How Chemical Engineering Helps Oil Recovery?

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Outline

- Introduction
- Chemical Flooding
- Collaborations
- Summary

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- **Introduction**
- **Chemical Flooding**
- **Collaborations**
- **Summary**

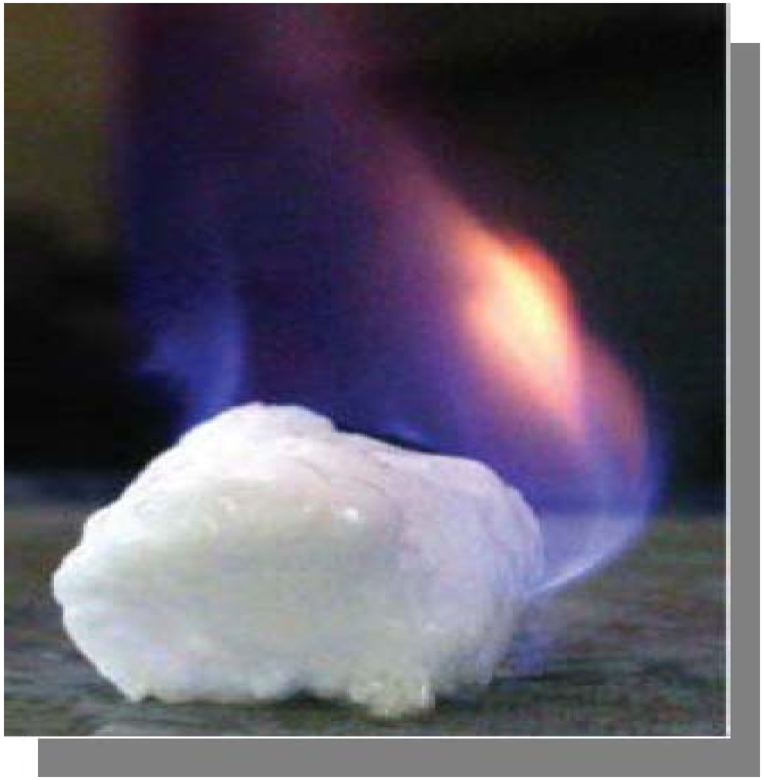
Fossil Fuel Resources

- **Conventional Oil and Gas**
  - Light Oil (viscosity < 100 cp)
  - Natural Gas

