UND UNIVERSITY OF NORTH DAKOTA
COLLEGE OF ENGINEERING & MINES

UND.edu

Petroleum Engineering
Collaborative Energy Complex 113
2844 Campus Rd. Stop 8154
Grand Forks, ND 58202-8155
Phone: 701.777.2533
Website: engineering.und.edu/academics/petroleum

September 16th 2019

Ms. Karlene Fine, Executive Director
North Dakota Industrial Commission
ATT: Oil and Gas Research Council
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

Dear Ms. Fine,

Re: UND proposal entitled: **Economic viability of horizontal open hole completions, Madison Group, ND.**

The Department of Petroleum Engineering at UND, PI: Mehdi Ostadhassan and co-PI: Hui Pu along with their industry partners: Resource Energy are submitting a research proposal to the North Dakota Industrial Commission, Oil and Gas Research Council. UND is respectfully asking for $**1,289,503** for this project for 36 months.

Enclosed please find two copies of the proposal and $100 check for the application fee.

Please feel free to contact us if you have any questions.

Regards,

Mehdi Ostadhassan, PhD
Associate professor
Department of Petroleum Engineering
Department of Biomedical Engineering
University of North Dakota
701-777-3754
mehdi.ostadhassan@UND.edu

Hui Pu
Assistant Professor
Department of Petroleum Engineering
University of North Dakota
701-777-6861
hui.pu@UND.edu

Jamie Mitzel
Senior Pre-Award Officer
University of North Dakota
701-777-4146
jamie.mitzel@UND.edu

UNIVERSITY OF NORTH DAKOTA

Proposal Transmittal Form

Five business days prior to the sponsor's due date, submit to Division of Research & Economic Development the following: 1) a completed transmittal

Division of Research & Economic Development | **Tech Accelerator, Room 2050** | **4201 James Ray Drive, Stop 8367** | **Phone: 701-777-2505**

SECTION A: SUBMISSION INFORMATION

For e-submission email full proposal to: vpr.proposals@und.edu

Phone # to call for pickup: **7-3754**

Competitive Proposal: ☑ Yes ☐ No

Project #:

Electronic Submission: ☐ Yes ☑ No

Due Date: Sep 16th 2019

○ Pre-Proposal ● New Proposal ○ Renewal ○ Revision ○ Supplemental ○ Progress Report

SECTION B: PROPOSAL DATA

Principal Investigator Name:	Dept Name:	Dept #:	PI Phone #:	PI Email:
Mehdi Ostadhassan	PtrE	2730	3754	mehdi.ostadhassan@und.edu
Co-PI Name:	Dept Name:	Dept #:	Co-PI Phone #:	Co-PI Email:
Hui Pu	PtrE	2730	3754	hui.pu@und.edu

Proposal Title: Economic viability of horizontal open hole completions, Madison Group, ND

Start Date: 1/1/2020 End Date: 1/1/2023

Effort - 5% minimum for PI and Co-PI (if applicable) per effort policy. *See Instruction, #9 for further requirements.

UND Personnel	UND Employee Name	Calculated Total %	% of Effort Paid By Agency	% of Effort Paid by Dept	If known, list the Local/Appropriated Funding Source currently paying salary
PI	Mehdi Ostadhassan	17%	17%	0%	
Co-PI	Hui Pu	17%	17%	0%	
Key Personnel		0%			
Key Personnel		0%			
Key Personnel		0%			
Key Personnel		0%			

University Commitments - check all that apply

☐ Faculty Release Time Beyond Current Allocation ☐ Graduate Tuition Waiver ☐ Other

☐ Office/Lab Space Beyond Current Allocation ☐ Department Funds Used as Matching

Additional Information - complete all sections

		Yes	No
UND to issue subaward to external entity?	*If "Yes", see Instruction #11	☐	☑
Proposing new building construction, major renovations or building additions?	*If "Yes", route to Facilities	☐	☑
Creating a new course/curriculum for credit?	*If "Yes" route to VPAA for SBHE approval	☐	☑
Is Program Income anticipated from this proposal? Example: sale of an item(s) or charging registration fees		☐	☑
Is a department, other than the PI's department involved in this proposal?	*If "Yes", see Instruction #11	☐	☑
Has lobbying occurred in relation to the proposal?		☐	☑
Does this proposal focus in part or completely on Native American populations?		☐	☑
Did this proposal result from a Faculty Research Seed money (FRSM) grant?		☐	☑
Is support staff/clerical staff salaries proposed?	*If "Yes", be sure to justify in the budget	☐	☑

SECTION C: SPONSOR/PROGRAM DATA

Agency Type: State Flow Through Type: State Function: Research - Applied

Grand Challenge, if applicable: Primary: Energy & Environmental Sustainability Secondary: SELECT

Agency Name: NDIC Flow Through Name: OGRF

Is there a limit on the number of proposals that can be submitted to the Agency from UND? ☐ Yes ☐ No

SECTION D: BUDGET DATA

incurred are project related and in accordance with contractual terms, conditions and time frames, and ensuring the technical and reporting requirements of the project are satisfied.

What is UND's Indirect Cost rate for this proposal? 39.0%

Does the Agency restrict the Indirect Cost allowable in the budget? If "Yes", provide documentation ☐Yes ☑No

Agency approved Indirect Cost rate if lower than UND's approved F&A rate: ______

Was a request approved by the VPFO to waive UND's Indirect Cost rate? If "Yes", provide documentation ☐Yes ☐No

Direct Costs	Indirect Costs (F&A)	Total	Total + Cost Share
$927,700.00	$361,803.00	$1,289,503.00	$2,789,503.00

Equipment/Equipment Fabrication greater than or equal to $5,000 per unit? *If "Yes", see Instruction #21 ☐Yes ☐No

SECTION E: COMPLIANCE DATA

Animals: ☐Yes ☑No Inst. Animal Care & Use Committee (All Live Vertebrate Animals)	**Human Subjects:** ☐Yes ☑No Institutional Review Board	**Biohazard or Recombinant DNA:** ☐Yes ☑No Institutional Biosafety Committee
Radioactive Materials ☐Yes ☑No Radiation Safety & Hazardous Materials Committee	**Controlled Substances:** ☐Yes ☑No **Select Agents BSL Level 3:** ☐Yes ☑No	

Other Compliance Topics - complete all sections

- Will any foreign nationals be working on this project? If unknown, choose No. ☐Yes ☑No
- Are you aware of any publication restrictions on this project? ☐Yes ☑No
- Are there plans to work with or travel to an International country? Country ______ ☐Yes ☑No
- Is it anticipated this project would result in new intellectual property? If unknown, choose No. ☐Yes ☑No
- Will UND's existing intellectual property be utilized? Invention ID#: ______ ☐Yes ☑No
- Is it anticipated this project will use intellectual property not owned by UND? ☐Yes ☑No
- Does this involve a confidentiality agreement, material transfer agreement or proprietary information? ☐Yes ☑No
- Has the PI, Co-PI and Key Personnel filed Conflict of Interest Disclosure forms within the past 12 months? ☑Yes ☐No
- Is this a PHS or PHS flow-through proposal? If "Yes", attach Page three of the proposal transmittal ☐Yes ☑No
- Is proposal for STTR/SBIR (Small Business Technology Transfer/Small Business Innovation Research)? ☐Yes ☑No
- Is a Small Business Subcontracting Plan required (contracts over $650,000)? ☐Yes ☑No
- If NSF proposal, is Responsible Conduct of Research (RCR) training complete? ☐N/A ☐Yes ☑No

SECTION F: APPROVALS

By signing this transmittal form, you are certifying that 1) the information submitted herein is true, complete and accurate to the best of your knowledge, 2) any false, fictitious, or fraudulent statements or claims may subject you to criminal, civil or administrative penalties, 3) you agree to accept the responsibility for the scientific conduct of the project and to provide progress reports, and 4) PI and any other key personnel are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from current transactions by any federal department or agency.

