Skoltech Center for Hydrocarbon Recovery

Mikhail Spasennykh

February 2016
Skoltech Center for Hydrocarbon Recovery (SCHR) has been created following decision of Skoltech Board of Trustees made in December 2013. Main goal of SCHR is to provide world class research, education and innovations in the area of exploration and production of unconventional and hard-to-recover hydrocarbons. Our aim is to establish Skoltech as a leader in developing technology and people for Russia’s future needs in the area of exploration and production hydrocarbons.

Main areas of SCHR activity in research, education and innovation are geomechanics, enhanced oil recovery, geophysics & petrophysics of unconventional reservoirs, thermal petrophysics, gas hydrates and advanced reservoir simulations. We focus our research efforts on development of new technological solutions for exploration and production of hydrocarbons at such geological objects as brown fields, tight oil, heavy oil, shale oil, oil fields in polar regions and Arctic shelf.

Following Skoltech strategy SCHR develops collaboration with world leading universities including Texas A&M University, USA, University of Calgary, Canada, Heriot-Watt University, Scotland and other. Among our university partner are famous Russian universities and including Moscow state university, Bashkir state university, Russian state university of oil and gas, and the institutes of Russian academy of sciences.

MS education programs was developed in collaboration with university partners and is focused on disciplines important for exploration and production of hard to recover and unconventional hydrocarbons including enhanced oil recovery, geomechanics, unconventional reservoirs, high performance computing and other.

Research facilities of SCHR includes computational laboratory and experimental laboratories focused on research in the areas of advanced petrophysics and geochemistry, geomechanics, enhanced oil recovery, and gas hydrates.

SCHR actively develops collaboration with Industry using different forms, including R&D and service contracts, research consortia, joint grants with government and other. Our main industry partners re Russian oil and gas majors, including GazpromNeft, Gazprom, Lukoil, Rosneft, Tatneft, Novatek and other oil and gas producers and service companies. Considerable part of SCHR budget comes from collaboration with industry.
Skoltech mission and vision

- Skoltech - new international university located in Skolkovo innovation center
- Main business units of Skoltech - Centers for Research, Education and Innovations (CREI)
- Each CREI has been created following decision of the Board of Trustees in order to provide research, education and innovations in strategy directions of future RF economy
- Focusing on breakthrough technological solutions
- Partnership with world leading universities
- Partnership with Russian industry
- World level of innovations, immediate implementation of knowledge and technological solution into practice (creation of startups or direct contacts with leading companies)
To maintain hydrocarbon production at high level in future (20+ years) industry should be technologically prepared for production of all types unconventional resources (heavy oil, shale oil, tight oil, unconventional gas and other hard to recover resources) in traditional regions and production of hydrocarbons in new regions with extremely harsh climatic conditions – Arctic shelf and polar regions.

Forecast of oil production in Russia and required technologies
Main goals

To provide world class research, education and innovations in the area of exploration and production of unconventional and hard-to-recover hydrocarbons.

Establish Skoltech center as a leader in developing technology and people for Russia’s future needs in unconventional and hard-to-recover hydrocarbon recovery.

Program term: 2014 – 2019

Research Areas:

- Geomechanics
- Enhanced oil recovery
- Gas hydrates and permafrost
- Geophysics & Petrophysics
- Advanced reservoir simulations

Hydrocarbon Resources:

- Brown fields,
- Tight oil
- Heavy oil
- Shale oil
- Gas hydrates
- Polar regions & shelf

Industry partners:

GazpromNeft, Lukoil, Rosneft, Tatneft, Surgutneftegaz, Zarubezhneft, Rospan, Salym Petroleum Development, other producers and service companies.

Funding

- Grant of Skolkovo foundation
- Other sources - up to 50% in 2018

Staff:

- 70 plan for the end of 2018, (25 now)

Research facilities:

- Geomechanic lab
- EOR lab
- PVT lab
- Advanced petrophysic lab
- Computational Lab

University Partners

- Partnership with 10 universities (USA, EU, UK, Canada, Russia)
University partnership program
15 joint R&D projects

Advanced reservoir modeling, HPC
Prof. John Killough

Flow assurance, Gas hydrates
Prof. Bahman Tohidi

Thermal EOR
Prof. Raj Mehta

Flow assurance

Chemical EOR
Roman Berenblyum (IRIS)