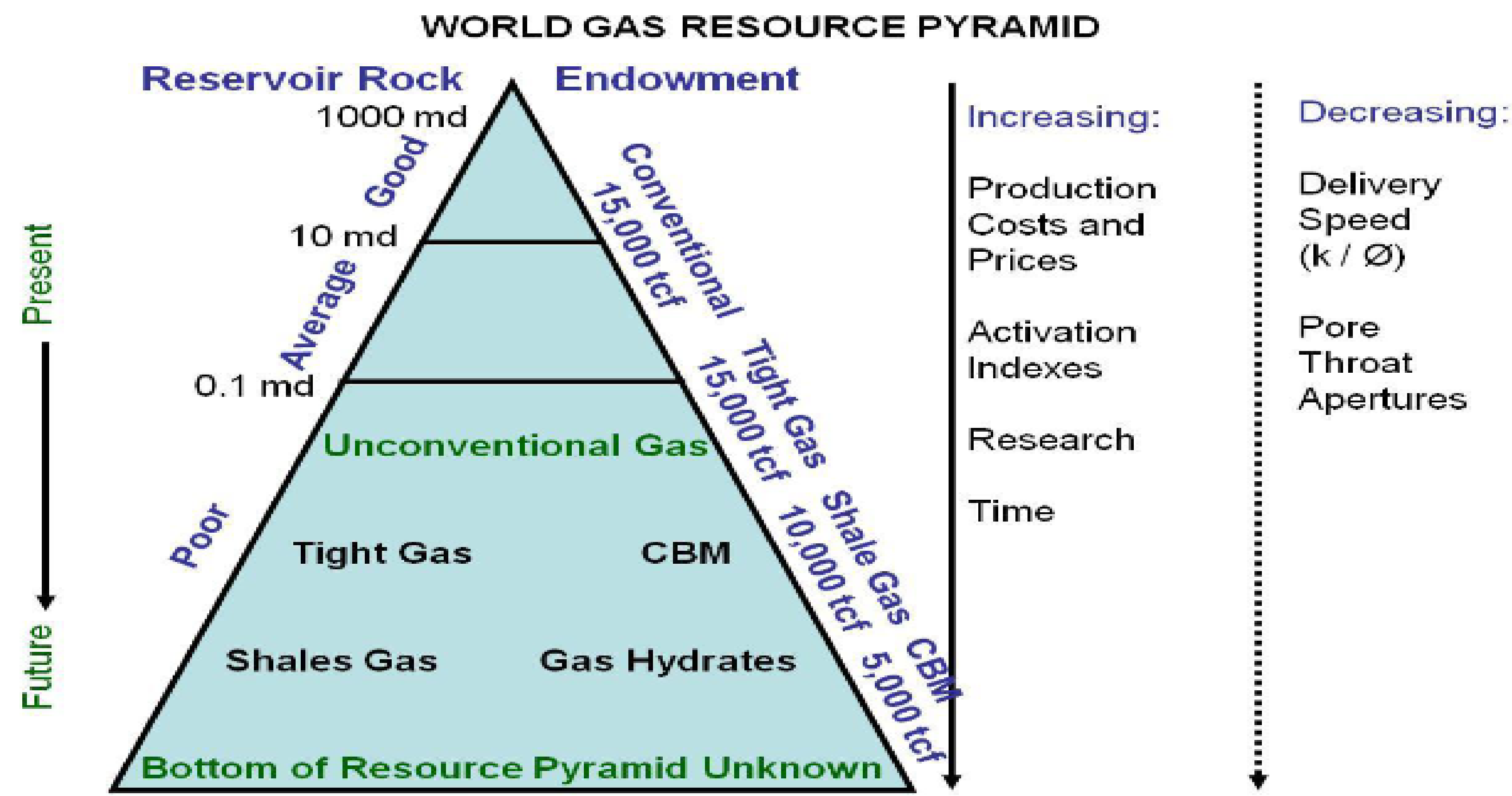
- **Unconventional Fossil Fuel**

Unconventional Gas Resources

- Coal bed methane (CBM)
- Tight gas
- Shale gas
- Gas hydrates



Unconventional Gas Resources



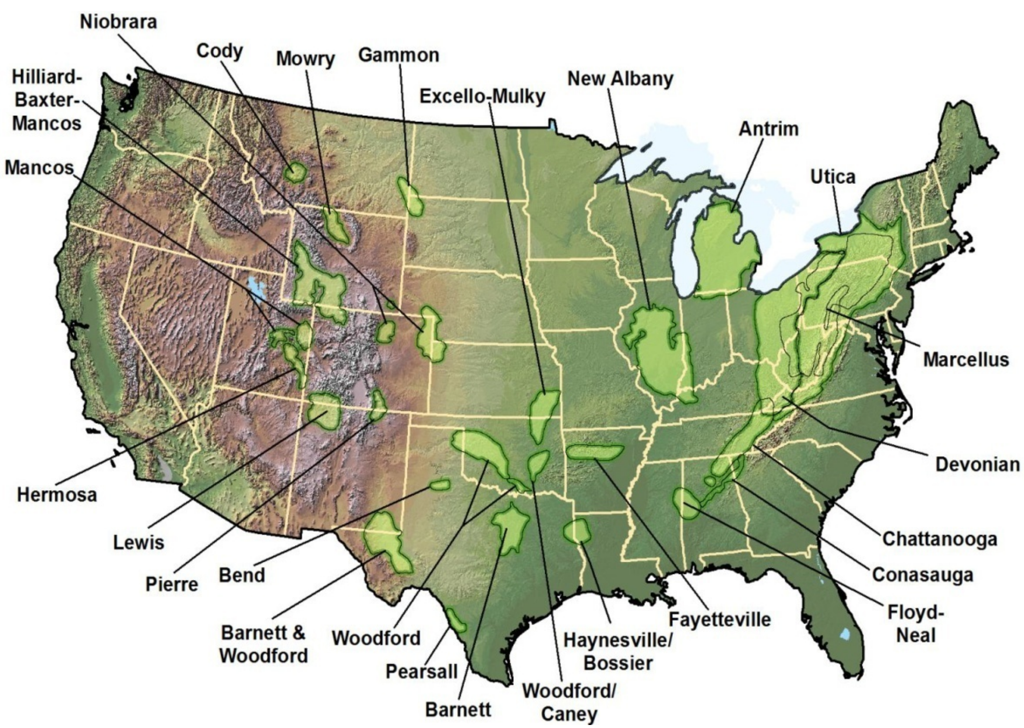
Estimates of global unconventional gas in place: 783,840 Tscf (equivalent, 130.64 Tboe)

Gas Classification

	Shale Gas	CBM	Natural Gas	Tight Gas
Formation	Shale Rock	Coal Bed	Sandstone/Carbonate Rock	Sandstone/Carbonate Rock
Genesis	Thermal and Biological	Thermal and Biological	Thermal, Biological and Crude Oil Cracking	Thermal, Biological and Crude Oil Cracking
Preservation	Free and Adsorbed Gas	Adsorbed Gas	Free Gas	Free Gas
Rock Property	Φ: 4%-6%, K:＜0.001md	Φ: 1%-5%, K: 0.5-5.0md	Low Φ: 8%-20%, K: 0.1-50md Middle Φ: 20%-25, K: 50-300md High Φ>25%, K>300md	Φ: 6%-8%, K: ＜0.1md

Shale Gas Plays

USA Shale Gas Play Locations



Famous shale gas plays: Marcellus、Barnett 、Eagle Ford.

USA 48 States:

resources 141.6～169.9×10^{12} m^3; reserves 24.39×10^{12} m^3.

Geological characteristics：

- **Large scale reserves**
- **Depth - reasonable**
- **Formation - thick**
- **High TOC**
- **Ro 1.0-2.5% (most)**
- **High gas content**

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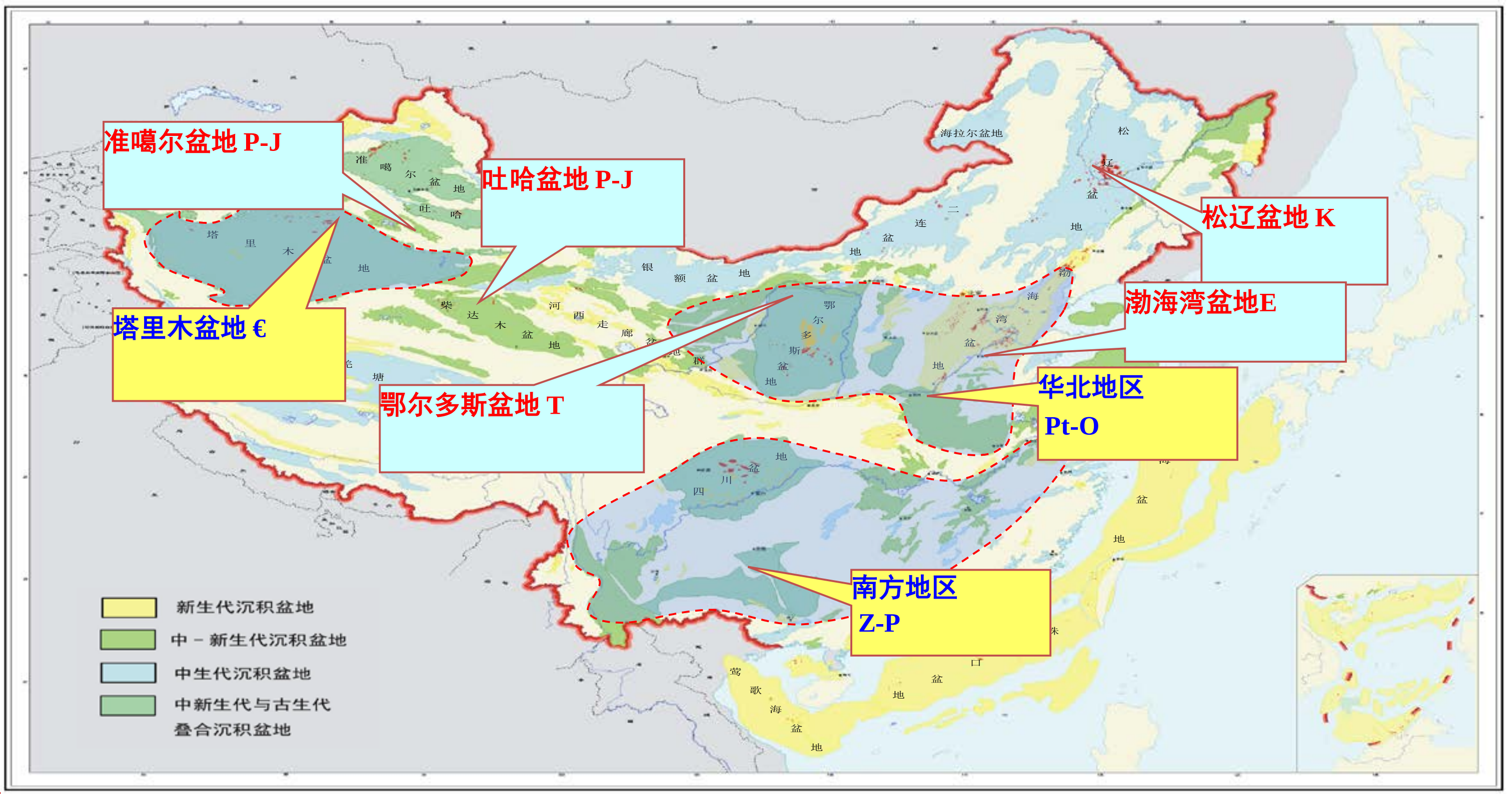
China Shale Gas Plays

China shale gas reserves: 25 tcm, comparable to USA 24.4 tcm, huge potential. Located in Sichuan, Erdos, Bohai Bay, Songliao, Jianghan, Tuha, Tarim, and Junggar Basins; rich resources, wide ranges, different types, and geological complexity.



Resources 134.42×10^{12} m^3; reserves 25×10^{12} m^3.