[signature] UND Principal Investigator	Date 9/12/19	[signature] Co-Principal Investigator Chair (Print & Sign)	Date 9/12/2019
[signature] UND Co-Principal Investigator (Print & Sign)	Date 9/12/19	Co-Principal Investigator Dean (Print & Sign)	Date
Principal Investigator's Chair (Print & Sign)	Date	School/College - Admin./Finance (Print & Sign)	Date
[signature] Principal Investigator's Dean	Date 9-12-19	Karen Katrinak [signature] Other (Print & Sign)	Date 9/16/19
Campus Capital Proj & Planning (as needed)	Date	[signature] Division of Research Authorized Official	Date 9/16/19

Application

Project Title: Economic viability of horizontal open hole completions, Madison Group, ND

Applicant: UND Petroleum Engineering Department and Resource Energy (industry partner)

Principal Investigator: Mehdi Ostadhassan, PhD

Date of Application: September 16th 2019

Amount of Request: $1,289,503.00

Total Amount of Proposed Project: $2,789,503.00

Duration of Project: 3 years

Point of Contact (POC): Mehdi Ostadhassan

POC Telephone: 701-777-3754

POC E-Mail Address: mehdi.ostadhassan@und.edu

POC Address: 2844 Campus Rd-Stop 8154

Grand Forks, ND 58202

Oil and Gas Research Program

North Dakota

Industrial Commission

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ABSTRACT

Expected Results:

With close collaboration and data sharing with the operator Resource Energy, the results of the proposed project will provide a possible solution for effective development of Madison Group formations. The significant amount of remaining resource in the target formation will be tapped through a comprehensive geological, geophysical, petrophysical, theoretical and laboratory studies. In this project we expect to get a clear and complete image of recoverable reserves from the Madison Group (Charles, Mission Canyon and Lodge Pole Formations) in Williston Basin, with a focus on Divide and Williams Counties, where recent operations by Resource Energy (our industry partner) took place. Ultimately, the outcome will lead to renewed interest in the Madison Group across the North Dakota. We would anticipate to propose the most appropriate EOR/IOR processes in the field in these two counties along with proper stimulation and completion methods that can provide the best production practices from newly drilled wells in the Madison Group. This project ultimately will increase total production of the state through an integrative approach by re-evaluating and reconsidering conventional reservoirs in Williston Basin that have been neglected due to the rise of the Bakken. Finally, by presenting the results, we'd expect to attract other operators to reinvest in conventional reservoirs in Williston Basin, and boost future operations in the state. All these will end in more revenues for the state of ND and more job opportunities and improved economy.

Duration:

The duration of the proposed project will be 36 months (01/01/2020 to 12/31/2022).

Total Project Cost:

The total cost of the project is $$2,789,503.00. The amount requested from the Oil and Gas Research Council (OGRC) is $$1,289,503.00 and combination of in-kind funding totaling at least $1.5M from Resource Energy.

Participants:

A UND research team of two faculty members, and five graduate (PhD) students from the Petroleum Engineering department will participate in the project. Industrial partner, Resource Energy, will support the project by providing in-kind support, access to the field, core samples, complete well log suite for a newly drilled well, proprietary information regarding production and completion, newly acquired 3D seismic data from the field, personnel and etc.

PROJECT DESCRIPTION

Background

The Williston Basin is now one of the most prolific areas for hydrocarbon production in the world. The Bakken Formation is the principal target but the history of oil discoveries goes beyond the Bakken, with major production initially from the Madison Group. The Madison Group includes 3 principal units: The Lodgepole (LP), Mission Canyon (MC) and Charles (CH) formations. According with the U.S. Geological Survey (USGS), The MC and CH formations are considered as one particular petroleum system, with inclusion of the Triassic Spearfish Formation in some areas of the Williston Basin, as a reservoir rock. The LP and the Bakken Formation (out of the Madison Group) are considered another petroleum system. In this case, the Bakken Formation will be the source rock for oil accumulations in the LP unit and possibly other units.

The Bakken-LP petroleum system boundary is defined where oil is generated from the upper and lower shale members of the Upper Devonian and Lower Mississippian Bakken Formation and have accumulated in the reservoirs including the LP Formation (Pollastro et al., 2008a, b). This petroleum system includes the area of hydrocarbon production from the Waulsortian mound reservoirs in Stark County, and potential areas of LP production based on mapped depositional facies (Diehl and Burke, 1995), as well as reported mound discoveries in other parts of Montana and North Dakota. Oil produced from LP Formation in Stark County has been geochemically typed to the upper and lower organic-rich shales of the underlying Bakken Formation (Jarvie, 2001). A well sampled in the in Divide County in ND and, Sheridan County, MT, produced from the LP showed that the oil has the same geochemical signatures as the oil in the Stark County mounds (Jarvie, 2001). The distance between these two wells indicates that LP accumulations may occur farther to the northwest in the basin (Jarvie, 2001), although none have been discovered at this time which shows the importance of further studies both geochemistry to locate the source rock and reservoir quality/petrophysical characteristics.

The Bakken-expelled hydrocarbons migrated upward when pathways were provided by faulting or where generation pressures exceeded fracture thresholds (Jarvie, 2001). Lateral migration of the Bakken oil is limited because of poor porosity and permeability in the Bakken shales. This may explain the absence of commercial accumulations in the LP in other areas in the basin, but too this may suggest a better chance to find LP new accumulations in areas with some brittle deformation, like local faults or fractures, that must be to identify in details in the future surface and subsurface mapping studies, to analyze a possible new play concept. This idea proposes reprocessing of available seismic data, and interpretation of such information based on more advanced algorithms that are recently developed to enable locating possible migration pathways.

The MC and CH are the youngest carbonate reservoirs in the Williston Basin. The MC-CH oils are self-sourced by MC Formation and Ratcliffe interval of the CH Formation carbonate source rocks (Brooks and others, 1987; Grantham and Wakefield, 1988; Osadetz and others, 1992; Price and LeFever, 1994; Jarvie and others, 1997; Obermajer and others, 2000; Jarvie, 2001). The characteristics of MC and CH oils are thought to be indicative of terrestrially sourced organic matter and derived from carbonate or marly shale source rocks. Suitable properties in the Ratcliffe interval (CH Formation) and other three organic-rich intervals in the MC with as much as 14 percent total organic carbon (TOC) supporting the existence of this self-sourced system (Jarvie, 2001). The TOC richness and potential of the source rocks indicate sufficient hydrocarbon generation capacity to account for MC-CH HC accumulations (Jarvie, 2001). However, the chemical variations of this oil suggests that they are not from a single source rock, but rather from source horizons interbedded with the multiple mid-Madison reservoirs in the basin. The presence of efficient seals throughout the MC and CH also infers the necessity of multiple source horizons within the Madison to explain variations between reservoirs and oil types (Jarvie, 2001). MC Formation reservoirs are in the majority of the subintervals (Kerr, 1988). Each sequence is capped by anhydrite and contains potential reservoirs of dolomitized mudstone and wackestone, or lime grainstone, often deposited in coastal settings (Kerr, 1988). Production in the basin is generally separated into four areas (Lindsay, 1988): (1) the Nesson anticline, (2) northeast of the Nesson anticline, (3) eastern basin margin fields, and (4) southern basin margin fields. In this regard, Nesson anticline reservoirs are the most prolific in the MC, producing from skeletal packstones and grainstones, and from buildups of oolitic-pisolitic, intraclast-bearing skeletal wackestones and packstones (Lindsay, 1988). Although this history, lack of studies in other areas in terms of geochemical screening, reservoir quality mapping has led to completely neglecting probable economic accumulations from these formations.