Unconventional hydrocarbons
Moscow State University

Petroleum geophysics,
Inst of Petroleum Geology, RAS, Novosibirsk

Unconventional hydrocarbons

Petroleum geophysics,
Inst of Petroleum Geology, RAS, Moscow

Chemical EOR
Mining University St.Petersburg

Temperature Logging
Bashkir State University, Ufa

Skoltech Center for Hydrocarbon Recovery
Skolkovo Institute of Science and Technology

Geology and Lithology
Oil and Gas State University

Geomechanics
Prof. Yuri Podladchikov
Research projects with industry

5 on-going R&D projects + 4 R&D projects under negotiations

Cazpromneft
Geomechanics, Bazhenov

Rosneft
Geomechanics, Arctic, Hydrates

Lukoil
Thermal EOR, Geomechanics, Petroleum basin modeling, Bazhenov

Cazprom
Geomechanics, Hydrates

Ritek
Thermal EOR, Bazhenov

Salym petroleum development
Chemical EOR (ASP flooding)

Skoltech Center for Hydrocarbon Recovery

Skolkovo Institute of Science and Technology

Chevron
Geomechanics modeling
Petroleum basin modeling
Full waveform inversion

Schlumberger
Adaptive meshing for in-situ combustion

Bashneft
Geomechanics, Bazhenov

Thermal EOR
## Research facility, education courses and joint R&D projects in collaboration with partner universities and Industry

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<th>Research direction</th>
<th>University partner</th>
<th>Research Facilities</th>
<th>Education courses</th>
<th>Joint R&amp;D projects</th>
<th>Collaboration with Industry</th>
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<tbody>
<tr>
<td>Geomechanics</td>
<td>U Lausanne TAMU</td>
<td>Geomechanics lab</td>
<td>✅ Geomechanics ✅ Hydraulic fracturing ✅ Unconventional hydrocarbons</td>
<td>2 R&amp;D projects with IPGG</td>
<td>50% of budget in 2018 RF oil and gas majors, and other companies including ✅ Gazprom ✅ Gazpromneft ✅ Rosneft ✅ Lukoil, ✅ Ritek, ✅ Zarubezhneft ✅ SalymPetroleum ✅ Tatneft ✅ Surgutneftegas</td>
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<td></td>
<td>Heriot Watt</td>
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<tr>
<td>Enhanced Hydrocarbon Recovery</td>
<td>U Calgary, Canada U Stavanger, Norw. Mining Univ., SPb</td>
<td>EOR lab. (ASP, SAGD, HPAI)</td>
<td>✅ Chemical EOR ✅ Thermal EOR</td>
<td>2 R&amp;D projects with University of Calgary 1 R&amp;D project – BSU</td>
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<tr>
<td>Gas hydrates, Permafrost</td>
<td>Heriot-Watt</td>
<td>Gas Hydrate Lab</td>
<td>✅ Introduction to oil and gas engineering ✅ Gas hydrates and flow assurance</td>
<td>2 R&amp;D projects with Heriot-Watt and 1 R&amp;D projects with MSU</td>
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<td>MSU, Moscow IPE, Moscow</td>
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<tr>
<td>Petrophyscis Geochemistry and Geophysics of unconventional reservoirs</td>
<td>U Utah IPGG, Novosibirsk MSU, IPE, Moscow BSU, Ufa</td>
<td>Petrophysics and Geochemistry lab</td>
<td>✅ Petroleum geophysics ✅ Computational algorithms ✅ Geophysical inversion ✅ Advanced petrophysics</td>
<td>3 R&amp;D projects with IPE, BSU, MSU (bazhenov, domanik, hadum formations)</td>
<td>Forms of collaborations: ✅ Research consortia/JIPs ✅ R&amp;D contracts ✅ Consulting ✅ Trainings ✅ Start-ups</td>
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<tr>
<td>Advanced reservoir simulation</td>
<td>TAMU BSU, Ufa MIPT, Moscow</td>
<td>Computational lab</td>
<td>✅ Fluid dynamics in Porous Media ✅ Petrophysics and reservoir engineering ✅ Geostatistics and reservoir simulation ✅ HPC in oil and gas</td>
<td>4 R&amp;D projects with TAMU 1 R&amp;D projects with BSU</td>
<td>✅ 4 on-going R&amp;D contracts ✅ 5 R&amp;D contracts under negotiations</td>
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# Skoltech Center for Hydrocarbon Recovery: Educational Program

