Skoltech Center for Hydrocarbon Recovery

Partnership Program

is the most effective way
for institution to grow up from the scratch
and start to conduct research, education and innovation
in the field of exploration and production of hydrocarbons
on a world level with significant value and impact in a few years

Spasennykh M.Yu. <M.Spasennykh@skoltech.ru>
May 18, 2016
Skoltech, Moscow

Skoltech
Skolkovo Institute of Science and Technology

Partnership with Universities: strategy

Stage 1 – Quick start /2015-2017	
Education	• Development and delivery of MS courses • Student internship
Experimental facilities	• Recommendations on research equipment and procedures • Development and launch of research equipment • Joint R&D in partner lab, training Skoltech personnel
Research and innovation	• Launch of Skoltech R&D projects on partner facilities • Joint grants (replacement of Skoltech funds)
Collaboration with industry	• Development and delivery of trainings for RF industry • Start R&D with industry (replacement of Skoltech funds)

Stage 2 – Mutually beneficial partnership/2017-2018	
Education	• Double MS diploma • Joint PhD programs
Experimental facilities	• Joint experimental research in Skoltech and partner lab • Support of lab operations in Skoltech
Research and innovation	• Joint R&D projects • Executing joint grants (replacement of Skoltech funds)
Collaboration with industry	• Creation of research consortia • Joint trainings for industry • Participation in joint R&D with Industry (replacement of Skoltech funds)

Center for Hydrocarbon Recovery: Partnership with Universities

MRA:

- UNIVERSITY OF CALGARY — *Thermal EOR*
- HERIOT WATT UNIVERSITY — *Gas hydrates, Arctic shelf*
- TEXAS A&M UNIVERSITY — *Reservoir modeling*, Cancelled in 2016
- **Inst of Petroleum Geology, RAS,** Novosib — *HFM, Geomechanics*
- **Institute of the Earth Physics, RAS, Moscow** — *Shale oil*
- **Mining Univer, SPb** — *Chemical EOR*, *On hold 2015*
- **Bashkir State University, Ufa** — *Enhanced recovery*, *Microfluidic research*

Discipline	University Partner	Research	Education	Form of collaboration
Enhanced oil recovery	University of Calgary BSU, Ufa Mining University	Thermal EOR for heavy oil Equipment for thermal EOR Thermal EOR for shale oil Chemical EOR	Thermal EOR, Chemical EOR	MRA Contract on equipment MRA (on hold since 2015)
Geomechanics	INGG RAS, Novosibirsk Lausanne university	Geomechanic modeling Hydrofracturing monitoring Geomechanics, basing modeling	Geocmechanics Hydraulic fracturing	MRA Megagrant (planned)
Shale oil	IPE RAS BSU, Ufa Moscow State University Gubkin University Kurchatov Institute	Mechanical properties of rocks Temperature logging, AFM study, HPC Unconventional petrophysics Unconventional lithology TEM of kerogen	Unconventional petrophysics and geochemistry	MRA MRA 1.4-GPN project 1.4-GPN project Subcontract on 1.4-GPN project
Gas Hydrates, Arctic shelf, Permafrost	Heriot – Watt University Moscow State University Moscow State University RSGPU	Hydrate bearing rocks study Gas hydrate production Gas hydrates on Arctic shelf Geological risks related to hydrates Permafrost property study	Introduction in oil and gas Gas hydrates in oil engineering Petroleum geophysics	MRA MRA (via IPE RAS) Joint grant RSF Joint lab in RSGPU (planned)
Advanced reservoir modeling	Texas A&M University MIPT MIT	4 projects on advanced modeling Modeling of kerogen rich formations Digital rock	Reservoir engineering Advanced reservoir modeling	MRA (Cancelled in 2016) 1.4-GPN project 1.4-GPN project NEXT project (submitted)

Research consortium on Bazhenov

- Skoltech
- **MSU,** *Bazhenov*
- **Gubkin University** *Bazhenov geology*
- **MIPT** *Reservoir modeling*

- **Kurchatov Institute** *Kerogen porosity*
- **Surgut University** *Oil chemistry*
- UNIL | Université de Lausanne — *Geomechanics, Basing modeling*
- Universitetet i Stavanger — *Chemical EOR*
- **MIT** *Digital rock*

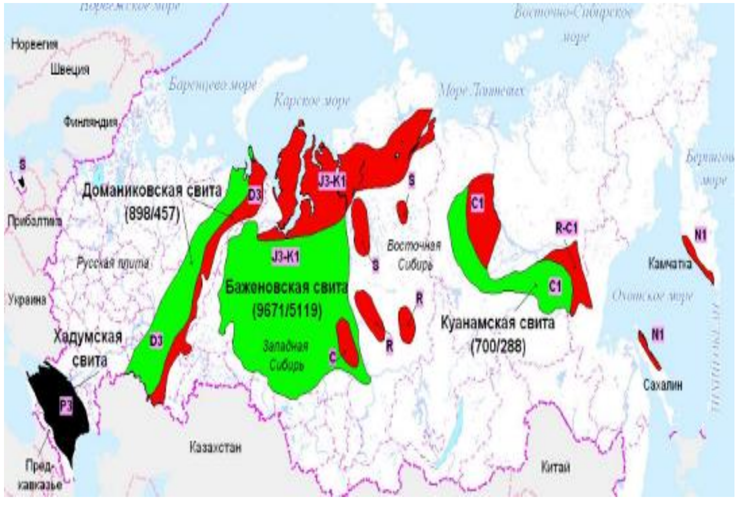
700-MRA Project 1

Project: Methods of well thermometry (thermal logging) for unconventional reservoirs