Oil production in the Charles Formation includes reservoirs from different intervals. Production from the lower section is along the subcrop unconformity from porous strata, where reservoirs are overlain by tight, red clastic Mesozoic rocks (Kerr, 1988). This reservoir rocks are identified in all three types of traps: stratigraphic, structural and combined. Upper Permian and Lower Triassic Spearfish Formation in the north-central part of ND is another conventional reservoir that needs more attention. MC-CH source rocks charge the Spearfish where it directly or nearly directly overlies the Madison Group. The Spearfish consists of shallow marine sandstones that typically lie directly on the Madison-Spearfish unconformity. Spearfish production is commonly commingled with MC or CH producing reservoirs. Production is generally on four-way fault closures, although there can be a stratigraphic component because of the unconformable and the discontinuous nature of the sandstones. (Gaswirth and others, 2010).

Resource Energy has made five acquisitions in Divide County since 2016, marking it as a major producer and operator in the basin (Figure 1). Resource Energy currently owns interest in over 576 wells in the Williston Basin (over 200 which are operated) with 7,500 barrels of oil equivalent per day of production (Resource Energy website, September 2019) (Figure 2). Resource Energy is trying to seek a full-scale development program in the Madison formation if a thorough understanding of reservoir can be obtained and a few challenges associated with the formation are addressed.

It's proven that Madison has been fed with HC from two different tested petroleum systems as being self-sourced or from the Bakken. Both systems have a good source and reservoirs rocks, with suitable seals and traps identified, however, Madison group as a conventional petroleum system has been forgotten with the rise of the Bakken. The Madison Group commercial discoveries are located in the principal and local structural elements of the basin based on the past and very old studies where the traps are related to faults, folds, and particular stratigraphic geometries. The observations of the petroleum systems behavior, shows secondary migration could have been challenging in long distances inside, thus suggests a detail mapping of the structural elements near recognized oil kitchens for the principal source rock intervals, where the risk related to the charge is lower, supported in a short distance fluid flow from the generation areas to reservoir rocks in the traps, for both petroleum systems. The estimates of hydrocarbons yet to find in The Bakken-LP and MC-CH petroleum system should consider the presence of a world class source rock in the basin, and confirmed elements and process in all the Mississippian sedimentary section, to obtain real (and probably very interesting) volumetric calculations. This proposal aims to first troubleshoot underperforming new drilled well in the basin into the Madison Group by Resource Energy through intensive laboratory studies and then attempts to have a new look into potential of economic accumulation of HC in this stratigraphic group to point out possible areas are prolific for future production via EOR methods.

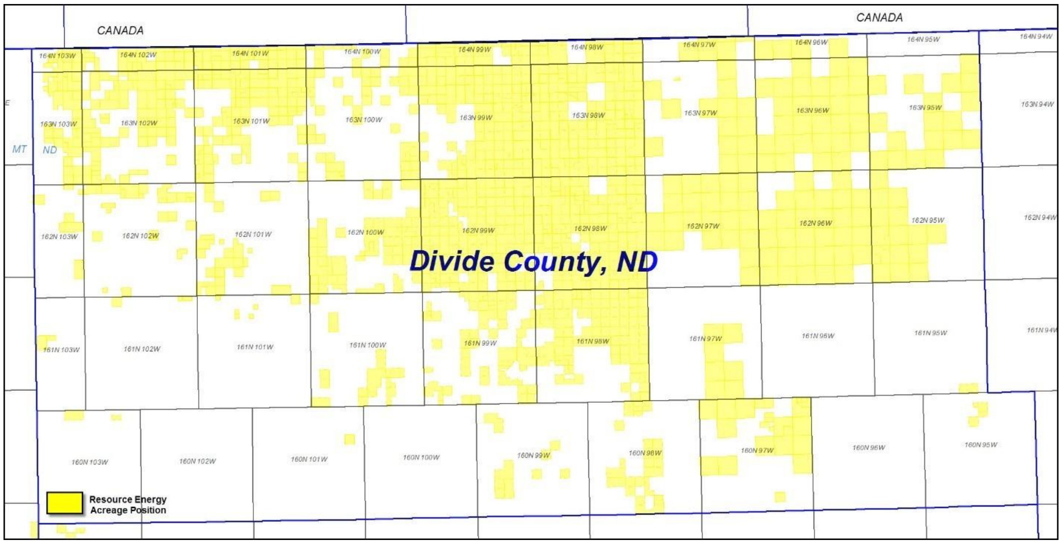


Figure 1. Resource Energy Acreage Position (source: Resource Energy)

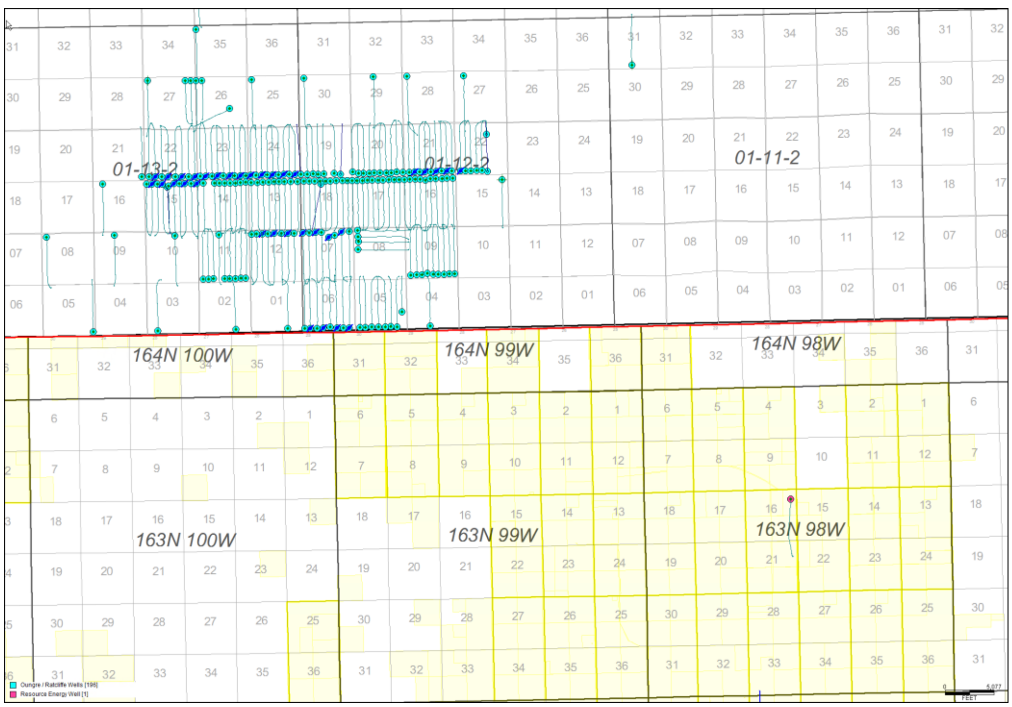


Figure 2. Producing Madison (Oungre/Ratcliffe) Horizontal Wells Operated by Resource Energy (source: Resource Energy)

OBJECTIVES:

This project aims to achieve the following objectives:

1) Update our current knowledge about the geology, petroleum system and production potential of the Madison Group in Williston Basin, ND and create a refined database of all available information collected so far in a Petra project.