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<tr>
<th>Fall Year 1</th>
<th>Path 1</th>
<th>Path 2</th>
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<tbody>
<tr>
<td>Term 1 (Sept.-Oct.) 8 weeks</td>
<td>Energy Physics and Technology</td>
<td>Skoltech</td>
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<tr>
<td></td>
<td>Introduction in Oil and Gas Engineering</td>
<td>Heriot-Watt</td>
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<tr>
<td>Term 2 (Nov.-Dec.) 8 weeks</td>
<td>Global Energy Decisions, Markets and Policy</td>
<td>Skoltech</td>
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<tr>
<td></td>
<td>Petrophysics and Reservoir Engineering</td>
<td>Texas A&amp;M</td>
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<tr>
<td>Winter (Jan.)</td>
<td>Research or Industrial Immersion</td>
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<td>Spring Year 1</td>
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<tr>
<td>Term 1(Feb.-Mar.) 8 weeks</td>
<td>Fluid Dynamics in Energy Applications</td>
<td>SCHR</td>
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<td></td>
<td>Petroleum Geophysics</td>
<td>Skoltech</td>
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<tr>
<td>Term 2 (Apr.-May) 8 weeks</td>
<td>Unconventional Hydrocarbons: exploration and production</td>
<td>Skoltech</td>
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<td></td>
<td>Geostatistics and Reservoir Simulation</td>
<td>Texas A&amp;M</td>
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<tr>
<td>Summer (Jun.-Aug.)</td>
<td>Field Camp (petroleum geology) or Industry Immersion</td>
<td>Skoltech</td>
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<table>
<thead>
<tr>
<th>Fall Year 2</th>
<th>Path 1</th>
<th>Path 2</th>
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<tbody>
<tr>
<td>Term 1 (Sept.-Oct.) 8 weeks</td>
<td>Geomechanics</td>
<td>Lausanne university</td>
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<td>Hydraulic Fracturing</td>
<td>UT Austin</td>
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<td>Gas Hydrates and Flow Assurance</td>
<td>Heriot-Watt</td>
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<td></td>
<td>Chemical Methods for Enhanced Oil Recovery</td>
<td>Stavanger</td>
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<td></td>
<td>Thermal Methods for Enhanced Oil Recovery</td>
<td>Calgary</td>
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<tr>
<td>Term 2 (Nov.-Dec.) 8 weeks</td>
<td>Chemical Methods for Enhanced Oil Recovery</td>
<td>Skoltech</td>
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<tr>
<td></td>
<td>Geostatistics and Reservoir Simulation</td>
<td>Texas A&amp;M</td>
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<tr>
<td>Winter (Jan.)</td>
<td>Research or Industrial Immersion</td>
<td>SCHR</td>
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<tr>
<td>Spring Year 2</td>
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<tr>
<td>Term 1 (Feb.-Mar.) 8 weeks</td>
<td>Research or Industry Immersion</td>
<td>SCHR</td>
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<tr>
<td></td>
<td>Research and MS Thesis</td>
<td>Skoltech</td>
</tr>
<tr>
<td>Term 2 (Apr.-May) 8 weeks</td>
<td>Research and MS Thesis</td>
<td>SCHR</td>
</tr>
<tr>
<td>Summer (Jun.-Aug.)</td>
<td>Research and MS Thesis</td>
<td>SCHR</td>
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Research equipment (planned for 2016)

Geomechanic lab
Universal Triaxial Loadframes MTS 816
- Full spectrum of mechanic tests ASTM, IRMS, ГОСТ
- Pressure (pore, confining) 140 MPa
- Temperature 0 - 200 ºC
- Porosity and permeability study at reservoir conditions
- Static and dynamic elastic modulus
- Microseismic monitoring

Enhanced oil recovery lab
Universal experimental unit for thermal EOR (University of Calgary)
- 6 000 Psi (400 atm), 400 C
- In situ combustion,
- High pressure air injection,
- Steam and hot water injection,
- SAGD,
- RTO

Universal flooding HPHT unit
- 80 Mpa
- 150 C
- 3 phases filtration
- X-ray control
- Full spectrum of flooding experiments, including fluids, gases, ASP, CO2, other
Research equipment (installed)

