

Shale Gas Exploration and Production



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Exploration & Production, Expert Forum 1.B: De-risking
& de-stranding gas resources**

Venue: KLCC, Kuala Lumpur, MALAYSIA



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Unconventional Resources

Shale Gas

Gas Hydrates

Shale Oil

Coalbed Methane

Tight Gas Sand

- Gas Reservoirs
 - Tight Gas
 - Shale Gas
 - Basin Centred Gas System
 - Gas Hydrates
 - Coal bed ethane
- Oil Reservoirs
 - Tight Oil
 - Heavy Oil
 - Oil Shale

Unconventional Resources



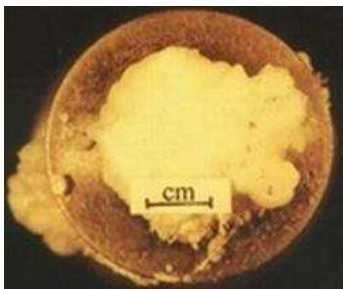
Shale Gas: Shale gas reservoirs almost always have two different storage volumes (dual porosity) for hydrocarbons, the rock matrix and the natural fractures



Tight Gas: siltstones, carbonates and very fine sandstones with low permeability / Located in conventional pore spaces in sandstone Low vertical permeability because of laminated structures/No significant gas flow without fractures, natural or induced



Coal Bed Methane Located in coal seams, often near surface/Natural Fractures often filled with water and gas /Key challenge is removal of water



Gas Hydrate: Hydrate Stability Zone under high pressure and low temperature in oceanic sediments and permafrost region

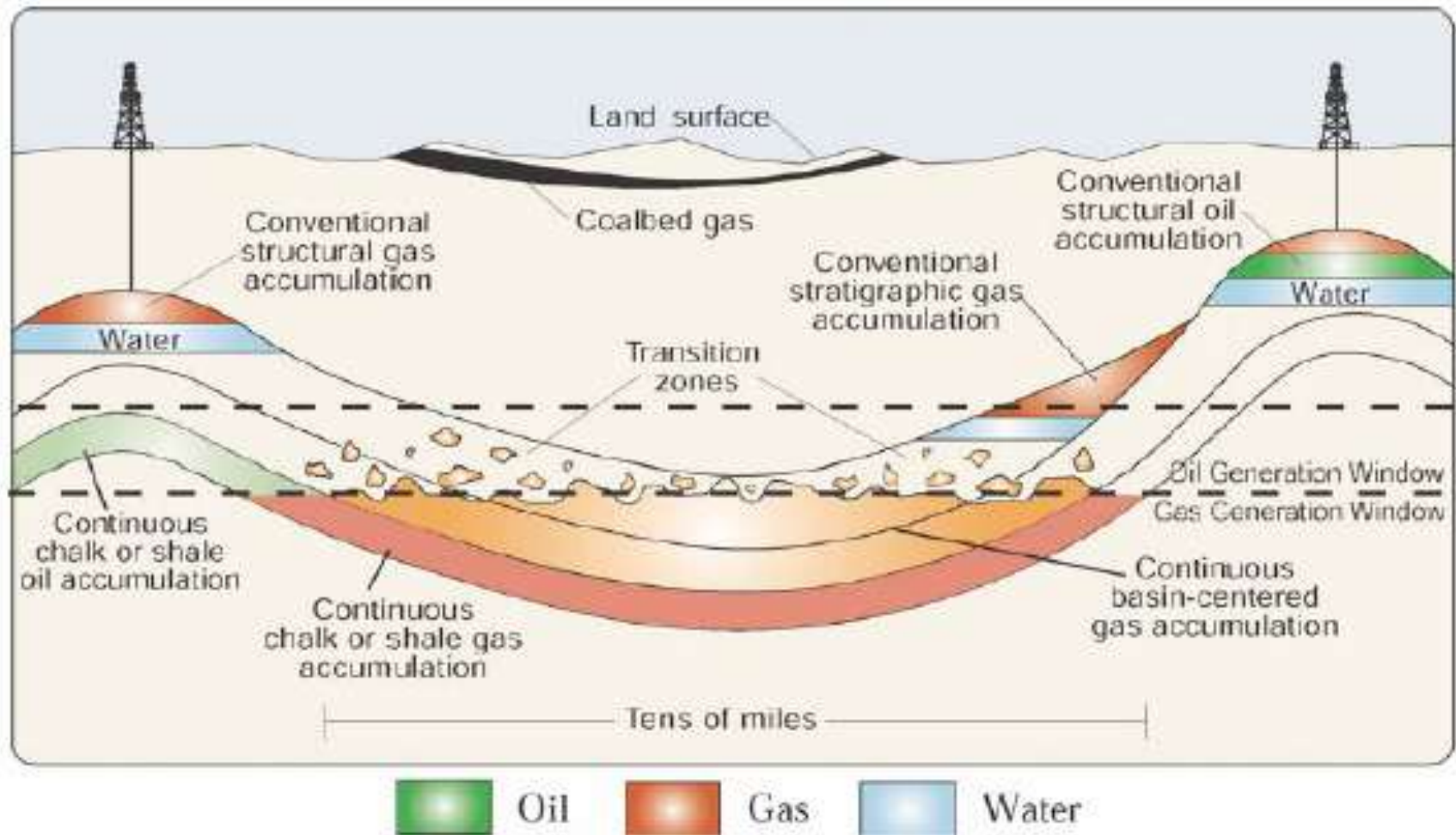
- **Shale gas best describes unconventional, where source and reservoir rocks are identical.**
- **Each Shale gas reservoir has unique characteristics.**
- **Shale has pore size of the order of nanometer**
- **Shale permeability is of the order of nanodarcy**