2) Improve our geological and petrophysical knowledge through extensive laboratory studies of core plugs and other samples with a good horizontal and lateral distribution from wells with available core plugs. This is mostly focused on the wells that are drilled by our industry partner to mostly troubleshoot the reasons for its underperforming status.
3) Create a general 3-D geologic, facies and then petrophysical model for Madison Group in Williams and Divide Counties in ND that can be updated with laboratory data to delineate more prolific regions.
4) Estimate and improve production in Williams and Divide Counties based on an accurate 3D static model under different EOR scenarios to suggest suitable regions for future drilling or field stimulation operations that'd lead to more production.
5) Promoting more detailed study on other conventional reservoirs in the basin in ND, rather than the Bakken and TF Formations and present their huge potential.
6) Ultimately to improve production of oil in the state and improve financial gains for our industry partner that'll lead to more job creating in the state, expand operations and improve state revenues.

METHODS

The goal of this project is to further characterize the Madison Group as one of the earliest producing units in Williston Basin through core analyses, and existing well log (field data) interpretation for reservoir modeling and simulation. In order to achieve the project goals, four major tasks will be undertaken while core plugs will be retrieved from several wells drilled in different parts of the basin through Madison Group in the Williston Basin with a focus on the one recently drilled by Resource Energy. Figure 3 shows a flow chart of the major components of subsurface study for Madison formation (note: surface injection facility is not included in flowchart). As indicated in the flowchart, the processes of many tasks are "dynamic", which means that the feedback from other step/process, such as modeling & simulation, coreflooding and core characterizations, will be heeded to modify the miscible injection scheme, even when it is underway. The criteria to pick the wells will include: 1) availability of well logs, 2) production history from low to high, 3) depth of the formation. The core plugs will be used to conduct the following tests:

Task I: literature review, well log data and sample collection

All available information about the Madison Group from the literature, or lab data stored at the State of ND Geological Survey, will be collected, compiled and summarized. All available well logs, from the Divide and Williams Counties will be acquired, sorted and digitized if necessary for a Petra project. Core plugs from appropriate wells with a good horizontal and vertical resolution/distribution will be collected for laboratory testing including samples from the newly drilled well by our industry partner "Resource Energy".

Task II: comprehensive laboratory measurements

A) <u>Detailed elemental and mineralogical analysis</u>: Multi-mineral petrophysical models based on well logs are necessity for reservoir studies which will be confirmed with laboratory mineralogical studies. This data will help us to recognize different elements and minerals presented in the formation with sampling rate that would cover a good interval of the unit that influence porosity, permeability, fracability (completion and stimulation design), and productivity. This will particularly reveal various types and amount of clay minerals in the samples. The presence of different clay minerals can affect the sample porosity, flow capability as well as saturation and mechanical properties. Brittleness is one of the most important geomechanical properties that plays an important role in fracturing and is affected tremendously by the presence of different clay minerals which enable us to better chose most appropriate stimulation method or unplugging the fluid pathways.

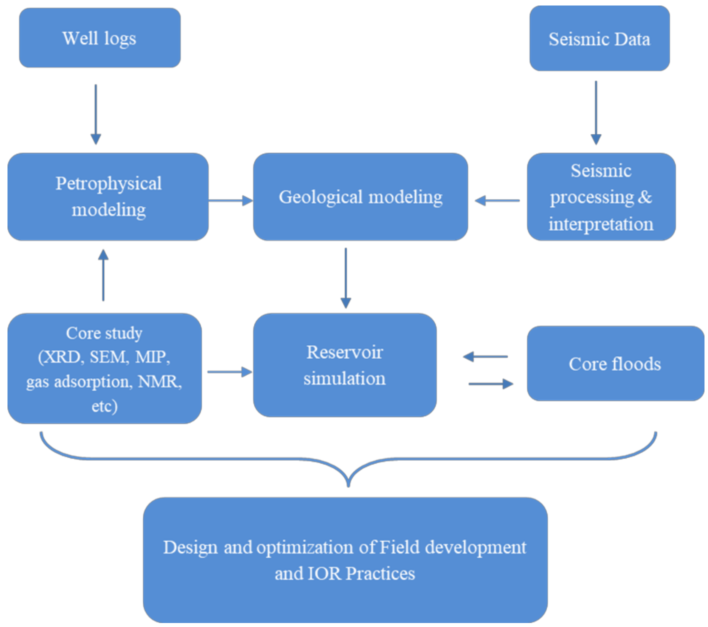
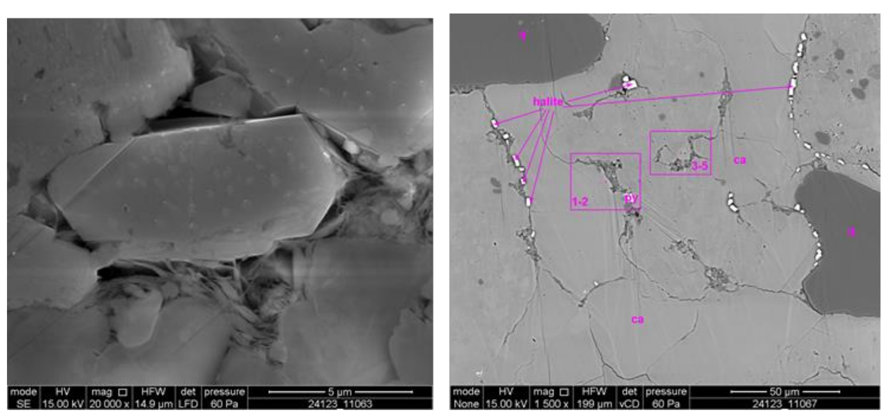
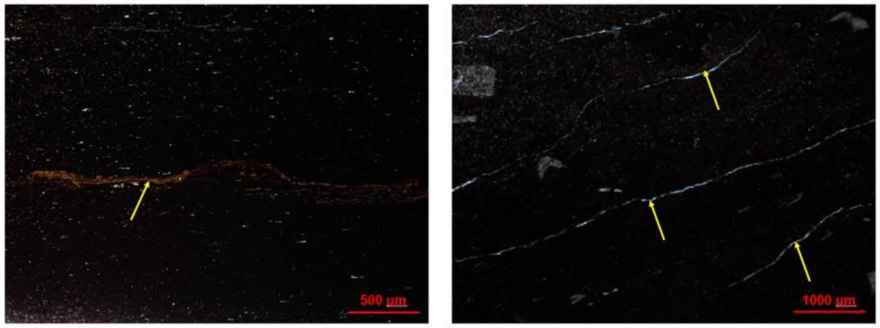


Figure 3. Flow chart of major components that will be undertaken from Task I to Task V in this study.

B) Imaging (electron and optical microscopy): microscopic studies can help us to better understand problems such as: estimating the total residual hydrocarbon generation and expulsion of organic matter in different formations, retention mechanism, relationship between pore space and pore structure, percolation mechanism in recovery processes and mobility. Using electron and optical microscopy will enable detecting if specific pathways are plugged with salt minerals, clays, bitumen etc. We can identify different pores structures and capillaries with varying geometries and better calculate reservoir porosity, flow patterns and pores structure analysis. The following image represents electron micrograph from Middle Bakken illustrating salt plugging (top row) and fractures filled with bitumen in the Middle Bakken (bottom row).





Well 5088, 10268 ft 4 | Well 5088, 10238 ft 2

Figure 4. Electron micrograph of the Middle Bakken showing salt plugging (top row), fractures filled with bitumen in the Middle Bakken (bottom row)- (unpublished data).

C) Geochemical analyses include measurement of the Total Organic Carbon (TOC) and all maturity parameters using Rock Eval 7S, and organic petrology studies to help us identify the source for the Madison Group. We believe through an extensive source rock evaluation, the amount of generated hydrocarbons or the original OIP can be estimated for the Madison. Organic petrology study will particularly help us to explain different organic origins in the depositional setting help us realize if Madison is fed with the Bakken. Through the experience we have gained from the Bakken, we will attempt to better define maturity maps for the basin to reveal sweet spots, migration pathways for further drilling and also to better understand burial history which can relate LP-BK and MC-CH petroleum systems with the Bakken-TF petroleum system. In addition, we will try to improve log-based models for future modeling and estimation of productivity of the wells.