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Canada Shale Gas Plays

Areas of Unconventional Gas Exploration and Development in Canada

- Tight Gas Sands and Carbonates
- Natural Gas from Coal
- Shale Gas
- Gas Hydrates

Resources:

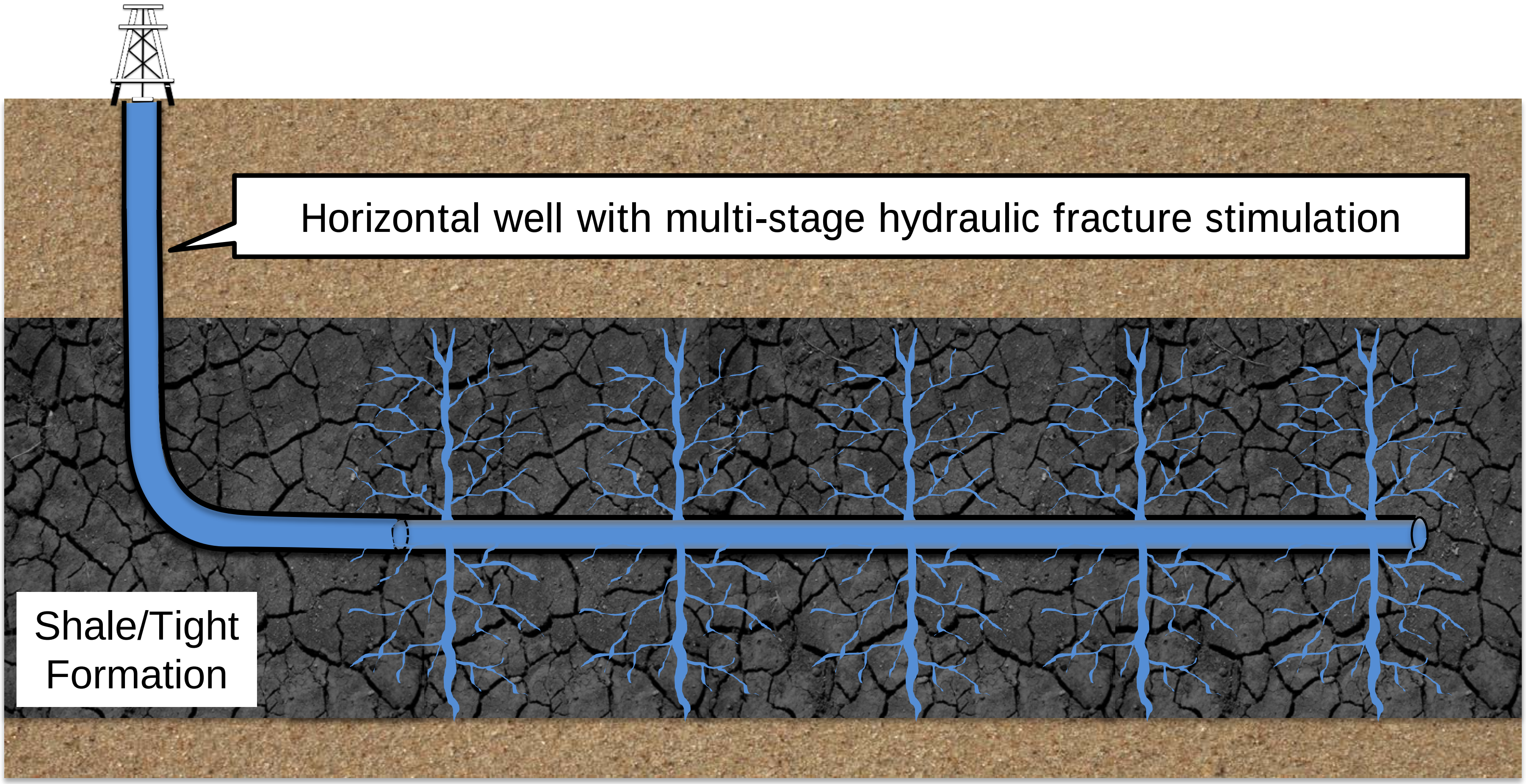
4,995 Tcf of shale gas in place

September 24, 2008

Production of Shale Gas Reservoirs

- **Horizontal well drilling**
- **Hydraulic fracking**

Production of Shale Gas Reservoirs



Courtesy of Mohammed Kanfar, PhD student, UofC

Unconventional Oil Resources

- Tight oil
- Shale oil
- Heavy oil
- Bitumen

Unconventional Oil Resources

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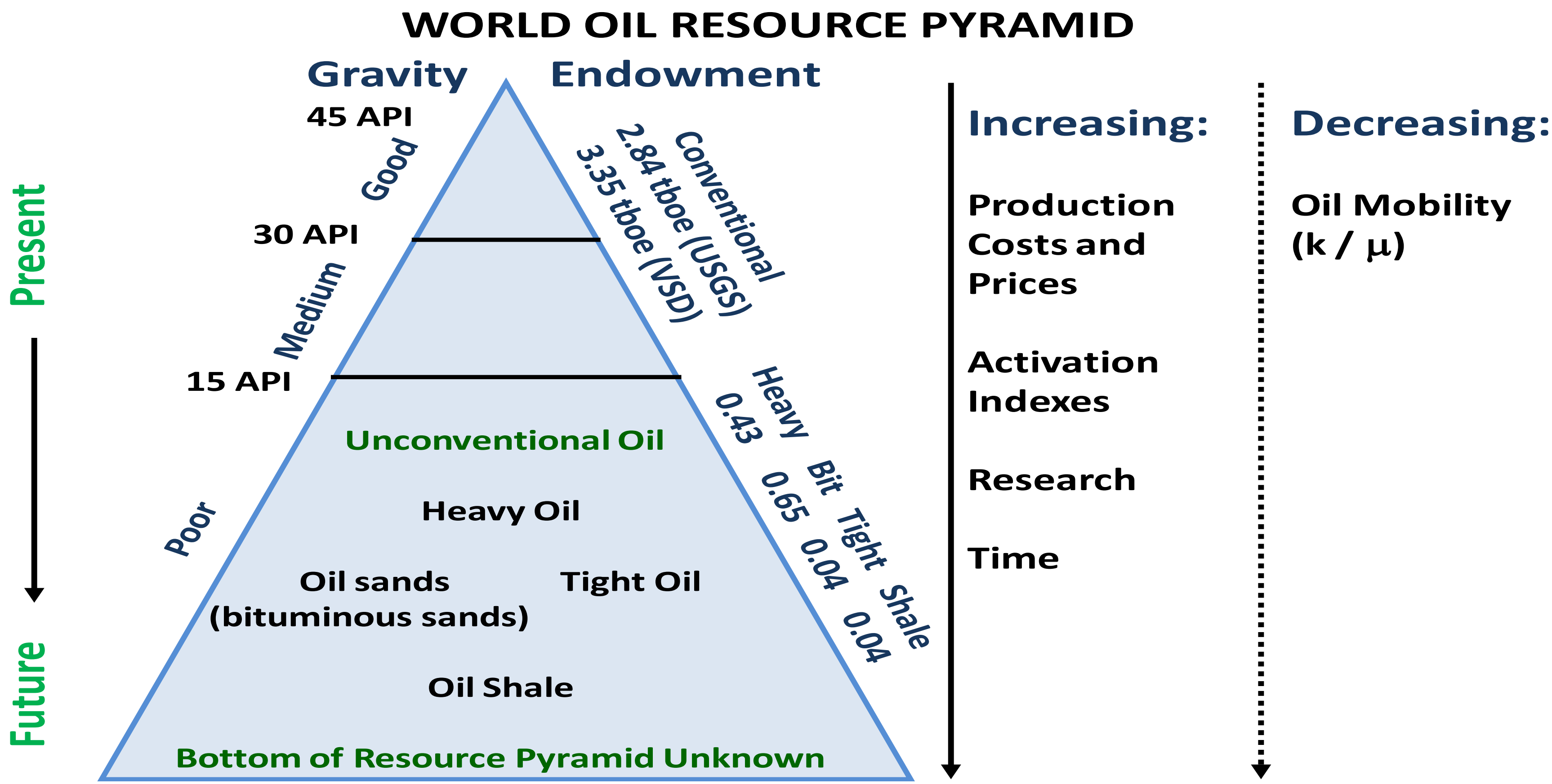