Shale gas reservoirs almost always have two different storage volumes(dual porosity) for hydrocarbons, the rock matrix and the natural fractures .

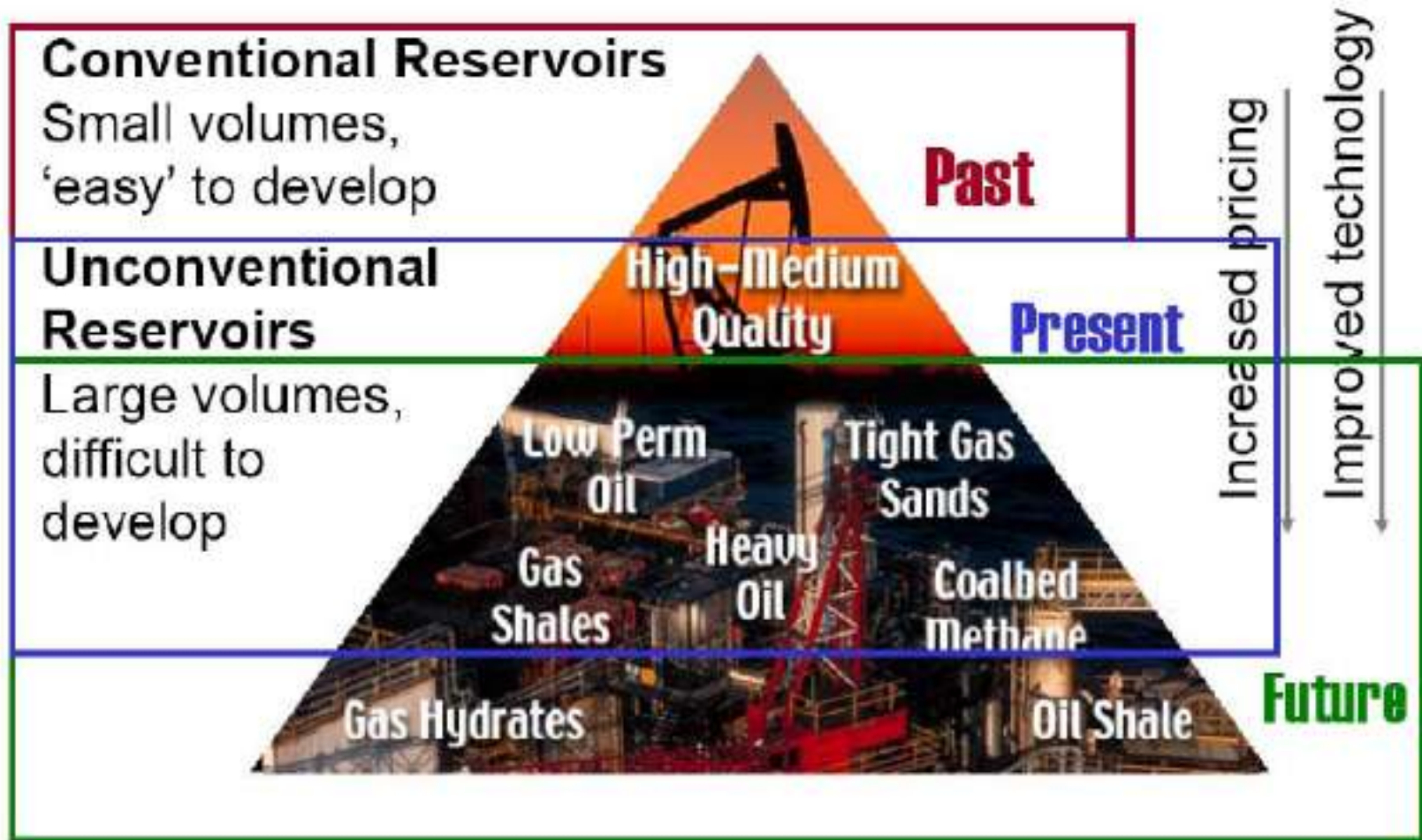
Heterogeneity and Anisotropy

- Shale, with its inherent heterogeneity and Anisotropy, has always been problematic in many operations ranging from seismic exploration, well-log data interpretation, well drilling and well-bore stability problems, to production.
- Research work focus at bridging the gap between invariant characteristics at nano scale of sedimentary rocks and their macroscopic properties.
- Maximum principal stress is vertical, giving rise to HTI (horizontal transverse isotropy). This means that the fracture system is comprised of vertical fractures which cause anisotropic effects on seismic waves as they pass through.