D) Petrophysical properties: measuring petrophysical properties include formation density, porosity, electrical resistivity, hydrocarbon saturation, wettability, permeability, capillary pressure, pore throat and size distribution and relative permeability on both core plugs and smaller pieces of samples using various petrophysical methods using conventional relative permeability measurements, mercury intrusion porosimetry to gas adsorption and image based pore structure analysis. Additionally, we will analyze the samples with high and low frequency NMR and integrate the outcome from previous steps to get the best understanding from different type of porosity and fluid content of the samples and how all these can be correlated with log data. The following image represents similar process in the Winnipegosis Formation done by ourselves (Figure 5).

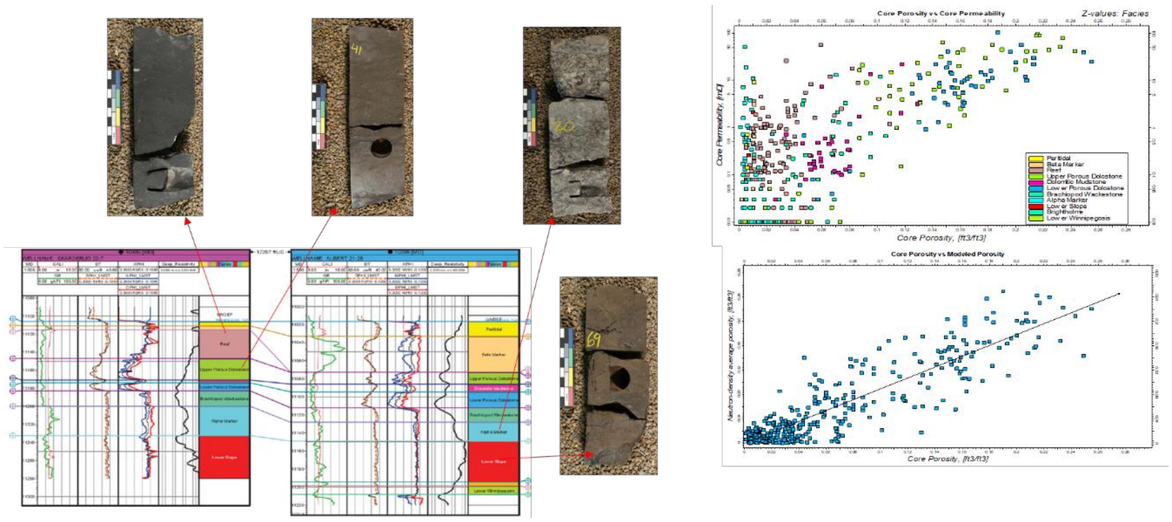


Figure 5. Core and log measurements matching in the Winnipegosis Formation (unpublished data).

E) <u>Geomechanical properties:</u> geomechanical testing is a way to simulate conditions in the subsurface to obtain Young's modulus, uniaxial compressive strength (UCS) and Poisson's ratio, poromechanic elastic parameters to evaluate reservoir and wellbore response to reservoir depletion, injection of fluids for EOR and well bore stability, stimulation and completion design under stress alteration We will develop a rock physics model to transform dynamic rock mechanical properties (from well log and acoustic measurements) to static ones.

Task III: Petrophysical Rock Typing (Based on the new method developed by PI, Ostadhassan)

A) <u>Rock typing:</u> FZI-Star (FZI*) and PSRTI are recently developed by the PI (Figure 6). as new petrophysical dynamic and static rock typing indices to fully define flow units in a carbonate reservoir in specific (Mirzaei-Paiaman et al., 2019). Experimental data (capillary pressure and relative permeability data) will be used to define petrophysical attributes of the reservoir to more accurately delineate productive units in the Madison. Ultimately, we also propose empirical equations that can be used to model capillary pressure and relative permeability characteristics of the rocks within the entire 3D model for the entire Divide and Williams Counties which will also increase the accuracy of the outcome of Task V (reservoir simulation and modeling) which would better resemble true behavior of the reservoir in the subsurface.

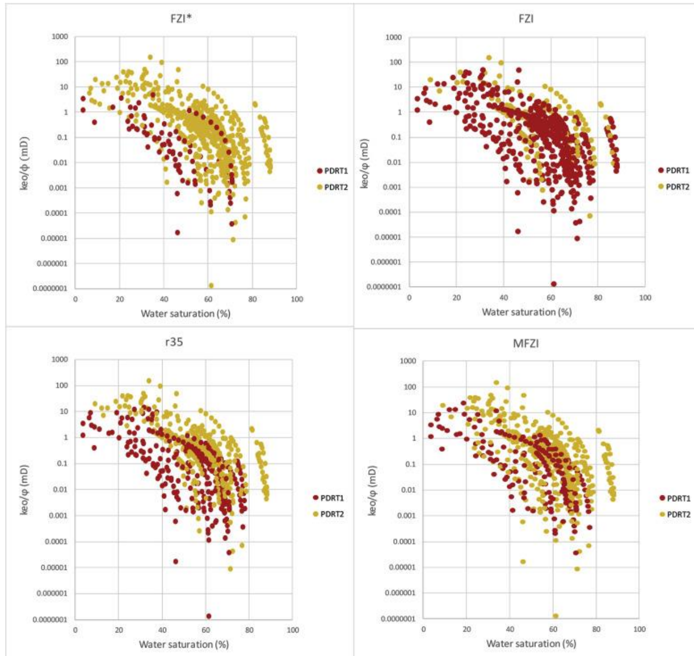


Figure 6. Identification of PDRTs using oil data by FZI* (top left), FZI (top right), MFZI (bottom right), and Winland r35 (bottom left) (Mirzaei-Paiaman et al., 2019).

B) <u>Coreflood experiments</u>: To further evaluate the proposed recovery methods and mechanisms we will conduct an injection of fluids into core plugs using various fluids including water, CO_2 and gas. This will enable the collection of oil recovery vs. time data to establish a time frame for the process that will help when setting up an economic analysis.

Task IV: Static modeling and Seismic Processing/Interpretation

A) <u>Seismic processing and interpretation:</u> 3D seismic data that was recently acquired by "Resource Energy" in Williams and Divide Counties will be processed with Seismic Unix (SU) and RadExPro software and then further interpretations, attribute generations and inversion analysis will be performed on the results using Hampson Russell and Petrel. It's expected that with the results from this part which should be tied to well logs more accurate structural and 3D geologic model to be developed for deeper insight into lateral variations in facies and petrophysical properties within the reservoir section, particularly fluid distributions.

B) <u>3-D static modeling</u> with Petrel provides ways to integrate all sorts of geophysical and geological data to better understand the geology of subsurface, and then the 3-D model is used as input to the flow simulation. In this study, a 3-D model characterizing the geologic framework and subsurface features of the rocks containing the Madison Group Formation and its confining strata will be constructed for the Divide and Williams Counties where the industry partner has operations. The logs include Gamma Ray, neutron-density porosity, resistivity and sonic log. In addition, core data from previous step consisted of porosity, permeability and initial water saturation will be incorporated to update the model and make it more realistic. It is important to note that initially a general Petrel model will be created based on well logs and 3D seismic data and this model will be updated through an iterative process when more petrophysical core data is collected for fine tuning and accuracy which will improve reserve estimation, volumetric calculations, and forecasting. In this step, *Stratigraphic model, Facies model, Petrophysical model* and *Structural model* will be generated under following workflow (Figure 7).

