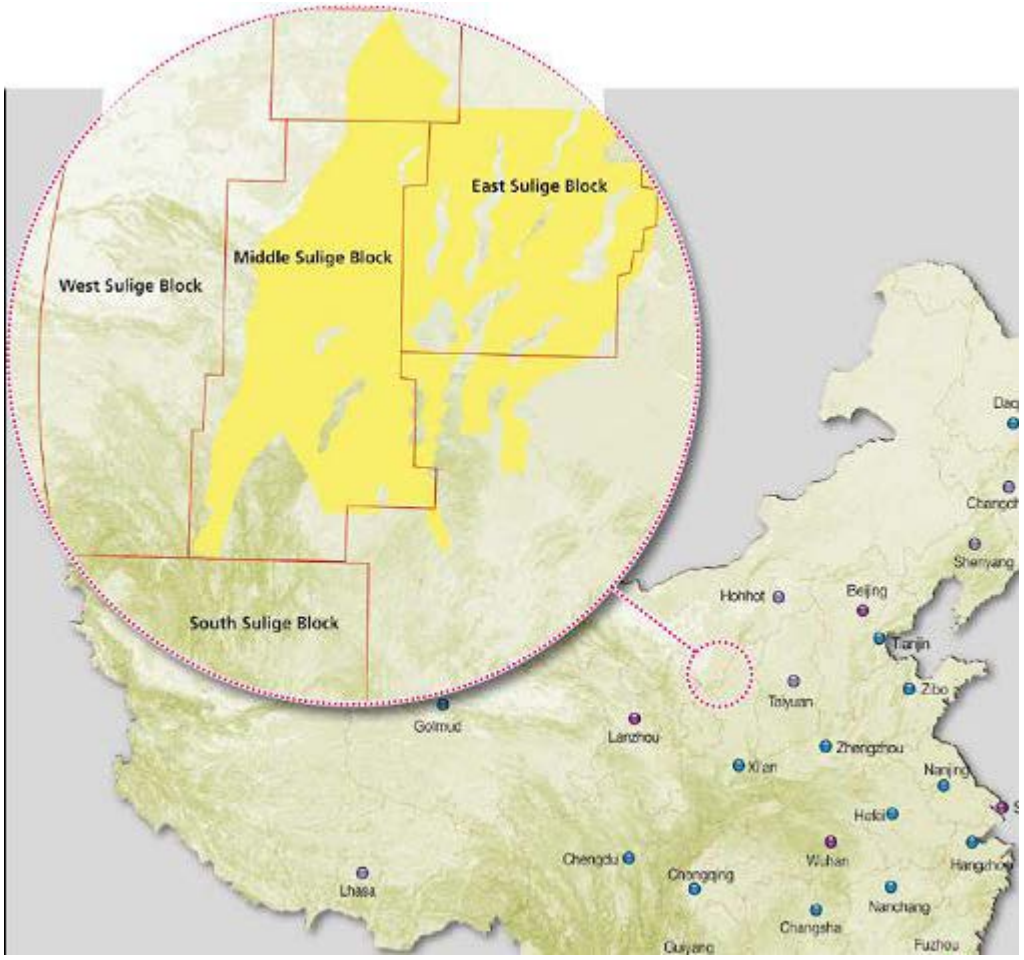
- **Challenges:**
  - Geographic Location;
  - Deep Water;
  - Gas Transportation and Construction & Installation in Ultra-Long Distances and Limited Weather Windows;
  - Leak Detection and Pipe Repair.



- **Technologies:**
  - heat-insulated pipes and operation with a view to preventing the permafrost rocks thawing;
  - high-resistant steel pipes with smooth interior coating designed for high working pressure, as well as new welding technology and materials;
  - long-distance subsea-to-shore tiebacks, or floating production systems developed to either withstand all ice loads, remain permanently on station, or alternatively to be disconnectable so as to avoid the most severe ice or iceberg conditions.

Tight Gas in China

- More than 10 basins in China which possess favorable geological conditions to form tight gas reservoirs;
- Prospective gas resource is estimated to be more than 12 TCM and above 20% of the natural gas resources.
- The Sulige gas field is the largest gas field in China, characterized by low permeability, low pressure and low abundance.



Tight Gas in China

- **Challenges:**
  - low permeability of the gas reservoirs and tight, thin effective thickness of single layer, dispersive longitudinal distribution;
  - Strong heterogeneity of reservoirs and low single-well control reserves;
  - Quick pressure drop and low single-well production;
  - Short stable production period and low average single-well production.

- **Technologies:**
  - Well location optimization;
  - Fast Drilling;
  - Inter-well Concatenation;
  - Separate Layer Fracturing and Commingled Production;
  - Downhole Choking;
  - Remote Control.