Occurrence of Shale Gas



Resource triangle unconventional resources



■ Conventional gas

- Accumulations in medium to highly porous reservoir with sufficient permeability to allow gas to flow to producing well
- Pressure regime tends to move gas towards producing well (i.e. natural flow)

■ Unconventional gas

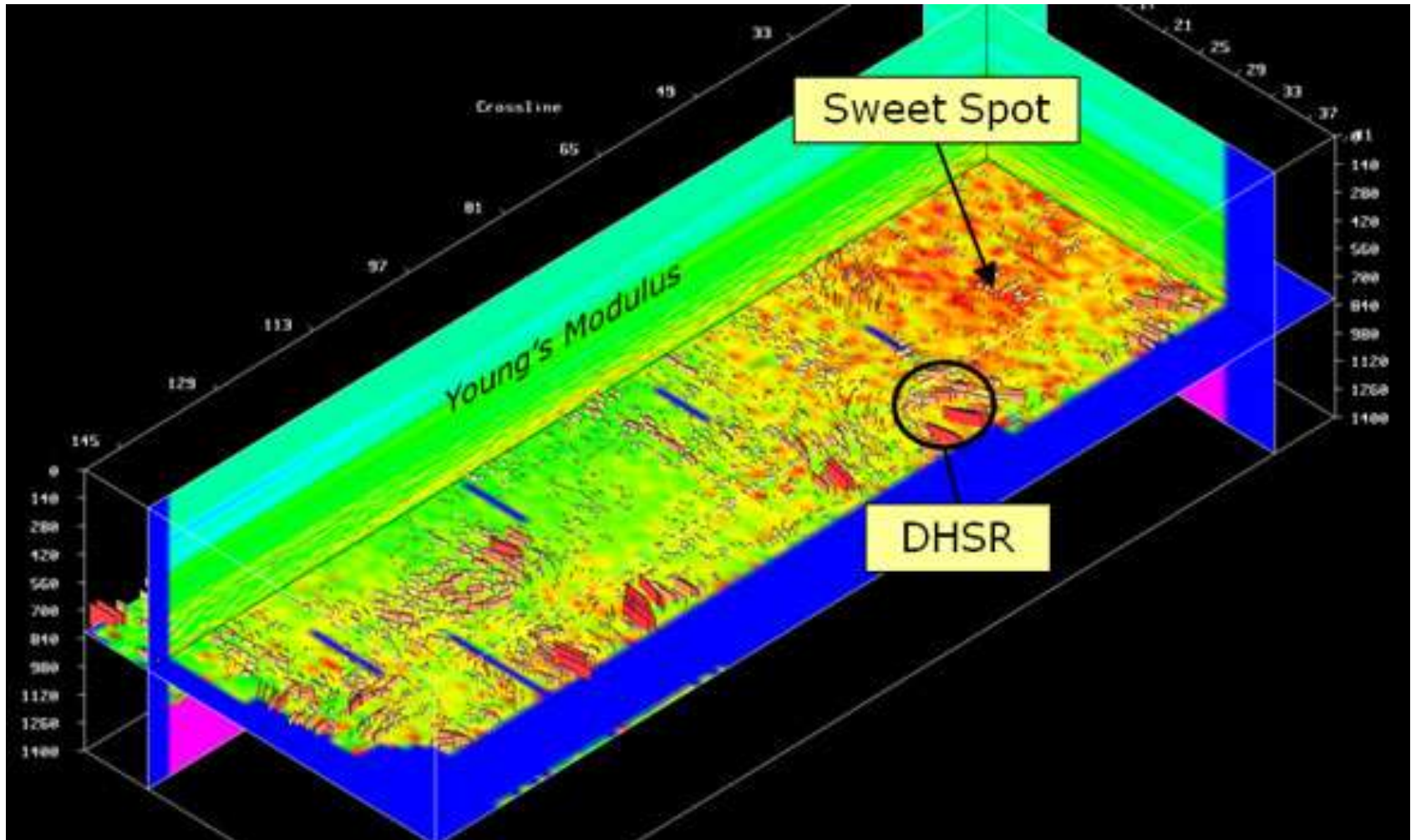
- Deposits of natural gas found in relatively impermeable rock formations – tight sands, shale and coal beds
- To get resources out of the ground, artificial pathways (fractures) have to be created
- Key technologies are horizontal drilling and modern fracturing techniques