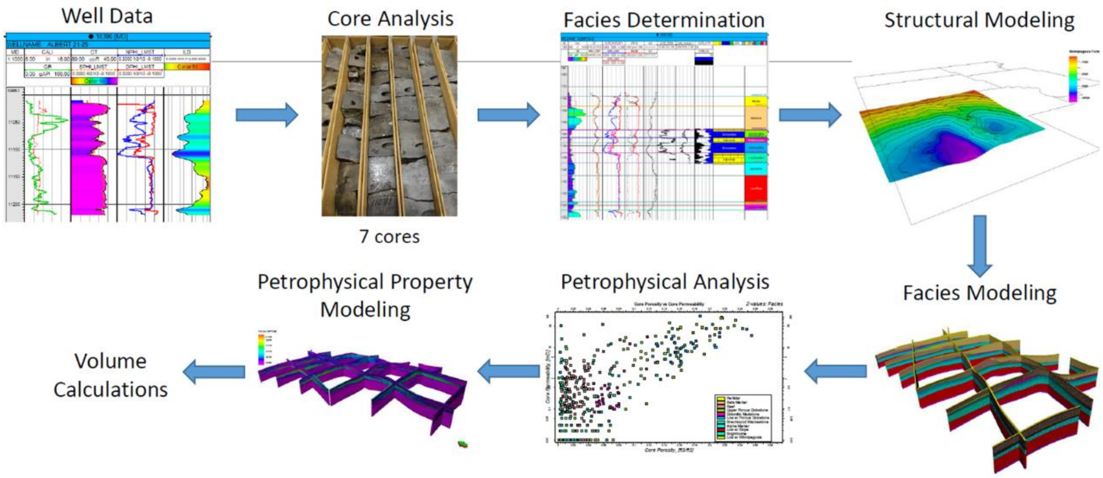


Figure 7. A generic workflow representing petrel modeling for future reservoir simulation.

Task V: Reservoir simulation and modeling

A) <u>Reservoir simulation and modeling</u>: While the Mississippian Madison Group has produced the largest volume of oil in the basin, a significant amount of oil after primary production and waterflooding is still remaining in the conventional reservoirs. Given the low oil recovery in these units, it is imperative to develop new IOR/EOR technologies that would increase the oil recovery from the vast oil resources left behind by primary oil recovery and waterflooding. While the geologic model provides a framework for planned simulation activities, reservoir simulation incorporates a variety of additional reservoir data to accurately simulate the reservoir's pressure and fluid mobilization response to injection or production processes. Much of the geologic and structural reservoir properties will be directly incorporated through the integration of the 3-D geologic model, however, additional PVT data, relative permeability data (obtained through special core analysis), and well production history are also necessary to simulation activities. All data will be input to the CMG Builder software to begin the process of building the dynamic model which comprises *History Matching* and *Fluid-Flow Simulation* to allow validation of geologic model and delineated rock types to match physical reservoir conditions through production and injection history. This is followed by predictive simulations of different injection scenarios to select the optimal case (Figure 8).

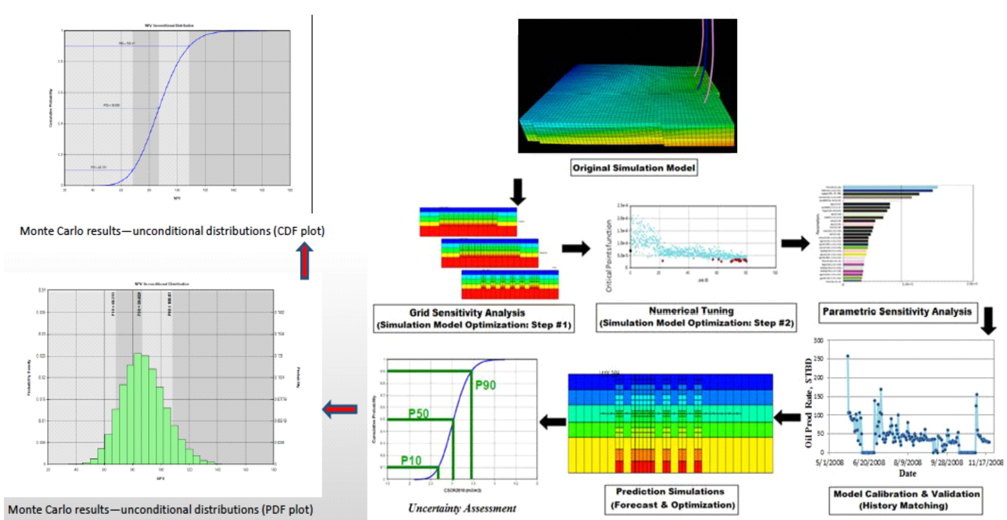


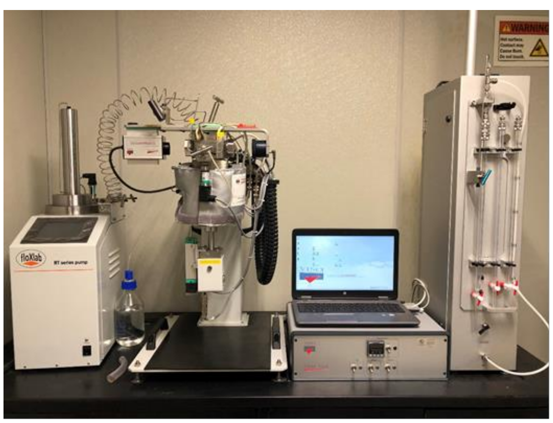
Figure 8. Reservoir simulation workflow (Jabbari, 2013).

B) <u>Completion and stimulation optimization</u>: good completion and stimulation practices are required for economic development of Madison formation wells. In this study, we will study and determine good completion and stimulation practices in horizontal wells in Madison, answer such question as "how many completions/stimulations do we need for best well performance and/or economics?", and will maximize the value from Madison horizontal wells. Our efforts will focus on some of the key elements of well completions and stimulation practices as they apply to horizontal wells. Optimization studies will be used to highlight the importance of lateral length, number of fractures, inter-fracture distance, fracture half-length, and fracture conductivity. These results will be used to discuss the various completion choices such as cased and cemented, open hole with external casing packers, and open hole techniques.

Anticipated Results:

The results generated by this project will lead to a thorough understanding of conventional and neglected reservoirs in the Williston Basin and the application of IOR/EOR technologies along with most suitable stimulation and completion methods to rejuvenate the Madison Group formations. The new insight that is obtained through this process will provide the North Dakota oil industry as a whole with in-state developed technology that not only fits oilfields that are under development by "Resource Energy", but also provides a possible solution to recover the vast remaining hydrocarbons in other oilfields in North Dakota, with focus on conventional plays that is recently emphasized by the state geological survey. Positive results are expected, the application of the proposed integrated study and EOR technology can have a significant economic effect on the ultimate recovery of oil from tight/conventional formations.

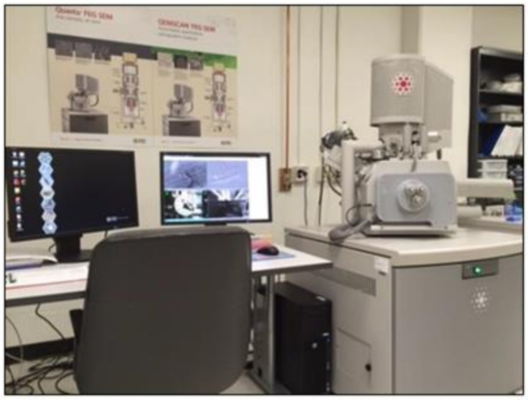
Facilities: the following images represent various labs/instrumentation that is available at UND including reservoir lab, materials characterization lab and geomechanics lab. Furthermore, Source Rock Analyzer (SRA) is also available with optical microscopes for geochemical analysis.