Estimates of global unconventional oil in place: over 4 Tbbls

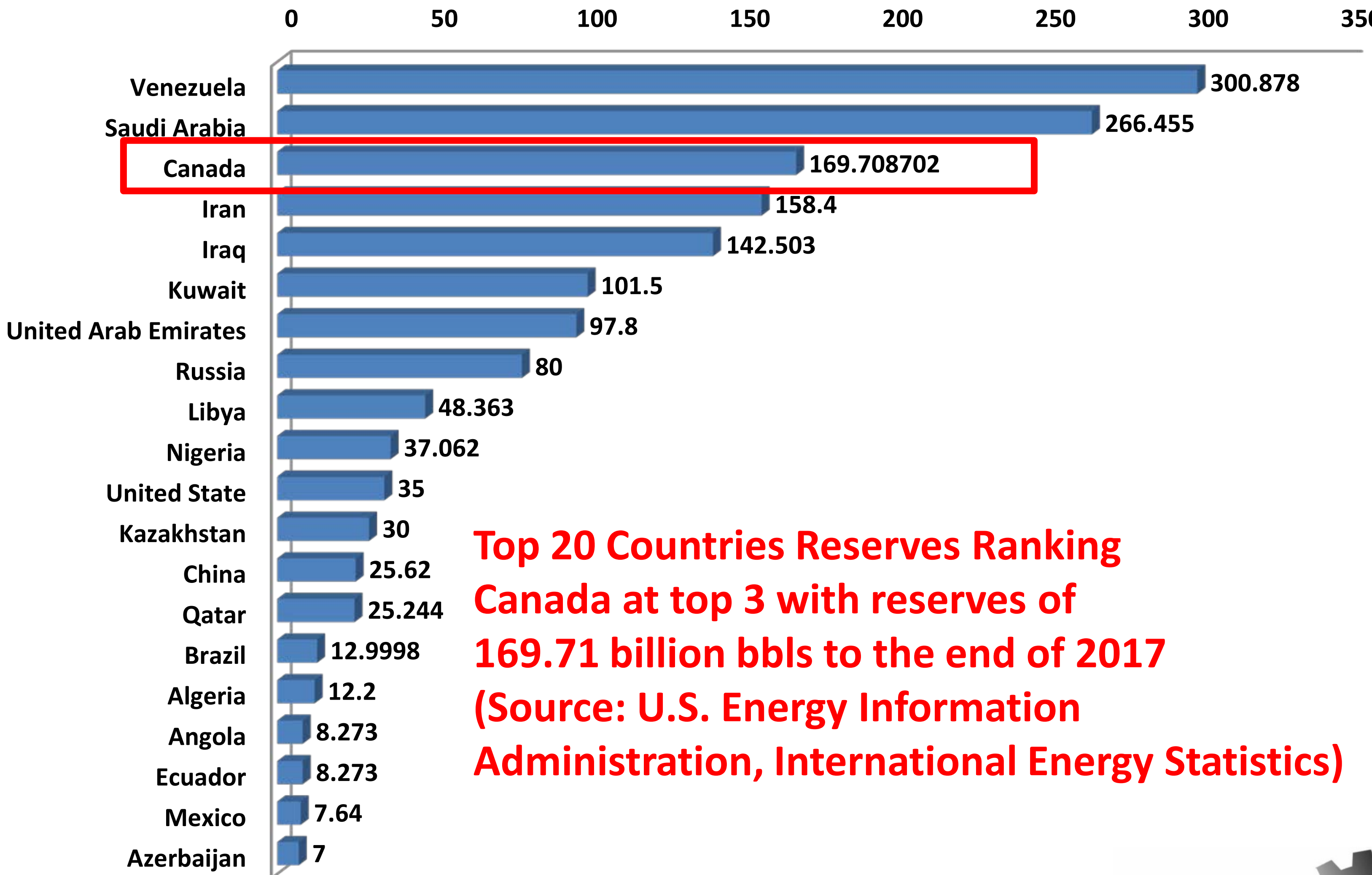
Oil Classification

Oil	Viscosity (cp)	Density (kg/m3)	Density (API)	
Conv. oil	<100	<934	>10	
Heavy oil	100-10,000	934-1,000	10-20	
Bitumen	>10,000	>1,000	<10	

What Are Oil Sands?

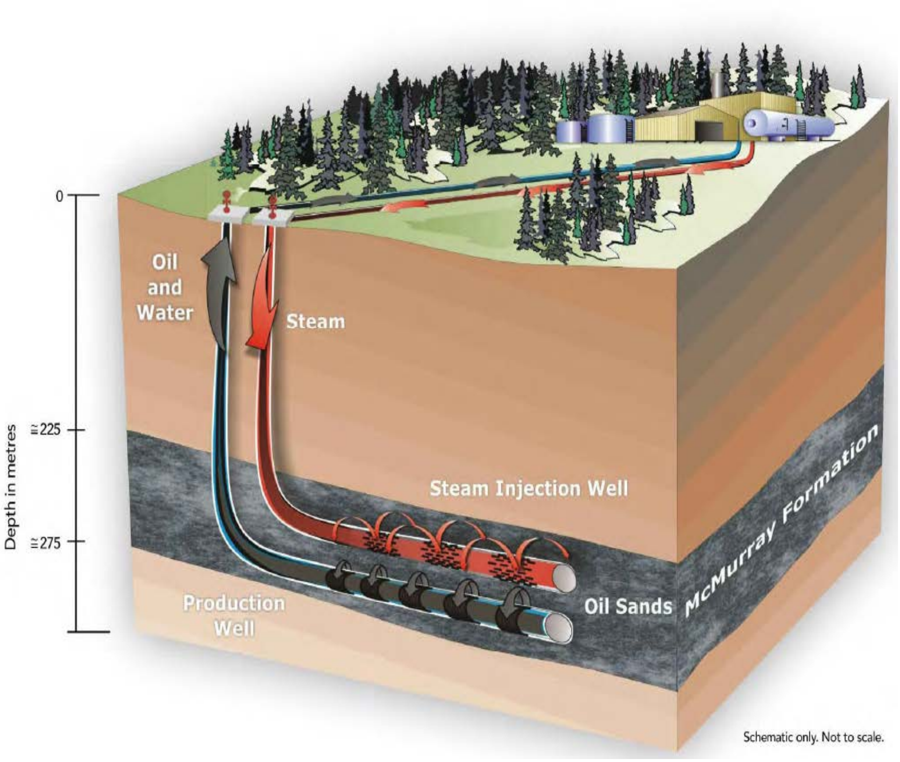
- Composition
  - Inorganic material (75-80%, of which 90% quartz sand)
  - Water (3-5%)
  - Bitumen (10-12%)
- Unconsolidated, crumbled easily in hands

Canada Has Immense Oil Reserves



Top 20 Countries Reserves Ranking
Canada at top 3 with reserves of 169.71 billion bbls to the end of 2017
(Source: U.S. Energy Information Administration, International Energy Statistics)

The Production Process



- **Recovery of the in-place oil: up to 70%**
- **Great capital and operating costs: $50 – 90% / bbl**
- **Oil sands: The fastest growing source of green housegas emissions in Canada**