Technology Quest

- When geophysics met geomechanics
- Linear Slip Theory for geomechanical properties is used to calculate stress values
- Three types of information extracted from seismic are useful in optimizing drilling locations: fracture characterization, geomechanical properties, and principal stress measurements (vertical maximum and minimum horizontal stresses).
- Anisotropic effects are observed on 3D seismic data as changes in amplitude and travel time with azimuth.

- Geophysical Imaging of geomechanical properties and processes using elastic waves.
- Seismic anisotropic data processing provide information of fractures in shale.
- Geomechanical properties from migrated CDP gathers, including Young's Modulus, Poisson's Ratio, and shear modulus, by first inverting the data for P- and S-wave velocities and density.
- **Differential Horizontal Stress Ratio (DHSR)**
- **The ratio of the difference between the maximum and minimum horizontal stresses to the maximum horizontal stress) is low, tensile fractures will form in any direction, creating a fracture swarm.**

Azimuthal Anisotropic Seismic Signal processing



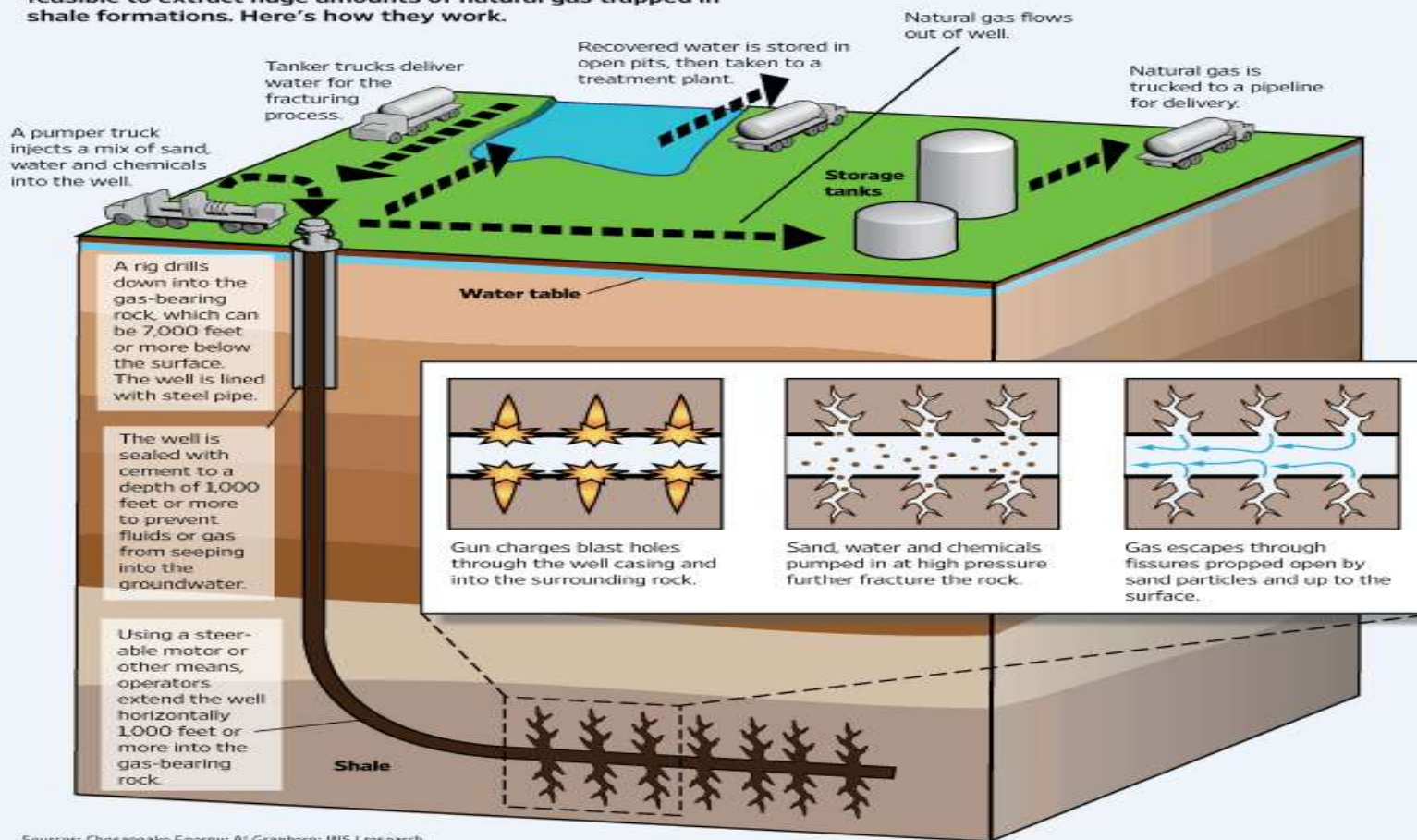
Hydraulic fracturing

- The hydraulic fracturing is used to increase or restore the rate of fluid flow within the shale reservoir and horizontal drilling creates maximum borehole surface area in contact with the shale.
- Hydraulic fracture complexity is the key to unlocking the potential of shale plays .
- Nano enhanced proppant(OxBall and OxFrac light, high-strength ceramic proppants) other additives are essential to successful fracture stimulation.

Hydrofracturing in Shale

Tapping the Gas

Horizontal drilling and hydraulic fracturing have made it feasible to extract huge amounts of natural gas trapped in shale formations. Here's how they work.



Microseismic Monitoring and Fracture Mechanics

- Micro seismic monitoring is a proven technology and has been widely used to monitor and evaluate the effectiveness of hydraulic fracture treatments in various formations, including shale.
- Real-time monitoring of micro-seismic events indicates fracking experts to immediately optimize the hydraulic stimulation process by modifying the fracture stage design while pumping into the formation.
- The real-time data is employed for experiment with how different perforation patterns impacted fracture propagation and make real-time changes in the fracture technologies.