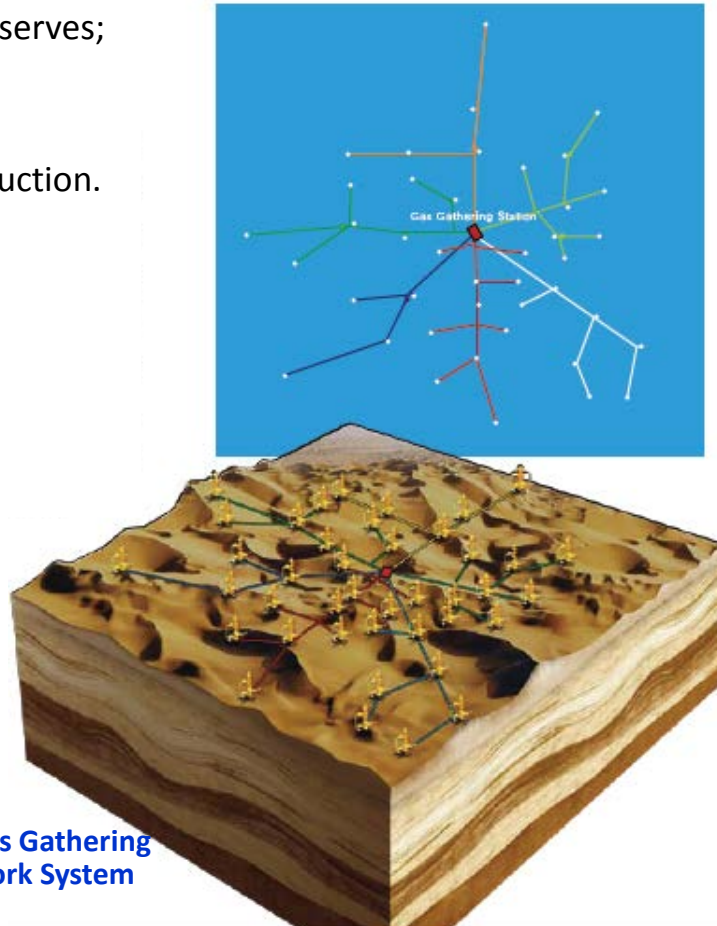


Diagram of a Gas Gathering Pipeline Network System

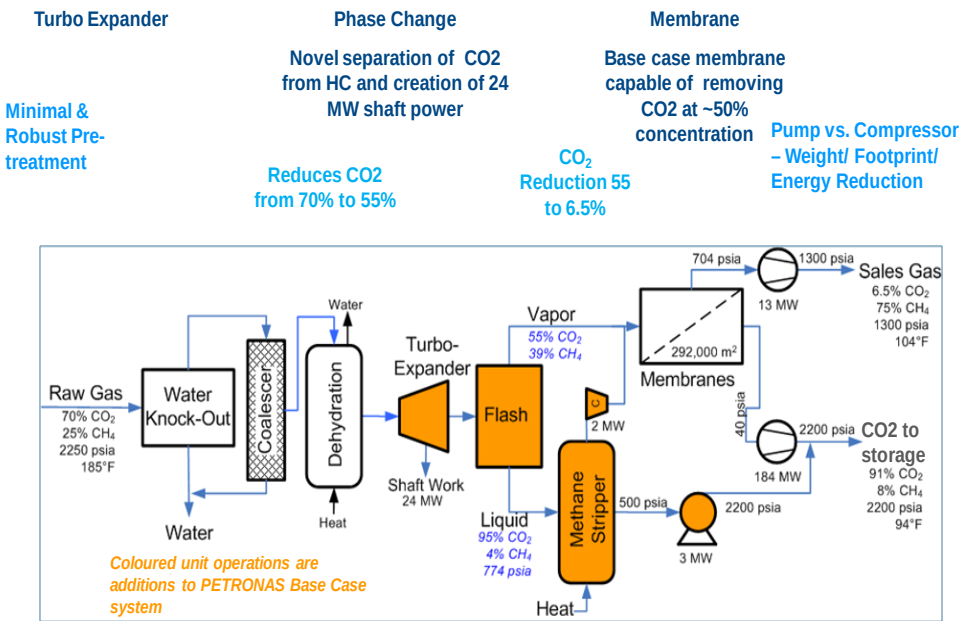
High CO_2 content in Malaysia

- All oil and gas fields in Malaysia are offshore;
- The increased energy demand in Malaysia, together with the declining production rate from now aging fields led to the reevaluation of the once avoided high CO_2 gas fields;
- Many of the remaining undeveloped gas fields have extremely high CO2 content, with some fields exceeding 70%.

Source: http://www.theodora.com/pipelines/southeast_asia_oil_gas_products_pipelines_map.html

High CO_2 content in Malaysia

- **Challenges:**
  - Developing offshore gas fields with as much as 70% CO_2 content.
  - To date, no offshore gas fields with CO_2 content above 40% have been developed.
- **Technologies:**
  - ***Separation***: phase separation via gas expansion and new advanced membranes;
  - ***Transport***: design tools to optimize the carbon steel used in pipelines and enable further optimization of corrosion inhibitor usage;
  - ***Sequestration***: development or adaptation for planning and monitoring sequestration, like microseismic monitoring.



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Conclusions

- Large quantities of natural gas are available today, and the potential for the future is even larger;
- The technology to access difficult reserves and to produce unconventional gas is mostly consolidated, but some exciting challenges remain to be confronted and surmounted;
- The exploration and development of new gas resources is capital-intensive and time-consuming, but has the potential to significantly increase reserves and production;
- The future is bright for natural gas.