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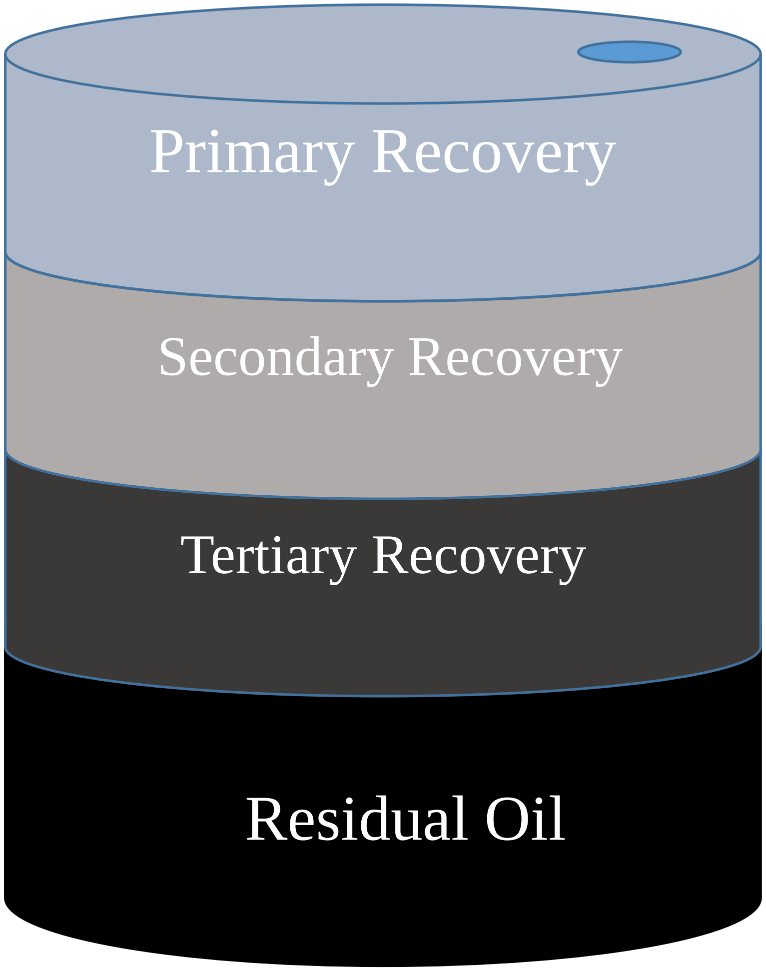
- **Chemical Flooding**
- Collaborations
- Entrepreneurship
- Summary

Oil Recovery Methods



- ❖Water flooding
- ❖Gas flooding

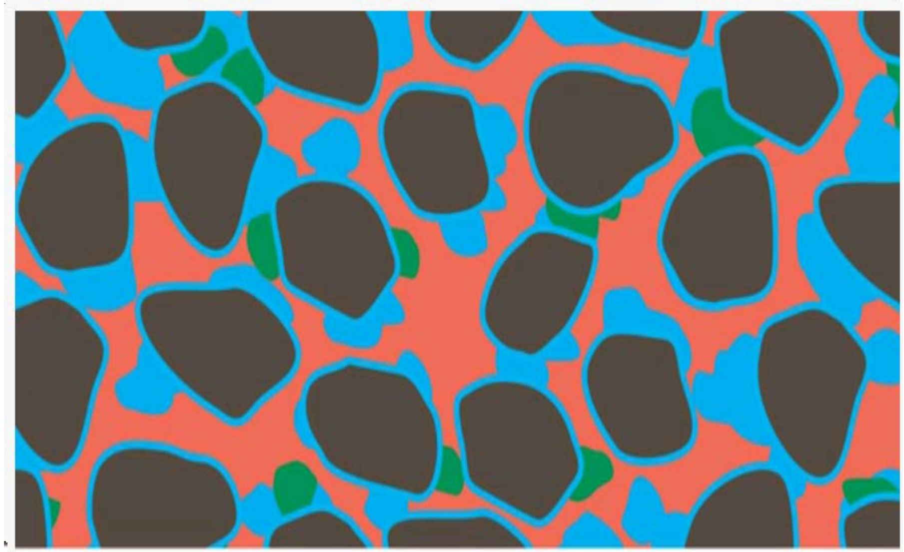
- ❖Chemical flooding
- ❖Miscible & immiscible gas flooding
- ❖Thermal methods

Chemical Flooding

- **ASP flooding:**
  - **Surfactant** helps to reduce the IFT between oil and water.
  - **Polymer** helps to increase the viscosity of displacing fluid.
  - **Alkaline** chemicals react with crude oil to generate in-situ soap and increase pH.

Tertiary Phase

Gas, chemicals or steam free some residual oil left after primary and secondary recoveries.



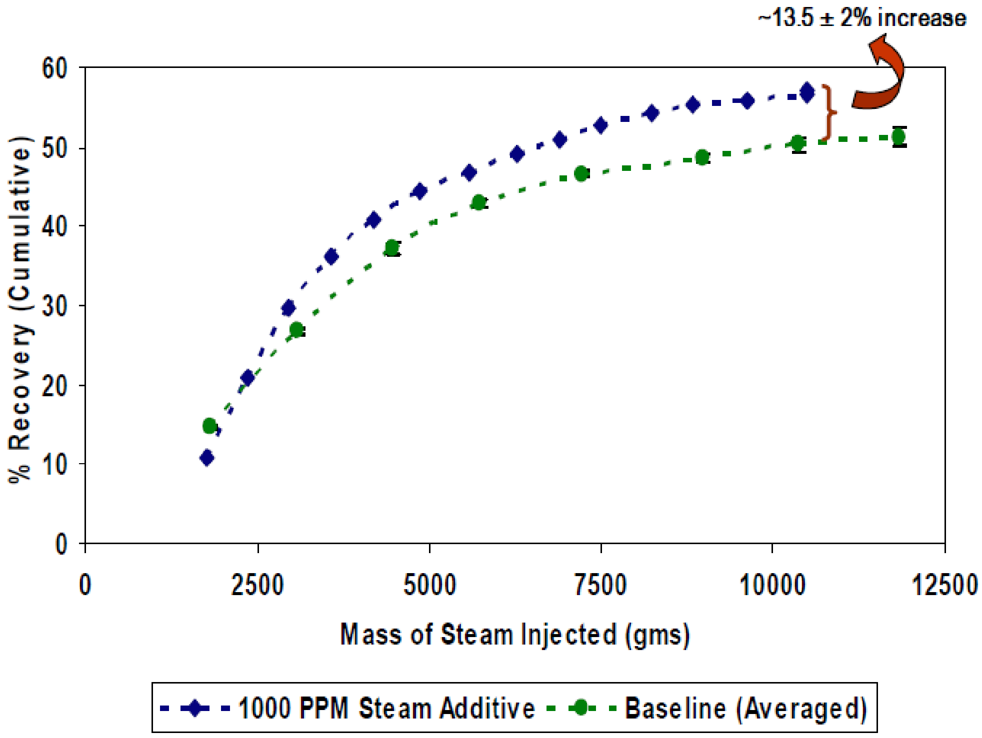
Chemical Flooding

- **Extensive research has been done to understand chemical flooding:**
  - ASP phase behavior experiments
  - Rheological properties of polymer and ASP solution
  - Polymer conformance control
  - Optimal ASP formulation using a mixture of surfactants
  - Chemical adsorption
  - Field-scale implementation and evaluation
  - Process optimization and geological uncertainty