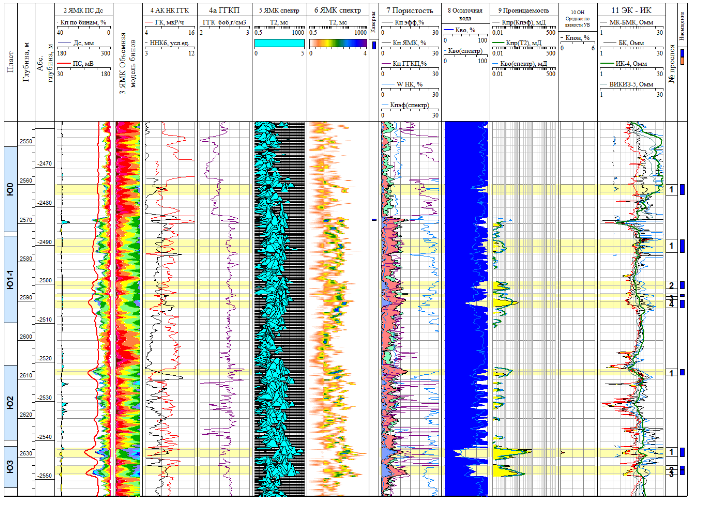
Partner: Bashkir State University, Russia

PI: Prof. Valiullin R.A.

Goal: Modern theory, research methodology and interpretation of thermometry applied to unconventional reservoirs.



Shale oils in Russia



Well logging

Work plan:

- Describe physical basis of thermometry for unconventional reservoirs ;
- Study horizontal wells;
- Study watered and low-yield wells;
- Study multilayer wells;
- Develop diagnostics of hydraulic fracturing completion;

Application in industry:

- Methodology on defining most promising reservoirs based on thermometry logging data;
- Methodology on defining water leak based on thermometry logging data;
- Multilayered reservoir diagnostics during the development and production of wells by thermohydrodynamic simulator;

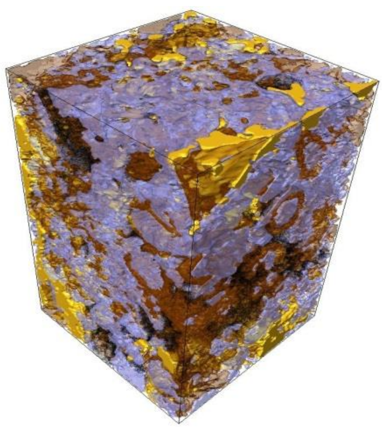
Skoltech
Skolkovo Institute of Science and Technology

700-MRA Project 2

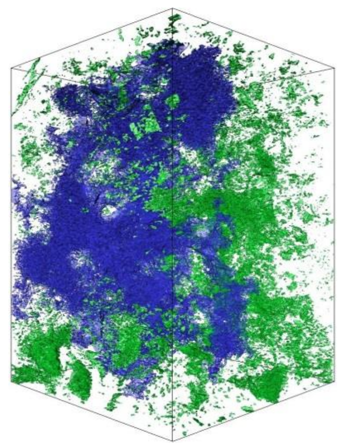
Project: Study of surface relief, mechanical properties and wettability of porous materials at micro and nano scales

Partner: Bashkir State University, Russia **PI:** Batyrshin E.S.

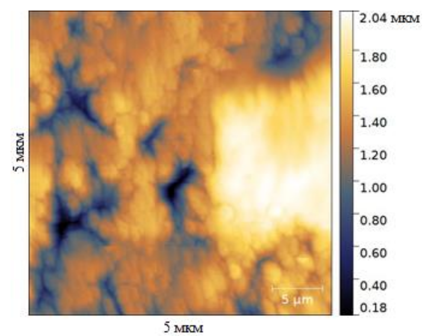
Goals:
- Method to measure mechanical properties of shales at micro- and nano-scale
- Method to measure wettability and surface morphology of shales at micro- and nano-scale



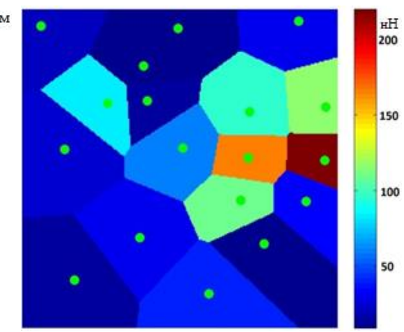
Shale rock model composed of: ● Pyrite, ● Carbonates, ● Quartz, ●Kerogen+Pores



Shale rock model composed of: ● Connected pores, ● Isolated pores



Surface of rock sample



Wettability map of rock sample

Work plan:
- Study rock mechanical properties at micro- and nano-scale;
- Study rock wettability at micro- and nano-scale;
- Study of physical and chemical interaction of rock and fluid at micro- and nano-scale
- Validate of Atomic Force Microscopy approach;

Application in industry:
- Extended “Digital rock” model;
- Completion design;
- EOR design;

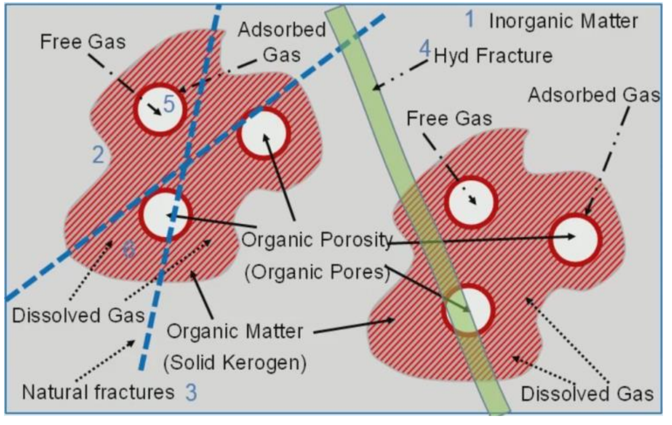
Skoltech
Skolkovo Institute of Science and Technology

700-MRA Project 3

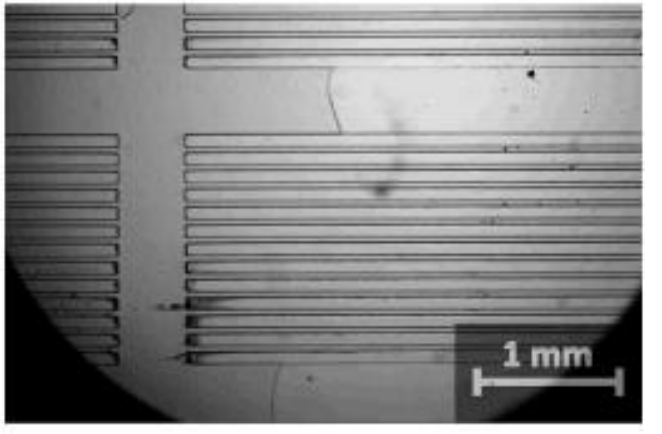
Project: Study of hydrodynamic flow in porous microstructures based on physical and chemical changes

Partner: Bashkir State University, Russia **PI:** Musin A.A.