Petrophysic and geochemistry lab

NMR for core analysis (Oxford instrument)
- Oil and water saturation, wettability, pore size distribution
- 2.5 MHz
- 53 mm core holder
- Reservoir conditions (34 MPa, 100°C)

Pyrolisis

HAWK workstation, Wildcat technology
- Maximum oven temperature: 850 °C
- Oven temperature rates: adjustable from 0.1° to 75 °C/minute
- Sample capacity: maximum sample weight is 400+ mg. Recommended weight is 70 mg.
- 126 sample capacity. 3 removable sample trays.
- F.I.D. pyrolysis detector (for hydrocarbons).
- Two infrared (IR) detectors (one for CO and the other for CO2).
- S1, S2, S3, S4, Tmax, Absolute Tmax, TOC (GOC and NGOC) and CC (carbonate carbon).
- HI, OI, PI, AI, OSI, POI, Roe and % CaCO3.

Thermal rock properties

Optical scanner for thermal rock property study (Russia)
- high-precision analysis of thermal conductivity, thermal diffusivity, thermal heat capacity
- Profiling of thermal properties at high space resolution (1 μm)
- Standard and reservoir conditions
- Different saturation (gas, water, oil)
- High efficiency (50 m of core samples per day)
Research, education and innovation projects
Thermal EOR for Heavy Oil Fields: Collaboration with UofC

Research Projects

- Simulation of In Situ Combustion Process: Initial Calibration of Air Injection Kinetic-Displacement Model

Education

- MS course “Enhanced Oil Recovery” will be delivered by University of Calgary in 2016
- Training on thermal EOR for industry - planned for May 2016

Lab Facilities

- Unique High-Pressure System for Thermal Oil Recovery Methods Physical Simulation – ready for testing in Calgary (delivery in Jan 2016)

Planned Industry Collaboration

- Research proposal for joint industry on Thermal EOR has been accepted by Lukoil
- Proposal for creation of all Russia center on thermal EOR on the base of Skoltech developed and submitted to Ministry of Energy of the Russian Federation
Innovative approach for hydrodynamic modeling of heavy oil reservoirs: joint project with Lukoil

Project Leader:
Stanislav Ursegov, Leading research scientist, PhD

Client: Lukoil
Form of collaboration: R&D contract
Project period: Jun 2015 - Dec 2016

Project Title:
The development of a hybrid approach for geological and hydrodynamic modeling of the Permian – Carboniferous heavy oil reservoir of the Usinsk oil field.

Main Task:
Due to the large size, the high complexity of the geological structure, and the long duration of the development period, the Client is able to perform multivariate hydrodynamic calculations of the heavy oil production in the Permian – Carboniferous reservoir using only sector models of its small pilot areas. In order to forecast the production level for the whole reservoir, an innovative hybrid approach should be developed;

Proposed Solution:
The innovative hybrid approach takes into account the strengths of both the sector deterministic modeling (the ability to respond to changes in the temperature conditions of the reservoir development) and the whole reservoir fuzzy logic modeling (the ability to pass the results of sector calculations through the actual history of the reservoir development thereby bringing them closer to the reality) and provides a high speed of hydrodynamic simulation.
Gas Hydrate and Permafrost Research: collaboration with Heriot Watt and Total

**Project leaders:**
Prof. Evgeny Chuvilin, Prof. Vladimir Istomin

**University partners**
- Heriot Watt University (prof. Bahman Tokhidi),
- Moscow State University (Mikhail Tokarev)
- Guangzhou hydrate center (prof. Shuanshi Fan)

**Research projects**
- Properties of gas hydrate bearing rocks and permafrost
- Novel technologies for gas production from natural gas hydrates
- Geological risks related to gas hydrate an permafrost

**MS courses**
- Introduction in oil and gas engineering
- Gas Hydrates and Flow Assurance

**External financing**
- Grant of Russian Science Foundation
- R&D contract with Total on permafrost research (under negotiation)
Oil Shale: Participation in Research Consortium on Bazhenov

**Project Title:**
«Integrated study of Bazhenov formation: assessment of oil fields and new technologies for oil recovery»