Chemical Flooding

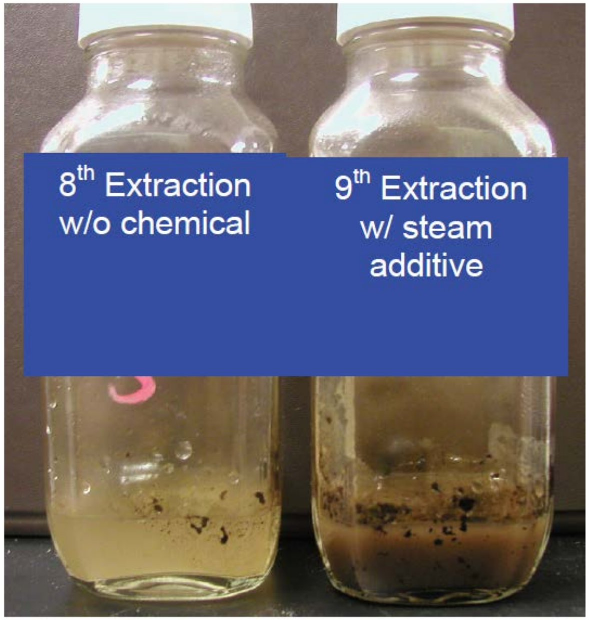
Hybrid versus pure steam

- Chemical additive co-injected with steam
- 1% chemical additive



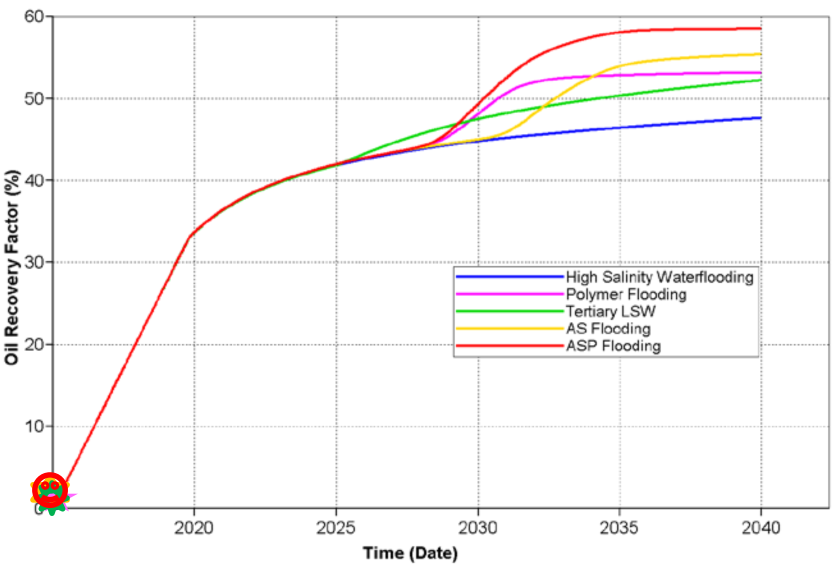
Key Mechanism:

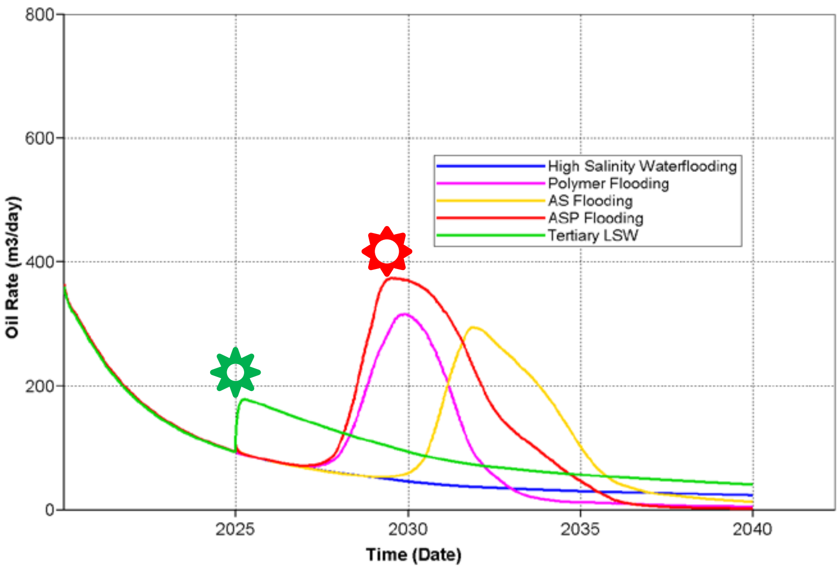
The chemical additive in condensed water retrieve more bitumen by allowing higher mobilization of the bitumen.



Field-Scale ASP Flooding

Tertiary ASP Flooding after Secondary Waterflooding





Chemical Flooding

- **Oilfield Applications**
  - **Most successful in Daqing Oilfield, China**
  - **ASP flooding production in 2015 was 3.5 million tons, 9% of total production.**

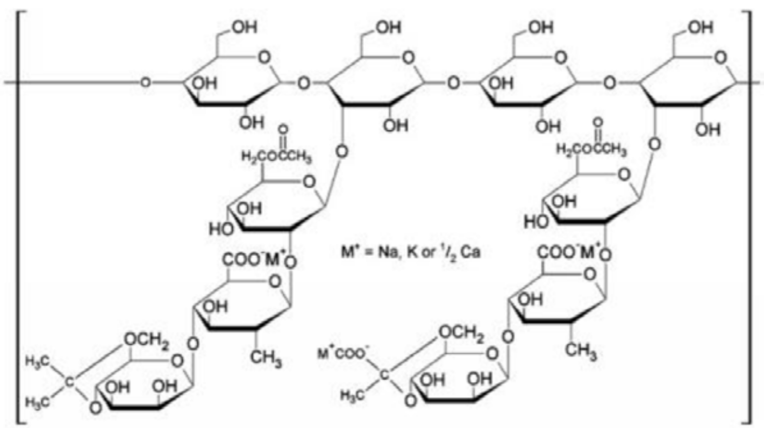
- **Reference:**
  - **H. Saboorian-Jooybari, M. Dejam, and Z. Chen, Heavy oil polymer flooding from laboratory core floods to pilot tests and field applications: Half-century studies, *Journal of Petroleum Science and Engineering*, 142 (2016), 85-100.**

Challenges

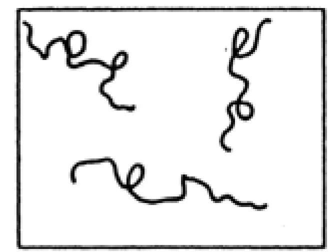
- **High Costs**
- **Not effective at high temperature**
- **Polymer precipitation in presence of various ions like Na^{+} and Ca^{2+}**
- **Polymer retention in porous media**
  - Adsorption on rock surfaces
  - Mechanically entrapped in narrow pore throats