Goal: Develop of methods of experimental studies and mathematical model of fluid flow in samples of low-permeability reservoirs with physical and chemical changes of the filtering continuum



Pore types in shale rock



Lab-on-chip: microchannels

Work plan:
- Experimental setup construction and microchannel samples fabrication;
- Experimental study of flow in microchannels;
- Mathematical modelling of flow in microchannels with physical and chemical changes;

Application in industry:
- Enhanced oil recovery design;

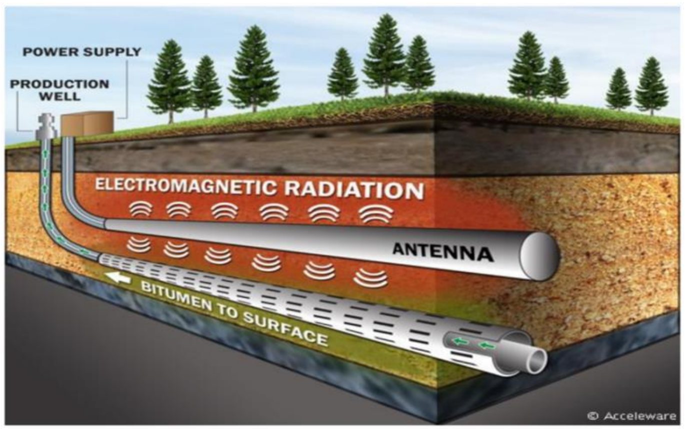
Skoltech
Skolkovo Institute of Science and Technology

700-MRA Project 4

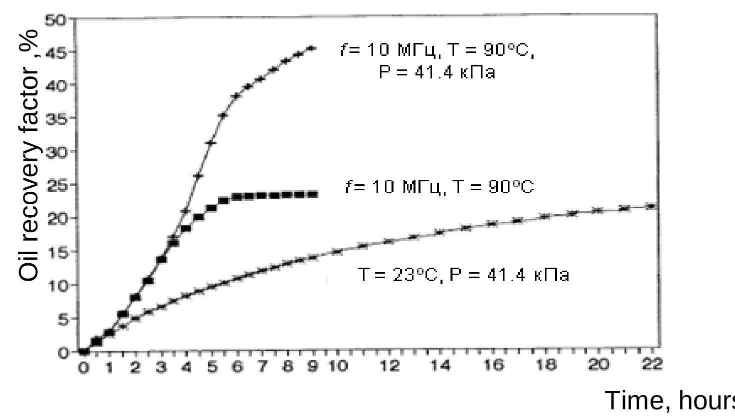
Project: Methods of electromagnetic influence on bottomhole formation zone

Partner: Bashkir State University, Russia **PI:** Prof. Kovaleva L.A.

Goal: Create a modern mathematical model that takes into account the processes of heat and mass transfer in a non-isothermal filtration of heavy hydrocarbon liquid in a porous media under the influence of high-frequency electromagnetic radiation.



Possible technological solution



Tests in labs

Work plan:
- Develop initial mathematical model based on published data;
- Develop laboratory setup and methodology;
- Conduct experimental research;
- Develop modern mathematical model;
- Validate modern mathematical model on laboratory setup;
- Verify modern mathematical model by comparing predictively with widely used commercial simulators on field data;
- Create research simulator;

Application in industry:
- Methods for stimulation of high-viscosity oils and bitumen production and enhanced oil recovery

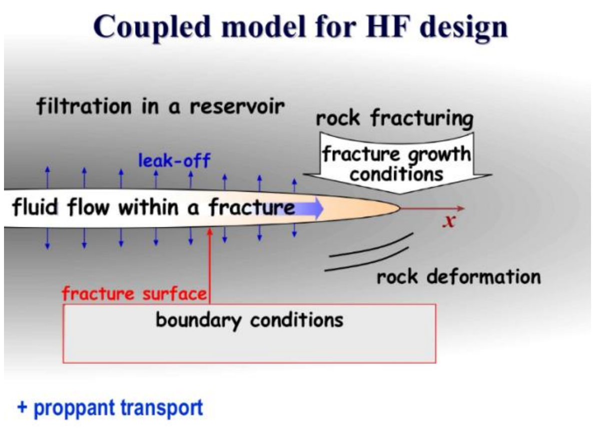
Skoltech
Skolkovo Institute of Science and Technology

710-MRA Project 1

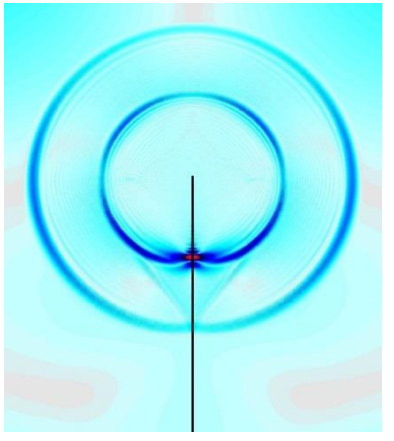
Project: Geomechanic modeling of hydraulic fracture growth and its connection to microseismicity

Partner: Institute of Petroleum-Gas Geology and Geophysics , Russia **PI:** Stefanov Yu.P.