PVT Lab

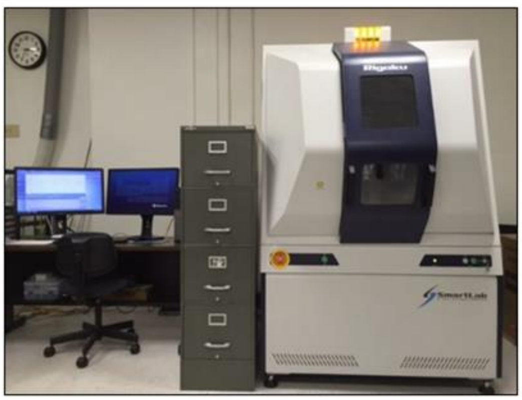
Core Flood Lab

Figure 9. Reservoir studies laboratory.



Quanta SEM for materials science

X-ray Fluorescent (XRF) Analyzers



XRF analyzer in UND

Oxford Geospec2 Core NMR

Figure 10. Materials characterization laboratory.

Triaxial/Resistivity/Acoustic/Permeability testing system

UCS Testing Apparatus

Figure 11. Geomechanics laboratory.

Resources: The research team has access to the state-of-the-art facilities both internally and externally, with adequate expertise, knowledge, and software to fulfill objectives and tasks proposed in this project.

Techniques to Be Used, Their Availability and Capability: The techniques will include a variety of laboratory characterizations and tests, advanced well log and seismic analysis and interpretations, detailed geologic modeling, and dynamic simulation to select and optimize the field development plans. UND's laboratories are equipped with the state-of-the-art laboratory instruments for rock characterization and fluid flow in porous media tests. UND Petroleum Engineering computer lab is equipped with advanced, industry-widely used well log interpretation software, geologic modeling and dynamic simulation software.

Environmental and Economic Impacts while Project is Underway: No significant environmental impacts while the project is underway while the team will make sure all state and government environmental rules and regulations are followed if specific recommendations are made for field implementation.

Ultimate Technological and Economic Impacts: Technological impact: the proposed research and development will focus on the vast hydrocarbon resources untapped in the Madison Group formation. This effort will use an integrated methodologies incorporating laboratory tests, logging, geophysics, modeling and simulation, in addition to strong collaboration and data sharing from the operator, to tackle the challenges in this conventional reservoirs. If the proposed efforts are successful, it will bring a revolutionary technology for Madison Group formation and possibly other conventional reservoir in North Dakota. Economic impacts: although the North Dakota Department of Mineral Resources estimates that over 1 billion barrels of oil (BBO) have been produced from approximately 6,100 Madison wells (NDIC, 2018), the remaining oil is enormous, the proposed project will possibly lead to renewed interest in the Madison Group across North Dakota's portion of the basin, this will bring significant economic benefits to the state.

Why the Project is Needed: Given the significant amount of remaining hydrocarbon in Madison Group and very low oil recovery in Madison Group formations, it is imperative to develop new technologies that will increase the oil recovery from the vast oil resources left behind by primary oil recovery and water flooding. The proposed integrated study of detailed reservoir characterization, modeling and simulation and laboratory evaluation will develop an IOR technique for the target formation. Overall, the results of the project will provide petroleum industry and the state of North Dakota with a potential avenue to significantly improve Madison Group formations.

STANDARDS OF SUCCESS

The standard of success for this research proposal can be measured by how well the team can fulfill the tasks described in the narrative in a timely manner. Consequently, by sharing results with the LRC, coal industry experts, our industry partners and within the team we can make sure to overcome the obstacles and assure 100% achievement of the project objectives. The success in this proposal has a direct relationship to submitting the reports and deliverables on-time to the funding agency. Also, presenting the results in peer reviewed journals and annual conferences would be a key factor to the success of the team and the project. We strongly believe the outcome of this project is in line with the mission and vision of the University of North Dakota to be a flagship university in energy related research in the region. Finally, establishing a robust relationship with our industry partner and the Research Council to support their growth and knowledge based operations is a major standard of success for this project. Attaining this level of success is only possible when the outcome makes to produce more from the Madison, and increasing revenue for the state, by abiding to the state environmental rules and regulations. If at the end of this project, we can suggest new areas or provide a clear image of Madison and its production potential and suggest the most suitable EOR or stimulation methods and respond to the question that why our industry partner newly drilled well underperformed, one can testify that we have been fully successful in our efforts.

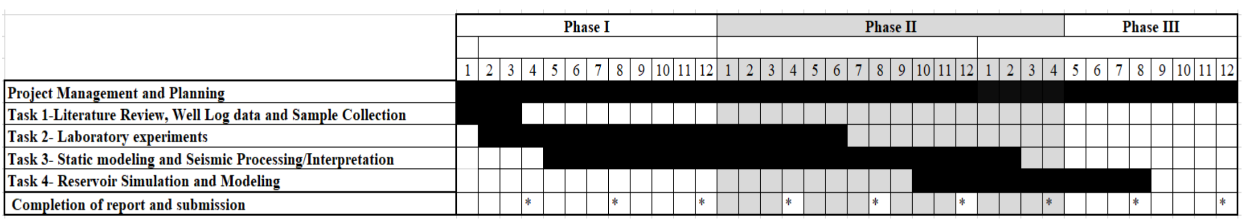
BACKGROUND/QUALIFICATIONS

Through the past few years Dr. Mehdi Ostadhassan has established a robust research team of PhD students, post-doctoral fellows and industry partners working on variety of topics to solve different problems from industry. He has published a number of research articles, presented his work in several international conferences and has been involved in different projects at the Petroleum Engineering department or in collaboration with other UND departments, other academic institutions, federal agencies or with the industry to investigate and characterize the Bakken Formation in particular from various perspectives. All these past and ongoing experiences has provided him adequate knowledge to assure successful completion of this proposal and achieving its objectives. Dr. Hui Pu's experience and expertise in laboratory studies, reservoir simulation and improved oil recovery in both unconventional and conventional reservoirs will be helpful for the success of this project. Recently he is working on unconventional reservoirs to investigate EOR in tight formations, and adsorption, nanopore characterization, pore size distribution and capillarity.

MANAGEMENT

An experienced team of scientists and industry experts have come together to collaborate in the proposed effort. This investigation will be directed by PI, Mehdi Ostadhassan at the University of North Dakota, petroleum engineering department. Ostadhassan will make sure the collaboration among the team members is effective. In addition, the presence of, the co-PI, Dr. Pu, increases the strength of the team to help tackle this project. Five PhD students are crucial for this work and will be supervised by the PI and co-PI while three of them will be working with the PI for the characterization and two with the co-PI for simulation and modeling. We will closely liaise our progress within the team through biweekly meetings and reports to ensure the efforts that are made lead to the successful completion of the project within the dedicated time frame. The expertise of the team will bring adequate time and expertise to this project and will ensure that the objectives and outcomes will be completed with the highest quality.