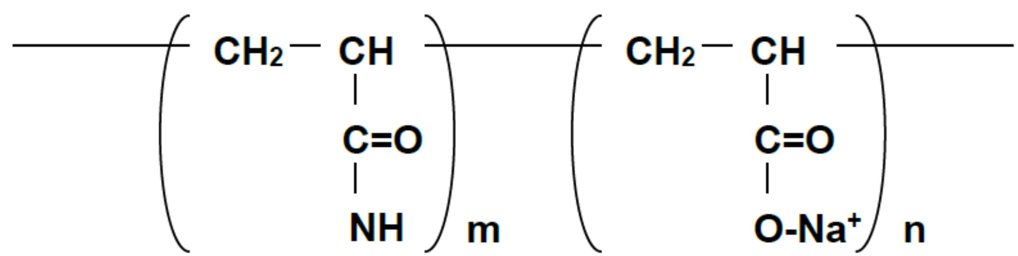
Common Polymers Used

Xanthan Gum



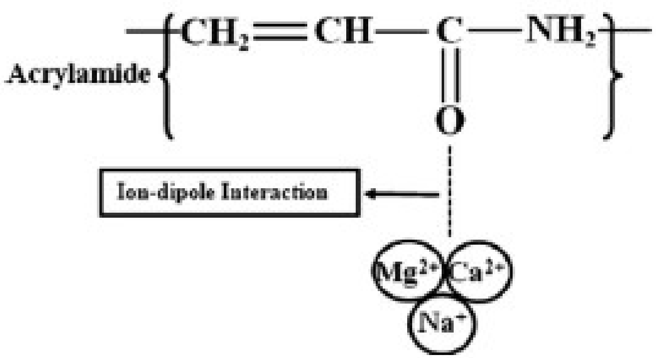
(Hydrolyzed Polyacrylamide) HPAM



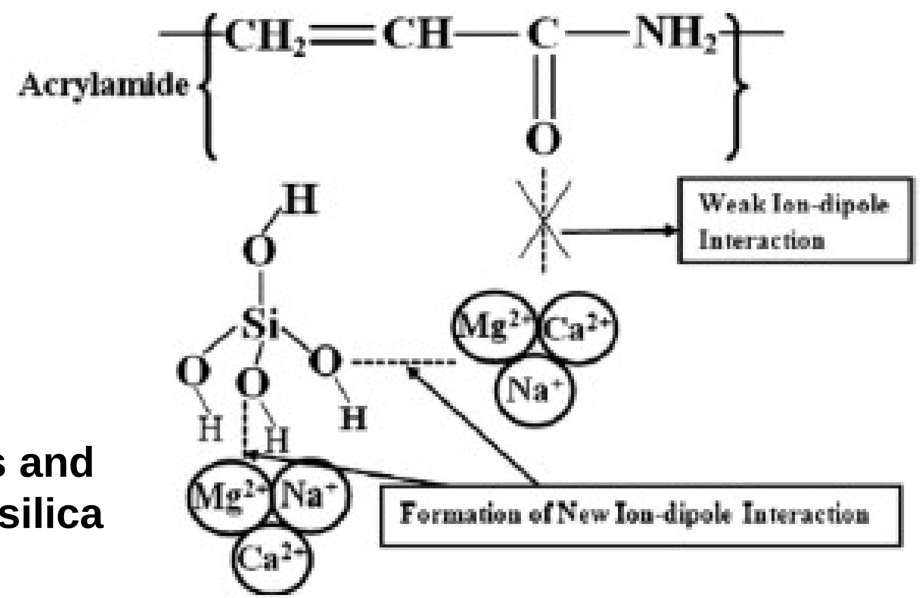


Adding Nano-particles

✓Reaction between ions and nanoparticles



Ion-dipole interaction between cations and oxygen in PAM solution in absence of silica nano-particles



Ion-dipole interaction between cations and oxygen in PAM solution in presence of silica nano-particles

Why hybrid polymer / nanoparticles?

- Good candidate for enhanced heavy oil reservoirs with high amount of salts
- Reducing amount of polymers required for chemical flooding
- Decreasing polymer retention in porous media
- Increasing oil recovery in micro-scale due to its high elasticity and shear thickening behavior

Challenging Issues Worldwide

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- **Chemical Engineering May Help in**
  - Wettability changing
  - Water breakthrough (block roles)
  - Mobility changing in nano-micro pores
  - Well corrosion

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Collaborations

- **Supervision of Chinese Students**
  - 20 post-doc fellows
  - 59 PhDs
  - 50 MSc
- **Hosting Chinese Visiting Scholars: 30**

Collaborations

- **Training of High Level Employees: 120**
  - China National Petroleum Corp. (CNPC)
  - China National Offshore Oil Corp. (CNOOC)
  - China Petroleum & Chemical Corporation (SINOPEC)

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Collaborations

Establishment of a Large Research Center in Beijing

Unconventional Oil and Gas Labs


Geo-physics


Geo-chemistry


Micro structure


Formation stimulation


Rock mechanics


Reservoir simulation

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Current Research

Studies of recovery processes for heavy oil and bitumen

Studies of unconventional oil and gas reservoirs

Development of accurate and fast solvers and simulators

Development of 3D Visual Analytics Technologies

Current Research Group

Graduate Students : over 50 MSc and PhD students

Post Docs and RAs: 11

Project Manager

Technical Managers

Administrative Assistants

Research Collaborators from Industry and Academia Globally

NSERC/Energi Simulation Chair

Alberta Innovates (iCORE) Chair

Research Consortium on Reservoir Simulation

Foundation CMG/Frank-Sarah Meyer Collaboration Center: Simulation & Visualization

Global Initiative in Research on Unconventional Oil and Gas: Beijing Site

18 Industrial Sponsors

- Brion Energy
- CMG Reservoir Simulation Foundation
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- IBM Canada
- Imperial Oil
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- Laricina Energy Ltd.
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- PetroChina - RIPED
- Sherritt
- Statoil
- Suncor
- Swan Hill Synfuels Inc.
- IBM Alberta Centre for Advanced Studies

Research Resources

Advanced simulation (commercial and research) software

Computing hardware – EXAS IBM Cluster

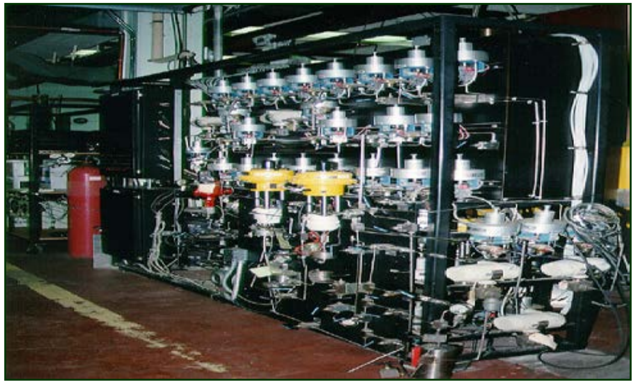
CMG Simulation Laboratory

FCMG Frank and Sarah Meyer Collaboration Center for Simulation & Visualization Integration

Advanced oil/gas recovery laboratories

Enhanced Oil Recovery Labs

- Porous Media and Unconventional Oil Recovery Lab
- In Situ Combustion Lab
- Hydrocarbon Upgrading Lab
- Heavy Oil Properties (PVT, Viscosity, Phase Behavior) Lab
- SAGD (Steam Assisted Gravity Drainage) Lab
- Solvent Enhanced Recovery Process Lab
- Simulation and Visualization Lab