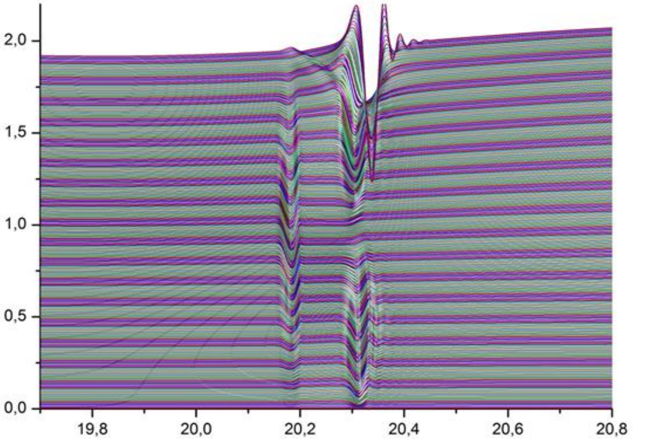
Goal: Develop technology of numerical modeling hydraulic fracture with different growth mechanisms



Schematic illustration of main physical processes within a hydraulic fracture



Velocity fields after a unit increment of a crack



Velocity horizontal seismic component

Work plan:
- Develop model of seismic waves generated by fracture growth;
- Analyze possible mechanisms of fracture growth;
- Develop numerical model and computational algorithms for modeling fracture advancement accounting to its orientation and medium structure;
- Assess impact of inelastic deformation and pore pressure change on the growth of hydraulic fracture

Application in industry:
- Technology of hydraulic fracturing (HF) control;
- Technology of assessing feasibility and effectiveness of HF;
- Reducing costs and risks of contamination during HF.

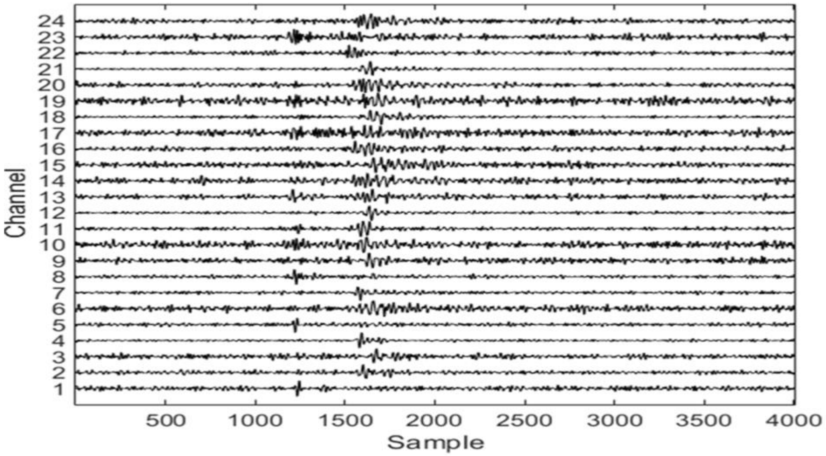
Skoltech
Skolkovo Institute of Science and Technology

710-MRA Project 2

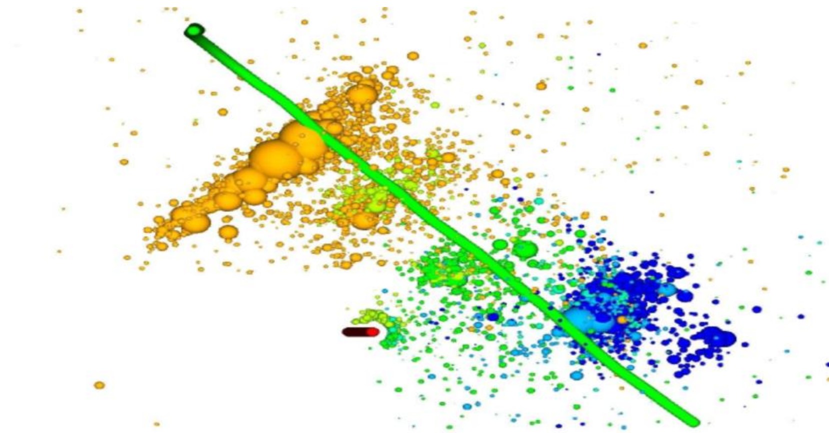
Project: Microseismic Monitoring Techniques for Hydrofrac Monitoring and Field Development

Partner: Institute of Petroleum-Gas Geology and Geophysics , Russia **PI:** Duchkov A.A.

Goal: Develop technology of using microseismic monitoring for detecting positions, mechanisms and types of hydraulic fracture propagation



Microseismogram



Microseismic imaging of induced fractures developed 5 stages hydraulic fracturing in reservoir with events temporally color

Work plan:

- Develop and implement microseismic data processing graph in application to hydrofrac monitoring;
- Refine medium parameters from microseismic monitoring data and cross-well seismic tomography;
- Define relation between microseismic source mechanisms and hydraulic fracture development;
- Develop microseismic monitoring technology for assessing hydrofrac geometry and development mechanisms.

Application in industry:

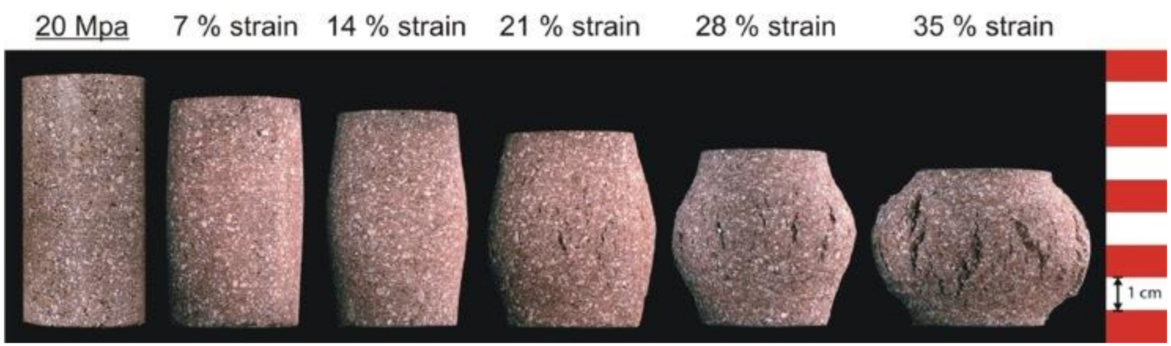
- Technology of data processing and analysis for microseismic monitoring of hydraulic fracturing;
- Technology of seismic velocity model building from microseismic data suitable for application hydraulic fracturing in unconventional reservoirs (characterized by strong seismic anisotropy).
- Technology of calibrating geomechanic models of fracture growth and reservoir production using microseismic monitoring.