Modern fluid mechanics (Knudsen Flow).

- Darcy and diffusive flows in the matrix and stress-dependent permeability in the fractures: Permeability measures the ability of fluids to flow through rock (or other porous media).
- The darcy is defined using **Darcy's law**, which can be written as

$$v = \frac{\kappa \Delta P}{\mu \Delta x}$$

where: v is the superficial (or bulk) fluid flow rate through the medium, κ is the permeability of a medium, μ is the dynamic viscosity of the fluid, ΔP is the applied pressure difference, Δx is the thickness of the medium.

- Potential transport mechanisms in shale include (1) convective, pressure-driven flow, (2) Knudsen diffusion, (3) molecular diffusion, (4) surface diffusion, (5) configurational diffusion, and (6) liquid diffusion.
- The description of matrix flow by considering diffusive (Knudsen) flow in nanopores. when Darcy flow becomes insignificant due to nanodarcy matrix permeability, Knudsen flow takes over and contributes, substantially, to the transfer of fluids from matrix to fracture network.

Conclusion

- Shale Gas exploitation is no longer an uneconomic venture with availability of leading-edge technologies.
- Geomechanical (break outs) information is obtained by wavelet analysis of petrophysical log data.
- NMR(Nuclear Magnetic Resonance) Logging is very efficient for characterization of reservoir, petrophysical imaging and Gas Dynamics in Gas Shale Nanopores.
- Nanoscale gas flow in Shale gas sediments has scope to cope with research on dry nanotechnology (smartfluid/nanofluid).
- Petrophysical imaging employs first,second & third generation wavelet to delve deep into complex shale gas reservoir.

United Nations Role In Hydrocarbon



- With a view to energy security of the world ,unconventional energy resources - coalbed methane (CBM) , Methane Gas Hydrate,shale gas, basin centred gas ,tight gas,oil shale and heavy oil- exploration and exploitation is pertinent task before geoscientist .
- **GOLBAL SHALE GAS INITIATIVE** (shalegas.energy.gov)
- GASH is the first European interdisciplinary shale gas research initiative(<http://www.gas-shales.org>)
- INTERNATIONAL CENTRE FOR HEAVY HYDROCARBON (ICHH)
UNDP /UNITAR –UN www.oildrop.org
- **WORLD ENERGY ORGANISATION** must be established by United Nations(www.un.org)

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- *THANK YOU*
- *Questions ?*
- *Suggestions*