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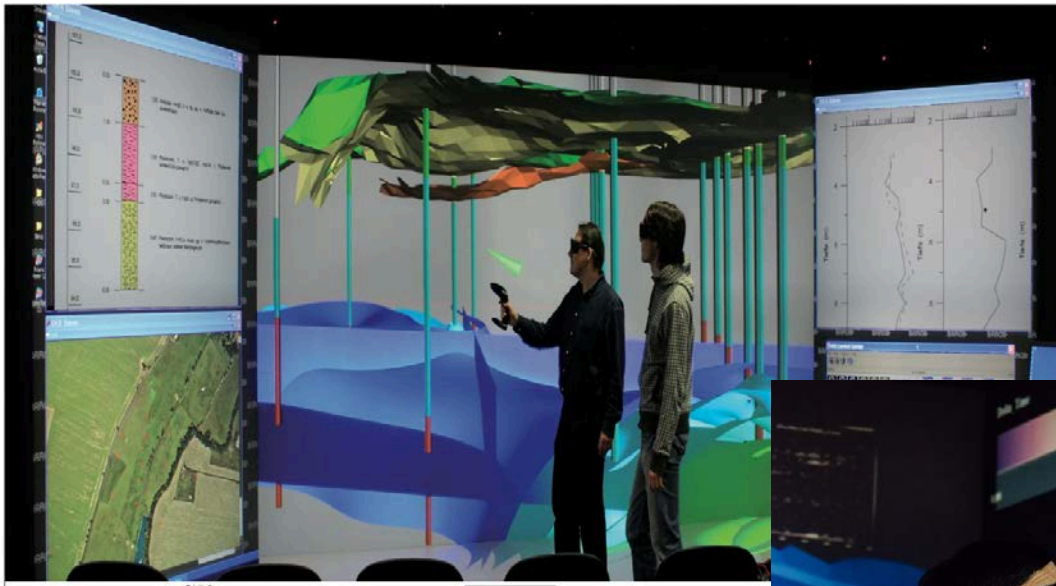
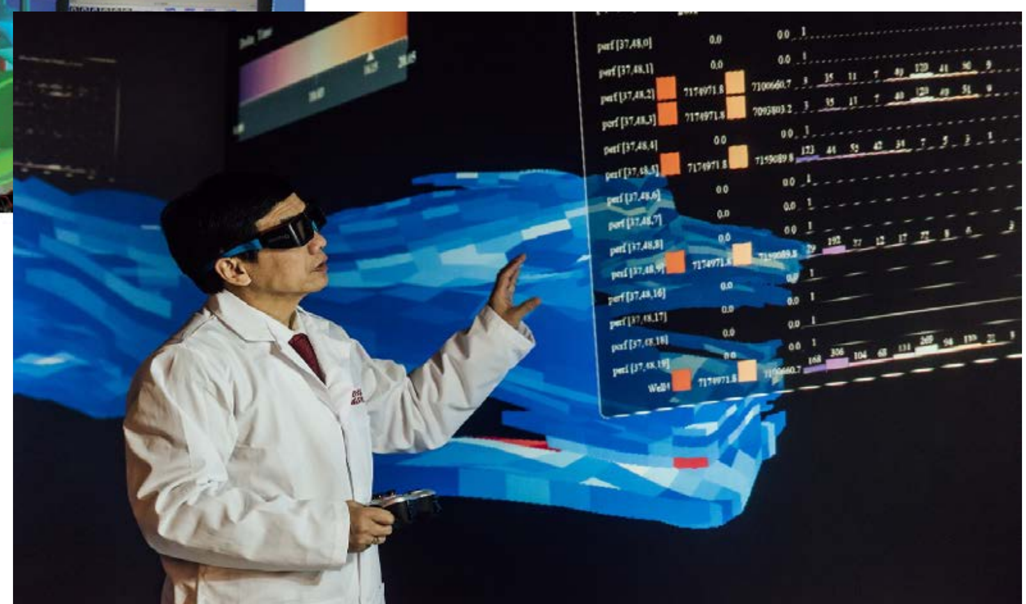
Big Data and Artificial Intelligence Research





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Recent Publications

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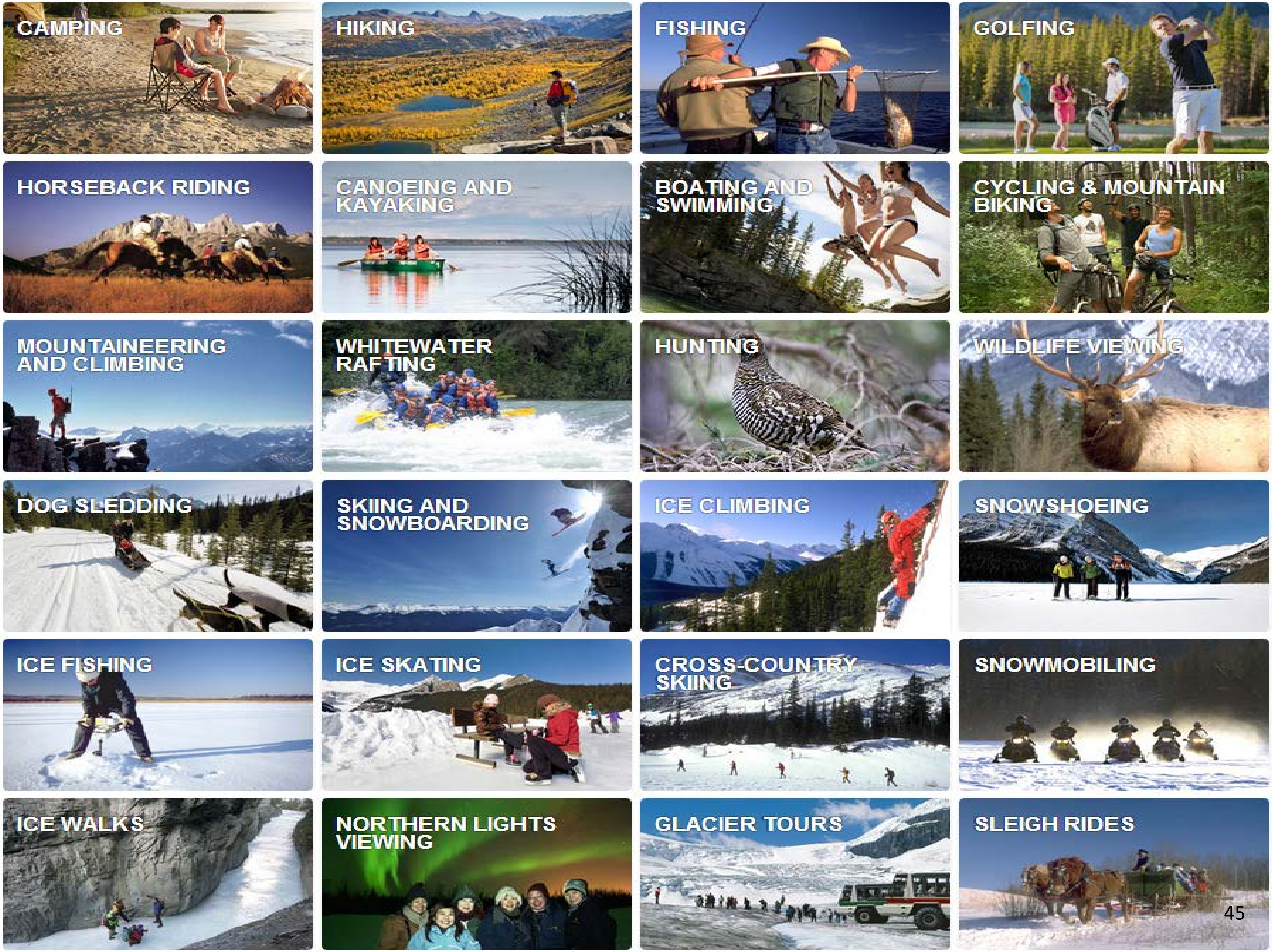
K. Wu, Z. Chen, J. Li, J. Xu, K. Wang, S. Wang, X. Dong, Z. Zhu, Y. Peng, X. Jia and X. Li, Manipulating nanoconfined water fluidity by temperature stimulation, ***Angewandte Chemie***, 57 (2018), 8432-8437.

H. Zeng, K. Wu, X. Cui and Z. Chen, A practical model of wettability effect on nanoconfined water flow: Insights and perspectives, ***Nano Today***, 16 (2017), 7-8.

K. Wu, Z. Chen, J. Li, X. Li, J. Xu and X. Dong, Wettability effect on nanoconfined water flow, ***Proceedings of the National Academy of Sciences (PNAS)***, 114 (2017), 3358-3363.

K. Wu, Z. Chen, X. Li and X. Dong, Equation of state for methane in nanoporous material at supercritical temperature over a wide range of pressures, ***Nature: Scientific Reports*** *6*, 33461 (2016), 1-10.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ICE CLIMBING
SNOWSHOEING
ICE FISHING
ICE SKATING
CROSS-COUNTRY SKIING
SNOWMOBILING
ICE WALKS
NORTHERN LIGHTS VIEWING
GLACIER TOURS
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