711-MRA Project 1

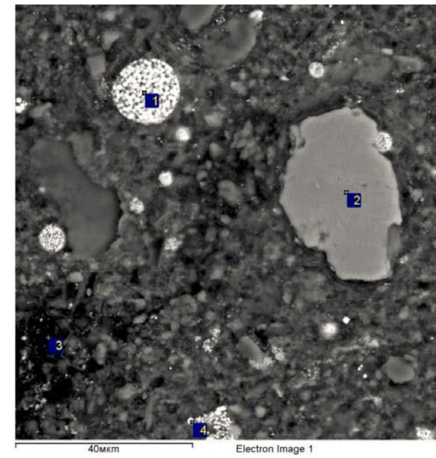
Project: Theoretical and experimental rock physics for unconventional hydrocarbon resources exploration and recovery

Partner: Institute of Physics of the Earth, Russia **PI:** Tikhotsky S.A.

Goal: Develop model of the behavior of elastic properties and mechanical sustainability of reservoir rocks under different stress-strain conditions



Lab plastic-brittle data



Rock mineral composition (scale: 40 µm):
1,4 — pyrite, 2 — apatite,
3 — kerogen

Work plan:

- Carry out lab high-pressure experiments studying mechanical properties of samples;
- Study microstructure, mineral, fluid and chemical composition of the reservoir rocks;
- Develop homogenization and simulation methods;
- Develop inversion methods.

Application in industry:

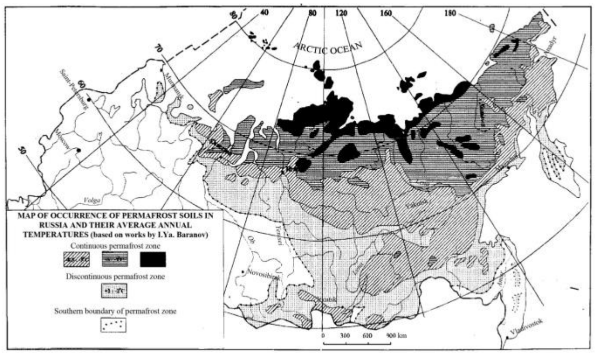
- methods and software for the localization of the unconventional oil-bearing formations and accurate determination of their effective transport and oil-bearing properties from well logs and field data;
- Methods and algorithms for the estimation of the quasi-static elastic moduli and non-elastic rheology of rocks for geomechanical modeling of the oil fields. The latter is important for the optimal drilling design, drilling risks lowering, prevention of drilling accidents and optimal design of the oil recovery, including hydrofracturing and recovery regime

711-MRA Project 2

Project: Geophysical methods for exploration of hydrocarbon fields on the Russian shelf and assessment of related geological risks

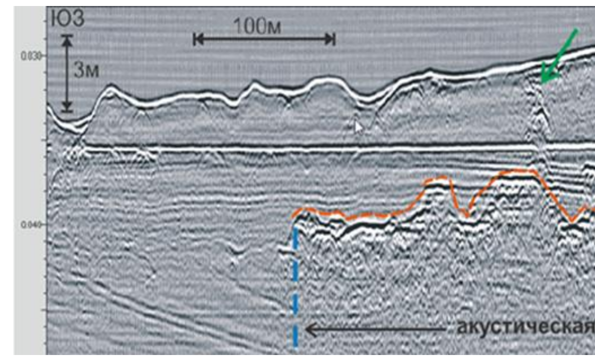
Partner: Institute of Petroleum-Gas Geology and Geophysics , Russia **PI:** Tokarev M.Yu.

Goals:
- Develop method for the hydrocarbon reservoir defining at sea shelf areas
- Develop method for estimation mechanical properties of non-consolidated sediments from seismic data



Permafrost soils in Russia

Core from subaquatic permafrost



Seismic image of
the scattered gas in sediments

Work plan:
- Develop joint inversion method of multi-type geophysical data for sea shelf studies;
- Develop model of gas hydrates reservoir formation and evolution;
- Study low-consolidated sea shelf sediments properties;
- Develop method of ecological risks evaluation and mitigation for hydrocarbon exploration and recovery;

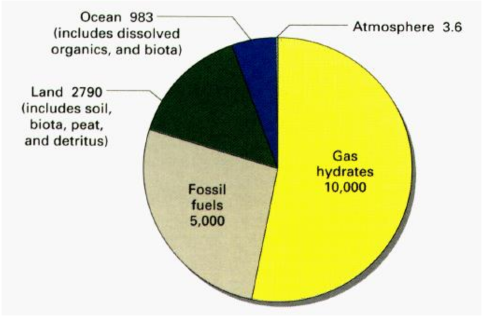
Application in industry:
- Technology of investigation geological structure and oil-gas-bearing capacity of reservoirs sexternal and internal Russian seas;
- Technology of assessment of geological risks associated with the hydrocarbon recovery at sea shelf.
- Geophysical methods for defining mechanical properties of near-bottom sediments with applications for drilling design and mitigation of construction risks.