**Project leader:** Prof. Mikhail Spasennikh

**Project term:**
2014-2016

**Project Funding** – M 330 Rub
Ministry of education and Science -90%
Gazpromneft–10%

**Project participants:**
Gazpromneft (industry partner), MIPT, Skoltech, MSU, Gubkin University

**Scope of work:**
- Integrated geological, lithological, geochemical and petrophysical study of Bazhenov formation at different regions of Western Siberia
- Development of integrated petrophysics model of Bazhenov for different regions of western Siberia
- Comparison of Bazhenov with oil shale reservoirs in US (Bakken, Eagle Ford, Barnett), evaluation of existing technologies for shale oil exploration and production
- Development of new technological solutions and tools for Bazhenovoil fields exploration and production (sweet spots, assessment of reserves, geomechanics and reservoir simulators, traditional and new technological solutions for oil production)
Oil shales: characterization and pore space structure

Project leaders: Dr. A.Kazak, Dr.S.Chugunov  
Clients: GAZPROMNEFT, NOVATEK

Research goal
→ Create 3D model of pore space image at a wide scale 1 nm – 1 m by integrating data from modern and novel methods of 3D tomography, microscopy and microstructural analysis

Current Status
→ Tight rocks were studied by X-ray micro-CT, FIB-SEM with elemental mapping, XRF scanning, mercury porosimetry and surface area.
→ Discovered and studied porous structure of kerogen

Results to Date
→ Main results published in 5 papers in industrial journals and presented to professional community at 2 scientific-industrial conferences and workshops.

Next Steps
→ To create 3D models for different types of tight rock from different regions of Eastern Siberia
→ To implement obtained results for reservoir simulation

Kerogen without pores
Kerogen with small pores
Kerogen with large pores
Thermal Petrophysics and Geothermics in application for oil shale formations

Project leader: prof. Yuri Popov

Clients: Gazpromneft, Lukoil

Low-permeable reservoirs

Traditional reservoirs

Heavy oils

Geothermal energy

Advanced geothermal methods and equipment

Thermal regime of the crust

Advanced geothermal methods and equipment

Thermal regime of the crust
New method of high-resolution continuous total organic carbon (TOC) profiling (Skoltech, 2015)

**Project leader:**
Professor Yuri Popov

**Research area:**
Thermal petrophysics of oil reservoirs

**Research goal:**
Development and application of novel petrophysical methods for characterization of oil reservoirs

**Current status:**
- >30 wells studied
- Developed novel method for reservoir characterization
- 2 patent applications are under consideration
- 2 research reports delivered and accepted
- 4 seminars for industry

- Non-destructive TOC profiling
- First thermal core logging for studies of oil/gas field structure
- High-precision measurements of thermal properties for EOR and basin modeling
- Rock anisotropy and high-resolution heterogeneity profiling for geomechanics
Hydro-geomechanics modeling of oil shale formation

Project leader: Artyom Myasnikov, Dr. of Sci.  
Clients: GAZPROMNEFT, LUKOIL

Goal: to develop novel technique of reservoir modeling for Bazhenov formation

Expected results: Incorporation of specific shale physics in reservoir models

Challenges: specific shale physics generates fundamental problems:

- Elastic and strength properties significantly depend on mineral composition and organic content
- Alternation of brittle and ductile zones
- Fissuring is observed at all scale ranges from micrometer to kilometer
- Anisotropy strongly affects direction of the hydraulic fracture propagation and interpretation of breakouts observations
- Fluid rheology and phase equilibrium of liquid and solid phases strongly depend on stress-strain state of the formation
- Kerogen may form a filtrating system which disappears under specific PT conduction

Obtained results 2015: 2 research reports (for Gazpromneft), 5 software products; 4 publications

- A new concept of REV is developed which make it possible to model multiscale fissuring and kerogen transformation
- New elastoplastic model shale formation is developed, initiated and validated
- HF propagation
- Wellbore stability
Seismic imaging is an important step in hydrocarbon reservoir exploration and characterization. To succeed in having reliable images of the subsurface, it is necessary to have good kinematical models, in order to properly positioning the seismic reflectors. New inversion techniques called “full waveform inversion” taking into account all the information in the seismograms not only for the pressure wave but also for the shear waves are successful in achieving this task but they are computationally intensive and require the use of high performance computing.

Source: Marwan Charara et al. "Nonlinear inversion of seismic waveforms: A North Sea offset VSP example" SMR, Cergy University & Total, SEG 2010
Thank you for attention!