742-MRA Project 1

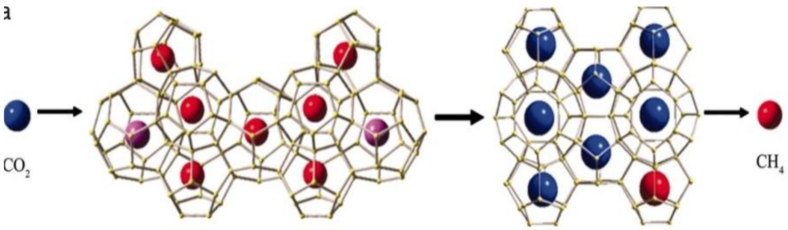
Project: Methane recovery from gas hydrate reservoirs by nitrogen/flue gas injection

Partner: Heriot-Watt University, UK **PI:** Prof. Bahman Tohidi

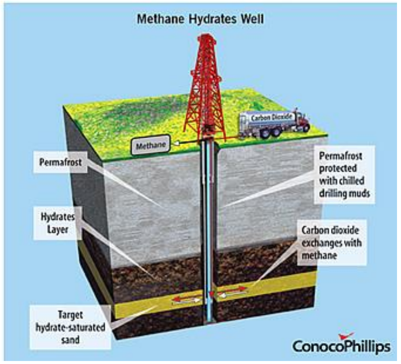
Goal: Develop physical and chemical bases for technology of methane recovery from methane hydrate deposits by injection of nitrogen and flue gas



Distribution of organic carbon in Earth (10^{15} tons of carbon)



Replacement of CH_4 by CO_2 in hydrate structure



Possible technology

Work plan:

- Study kinetics of the decomposition of methane hydrate and the formation of carbon dioxide hydrate in the pore space after the injection of flue gas;
- Investigate how methane recovery factor depends on permeability, porosity, mineral composition of rocks and composition of the flue gas
- Estimate CO_2 hydrate formation in reservoirs and shift in geomechanical properties of sediments.
- Develop a physicochemical model for the effectiveness of methane recovery from hydrate-saturated deposits by injection of flue gas.

Application in industry:

- Technology of methane recovery from methane hydrate deposits
- Technology of utilization of flue gases from large industrial facilities in permafrost collectors;

Skoltech
Skolkovo Institute of Science and Technology

742-MRA Project 2

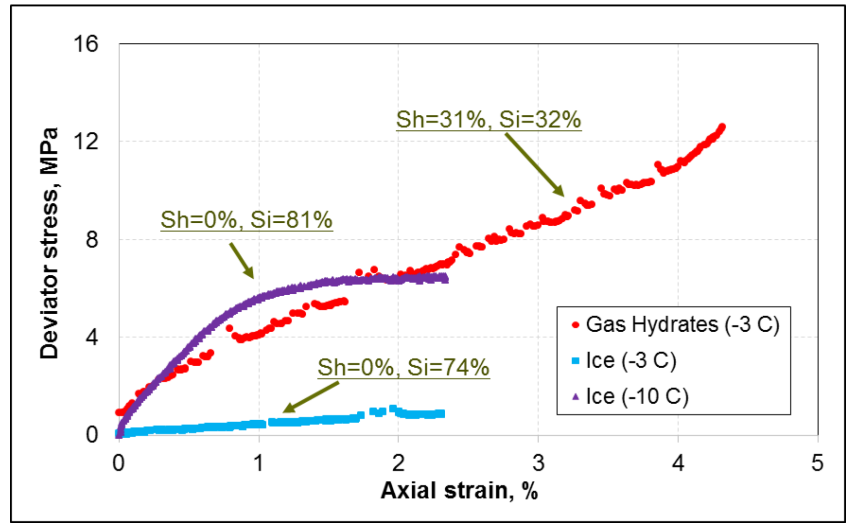
Project: Geomechanical, geophysical, geothermal properties of gas hydrate-bearing permafrost sediments

Partner: Heriot-Watt University, UK **PI:** Prof. Bahman Tohidi

Goal: Study physical, mechanical, acoustic and thermal properties of frozen soils containing gas hydrates

Three-axle compression press

Rock sample after shearing



Influence of gas hydrates on geomechanical properties of frozen rocks. Sh – hydrate saturation, vol%; Si – ice saturation, vol%

Work plan:

- Study influence of temperature and pressure on geomechanical, geophysical and thermal properties of frozen and/or hydrate-containing rocks;
- Estimate salinity effect on the properties of frozen and/or hydrate-containing rocks.
- Develop model for diagnosing and quantification of gas hydrate content in permafrost.

Application in industry:

- Identification of gas hydrate accumulations in the permafrost zone;
- Estimation of geological risks due to gas hydrate in permafrost;
- Prediction of properties of gas hydrates in cryolitozone;
- Estimation of porous medium physical properties of the bottom-hole zone during hydrate formation.

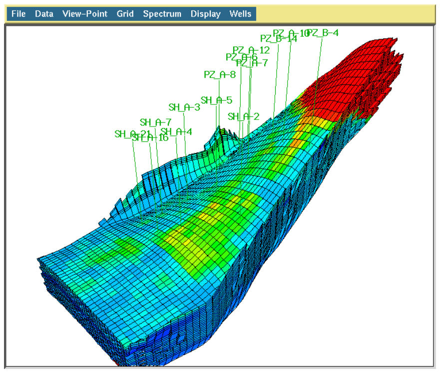
Skoltech
Skolkovo Institute of Science and Technology

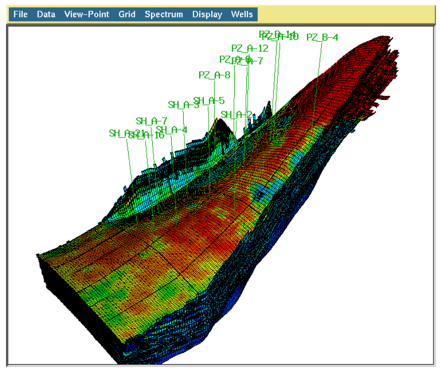
746-MRA Project 1

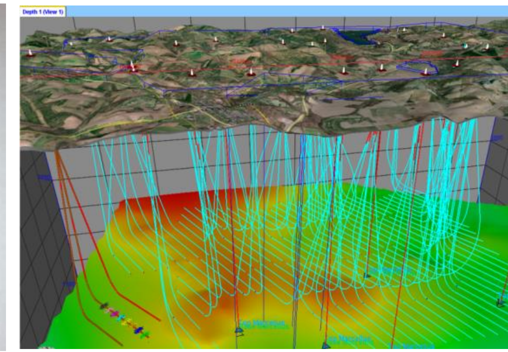
Project: High Performance Simulation in Conventional Reservoirs

Partner: Texas A&M University, USA **PI:** Prof. John Killough

Goal: Develop complex multi-porosity simulation model







Comparative Study: Production Results in 2 000 days

36,080 Grid Cells
Simulation Time: 2 Minutes

1,021,750 Grid Cells
Simulation Time: 3 Hours

Multiscale modeling

Micro scale (µm)

Field scale (km)

Work plan:

- Develop Prototype of Multiple Porosity Model;
- Develop Multiscale and Upscaling Techniques;
- Carry out Numerical Simulations to Match Field Data and Determine Model Predictability;
- Enhance Simulator Efficiency for Large-Scale Applications;

Application in industry:

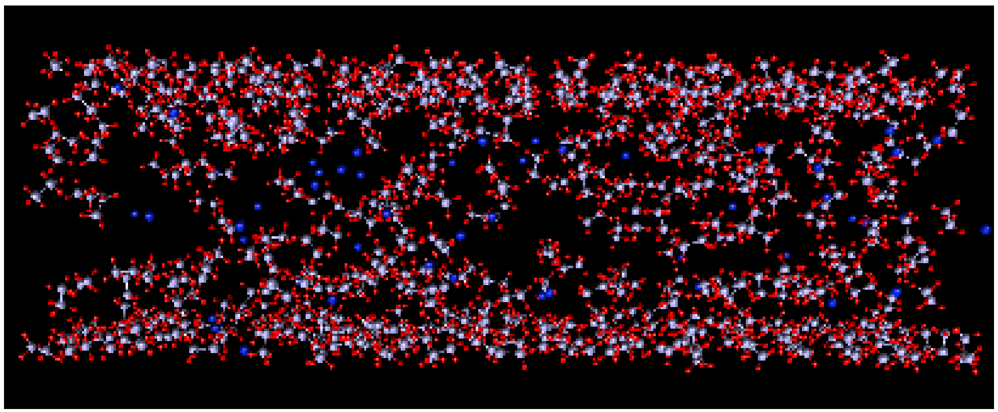
- Model capable of handling multiple porosity scales simultaneously interacting with one another;
- Technique for handling the many scale levels from pore-level to large-scale fractures;
- Technique for enhancing simulator efficiency to extend beyond single wells and into full-field simulation capabilities to allow economic evaluation of oil reservoirs.

746-MRA Project 2

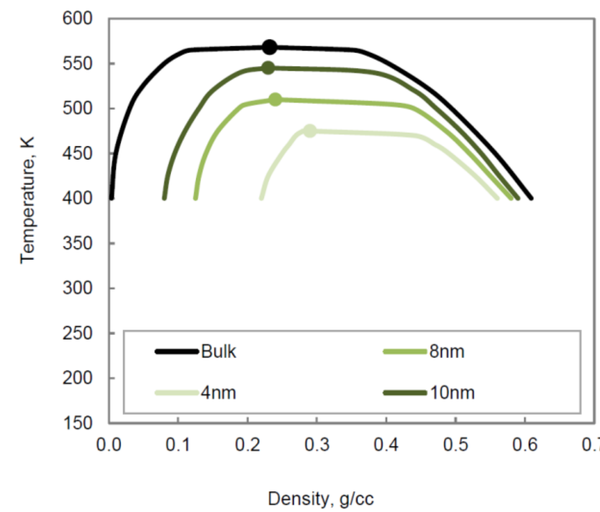
Project: Predictive Models for Hydrocarbon Phase Behavior and Fluid Properties in Hydrocarbon Reservoirs

Partner: Texas A&M University, USA **PI:** Prof. Yucel Akkutlu

Goal: Develop laboratory methods for the PVT study of hydrocarbons produced from organic-rich resource rocks and to predict the hydrocarbon fluid phase behavior and their transport properties in reservoirs under the reservoir conditions



Methane-ethane mixture in slit-pore



Phase diagrams of n-octane in graphite slit-pores

Work plan:

- Estimate effective pore size for the condensate system.
- Develop pore-size adjusted phase diagrams for the hydro-carbons, water, CO_2, N_2;
- Develop pore-size adjusted multi-component phase diagram for the reservoir fluid;
- Develop mixing rules suitable for the reservoir fluid under confinement;
- Develop single-well history-matching case studies.

Application in industry:

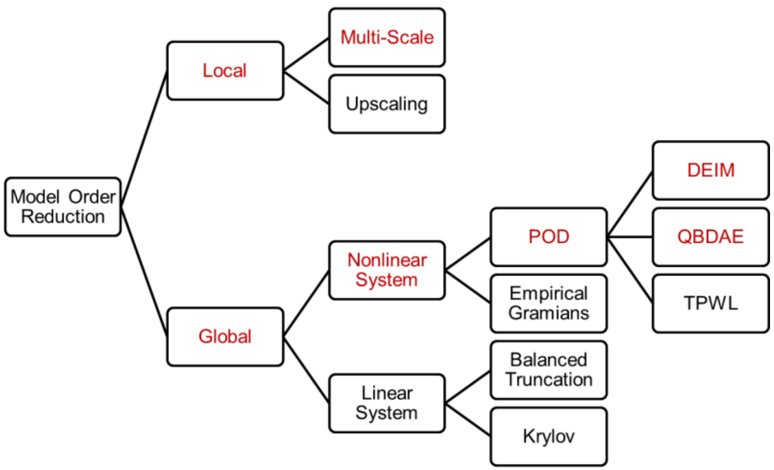
- Predict producing gas-oil ratios and reserve accurately by taking in account how important the confining effects are for the organic-rich shale system

746-MRA Project 3

Project: Fast Multiscale Model Reduction-Based Methods for Reservoir Simulation and Optimization

Partner: Texas A&M University, USA **PI:** Prof. Eduardo Gildin

Goal: Develop reliable and efficient model of complex large-scale geosystems, amenable for fast simulation in uncertainty quantification, parameter estimation and optimization applications



Model reduction techniques

- Which model should I work with?
- How to measure my approximation/error within and among each tier?
- How to add Uncertainty?
- What about complexity?

Understanding "complexities" in reservoir models

Work plan:
- Understand complexity in porous media flow by the analysis of system-theoretical properties;
- Develop local-global model order reduction algorithms for flow in porous media;
- Interplay between multiscale methods and model-order reduction by means of the development of error estimators;
- Develop realistic test-bed for implementation of reduced-order models in porous media flow.

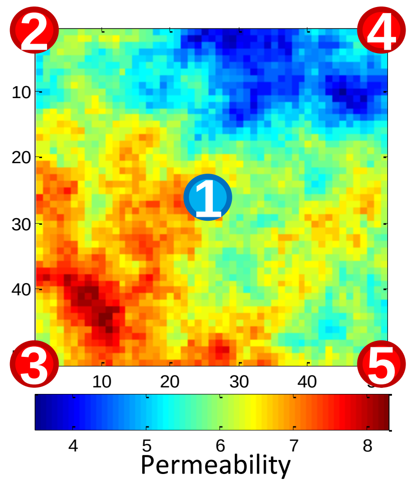
Application in industry:
- Multiscale model reduction of large scale dynamical systems
- Conventional and unconventional reservoir simulation and optimization;
- Closed-loop reservoir management.

746-MRA Project 4

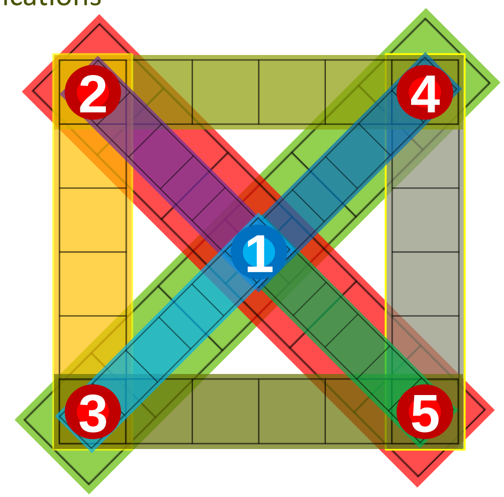
Project: Real Time Data Assimilation Accounting For Multi-Physics Reservoir Processes

Partner: Texas A&M University, USA **PI:** Prof. John Killough

Goal: Develop reliable and efficient model of complex large-scale geosystems, amenable for fast simulation in uncertainty quantification, parameter estimation and optimization applications



Conventional reservoir model:
spatial properties;
Dimension is defined by size and complexity of the reservoir.



Flow network model
Relationship between wells
Dimension is defined by number of wells

Work plan:

- Assimilate data and estimate parameter of multi-physics reservoir attributes;
- Evaluate reservoir performance uncertainty using computationally efficient schemes;
- Implement data assimilation and uncertainty quantification in parallel architectures;
- Develop real time data assimilation and feedback control of oil recovery process.

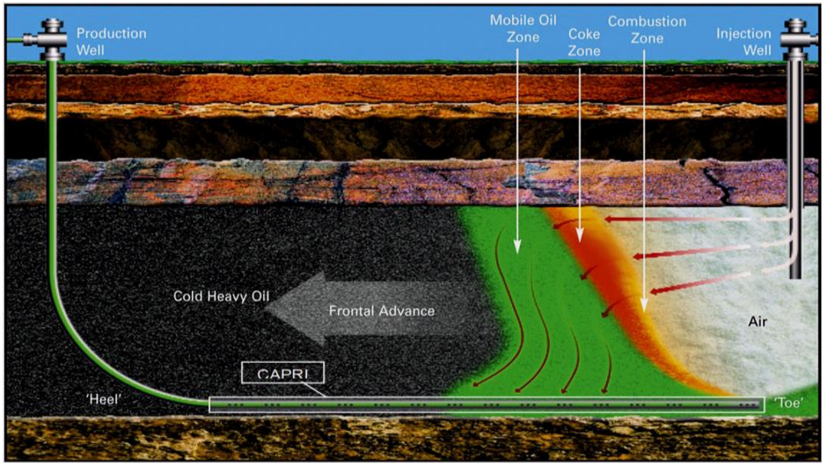
Application in industry:
Data assimilation and techniques for fast quantification of uncertainty in reservoir modeling, data assimilation, feedback control of enhanced recovery processes

745-MRA Project 1

Project: High Pressure Air Injection (HPAI): Physical Modeling Matrix for HPAI Feasibility Assessment, Field Design and Kinetic Parameters

Partner: University of Calgary, Canada **PI:** Prof. Raj Mehta

Goal: Designing experiments which generates 'meaningful' data for evaluation of process performance, obtain field design parameters and oxidation reaction kinetics data for numerical simulation



In-Situ combustion technology

Combustion tube for laboratory experiments

Work plan:

- Develop matrix for systematic screening/evaluation of target reservoirs for High-Pressure Air Injection (HPAI)-based oil recovery processes using elemental physical modeling at reservoir conditions;
- Develop methodology for the relevant experiments for physical simulation of the HPAI-processes in the laboratory;
- Design and carry out experimental programs.

Application in industry:

- Reservoir screening, field design parameters and process performance monitoring for implementation of the HPAI-based oil recovery processes;

Skoltech
Skolkovo Institute of Science and Technology