TIMETABLE



BUDGET

Year	NDIC Share	Applicant's Share (In-Kind)	Industry Partner (Sponsor's Share)	Project Total Expense
Year 1	$ 436,321	$ -	$ 500,000	$ 936,321
Year 2	$ 426,591	$ -	$ 500,000	$ 926,591
Year 3	$ 426,591	$ -	$ 500,000	$ 926,591
Total	$ 1,289,503	$ -	$ 1,500,000	$ 2,789,503

	YEAR 1 NDIC SHARE			YEAR 1 UND SHARE			Industry
EXPENSES, Personnel	**Salary**	**Benefit**	**Tuition**	**Salary**	**Benefit**	**Tuition**	**Sponsor's**
Mehdi Ostadhassan, PI	15,902	3,498					
Hui Pu, co-PI	15,902	3,498					
Five PhD Students	124,752	1,248	93,500				
Total Personnel	$ 258,300						
EXPENSES, Nonpersonnel	**Expense**						
Supply/Materials-Professional	5,000						
Equipment							
Lab Fees	46,600						
UND Lab Facility							
Travel, Meetings, Conferences	2,000						
Office Supplies	2,000						
Total Nonpersonnel	$ 55,600						
Total Direct Expenses	$ 313,900						
F&A (39%)	$ 122,421						
TOTAL EXPENSES	$ 436,321						

	YEAR 2 NDIC SHARE			YEAR 2 UND SHARE			Industry
EXPENSES, Personnel	**Salary**	**Benefit**	**Tuition**	**Salary**	**Benefit**	**Tuition**	**Sponsor's**
Mehdi Ostadhassan, PI	15,902	3,498					
Hui Pu, co-PI	15,902	3,498					
Five PhD Students	124,752	1,248	93,500				
Total Personnel	$ 258,300		$ 93,500			$ -	
EXPENSES, Nonpersonnel	**Expense**						
Supply/Materials-Professional							
Equipment							
Lab Fees	46,600						
UND Lab Facility							
Travel, Meetings, Conferences	2,000						
Office Supplies							
Total Nonpersonnel	$ 48,600						
Total Direct Expenses	$ 306,900						
F&A (39%)	$ 119,691						
TOTAL EXPENSES	$ 426,591						

	YEAR 3 NDIC SHARE			YEAR 3 UND SHARE			Industry
EXPENSES, Personnel	**Salary**	**Benefit**	**Tuition**	**Salary**	**Benefit**	**Tuition**	**Sponsor's**
Mehdi Ostadhassan, PI	15,902	3,498			-		
Hui Pu, co-PI	15,902	3,498					
Five PhD Students	124,752	1,248	93,500				
Total Personnel	$ 258,300					$ -	
EXPENSES, Nonpersonnel	**Expense**						
Supply/Materials-Professional							
Equipment							
Lab Fees	46,600						
UND Lab Facility							
Travel, Meetings, Conferences	2,000						
Office Supplies							
Total Nonpersonnel	$ 48,600						
Total Direct Expenses	$ 306,900						
F&A (39%)	$ 119,691						
TOTAL EXPENSES	$ 426,591						
TOTAL	$ 1,289,503						

Personnel: Dr. Ostadhassan and Dr. Pu are asking for 1.6 and 1.7 months, respectively, of summer salary including fringe benefits for three years. This amount is $19,400 per year, per person which constitutes %22 of benefits.

Other personnel: Five PhD students will be working full-time on this project for the period of three years as Graduate Research Assistants (GRA). Based on the university rates, they will be paid $2,100 monthly including 1% of benefits for the whole year thus the amount will be $75,600 per person for the project life (three years). Additionally, based on UND tuition rates for graduate students, we expect to pay $56,000 per student for their education and credits towards the PhD degree for 60 required credits.

Laboratory Fees, Materials and Supplies: We require $155,000 in order to purchase different parts, to purchase transducers, wave recording system, sealing material, strain gauges, LVDTs, pumps, computers, calibrating parts, rubber sleeve, coring bit, polishing papers, copper sheets and pressure vessels and pay for laboratory experiments including the use of FIB-SEM, XRD, XRF, SRA, optical microscope, CT scan, MIP, gas adsorption and other necessary testing that will be outsourced.

Travel: We have allocated the budget for travel based on the state rates for the three years of the project duration. The allocated money will cover lodging, air fare and ground transportation to attend conferences, workshops and also visit the field for sample collection.

Office supplies: The amount for office supply is decided based on the past experience from previous projects.

CONFIDENTIAL INFORMATION

None for the university but other data that is proprietary for the industry partner can be subject to confidentiality and ownership.

PATENTS/RIGHTS TO TECHNICAL DATA

None for the university but other data that is proprietary for the industry partner can be subject to confidentiality and ownership.

STATUS OF ONGOING PROJECTS (IF ANY)

PI: None

Co-PI: Hui Pu is working on NDIC OGRP project G-041-081 “Functional Nanoparticle-Augmented Surfactant Fluid for Enhanced Oil Recovery in Williston Basin” and this will be completed on April 30, 2020.

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Resource Energy

September 12, 2019

Ms. Karlene Fine
North Dakota Industrial Commission
ATTN: Oil and Gas Research Program
State Capitol – Fourteenth Floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840

RE: Support for proposal "Economic Viability of Horizontal Open Hole Completions, Madison Group, Divide County, North Dakota" submitted by University of North Dakota

Dear Ms. Fine:

Resource Energy is pleased to enumerate its intent to provide funding equivalents of approximately $1.5 million to support the proposed effort by Dr. Mehdi Ostadhassan, Associate Professor of Petroleum Engineering Department at the University of North Dakota and his team for the submitted proposal, "Economic Viability of Horizontal Open Hole Completions, Madison Group, Divide County, North Dakota" for three years. Resource Energy will provide in-kind support for this project through several expenditures and activities. These activities include but are not limited to the following: drilling of new wells, data organization and compiling of the two wells recently drilled and completed in 2018 by Resource Energy, mapping, reservoir characterizations, geo-modeling, and economic unit & whole project modeling. Many of these data will also incorporate proprietary information and results from the recent large-scale development just north into Canada where over 200 Madison horizontal wells have been drilled and completed in the past two years (2017-2018).

We will also be providing access to newly acquired 3-D seismic data (265 square miles, original cost $18 million) to our research partners. The primary goal will be to fully evaluate the significant economic recoverable reserve potential of this untapped resource in the US and more specifically in Divide County, ND. We are confident the proposed effort will greatly expand the critical knowledge base regarding the shallower Madison potential in Divide County and over a broader eight county area throughout the existing Bakken development area.

Resource Energy, over a short three-year term, has amassed 125,000 net acres, owns 576 wells, and operates 204 wells. It has the necessary infrastructure to quickly, safely, and efficiently implement a full-scale development program in the Madison Group if a few of the success components can be better understood. It is Resource Energy's goal to put necessary organizational resources, time, and money into the success of the partnership with the various constituents to evaluate the economic potential and ultimately execute on a full-scale development program.

We look forward to the opportunity to work with the NDIC and UND Petroleum Engineering Department in efforts to further add value to the state and its various constituents.

Sincerely,

Paul Favret

Paul D. Favret
Chief Executive Officer

Mehdi Ostadhassan, PhD
Associate Professor
Graduate Program Director
Department of Petroleum Engineering
Department of Biomedical Engineering
College of Engineering and Mines

Adjunct Associate Professor
Department of Biomedical Sciences
School of Medicine and Health Sciences
University of North Dakota

mehdi.ostadhassan@und.edu
www.undreservoirdogs.com
ORCID ID: **https://orcid.org/0000-0001-9235-4399**
h-index: **16**

Tel: 701-777-3754
2844 Campus Road, Room 113J, Stop 8154
Grand Forks, ND 58202, USA

1. Educational Background:

Institute	***Major***	***Degree***	***Year***
Petroleum University of Technology, Iran	Petroleum Engineering	B.S.	2005
Petroleum University of Technology, Iran	Petroleum Engineering	M.S.	2007
IFP-School (ENSPM), France	Petroleum Geophysics	M.S.	2008
University of North Dakota, US	Petroleum Engineering	Ph.D.	2013

2. Professional Experience:

Institute	***Position***	***Duration***
University of North Dakota, Grand Forks, USA	Associate Prof.,	2013-Present
Energy & Environment Research Center, Grand Forks, USA	Research Scientist	2012-2013
University of North Dakota	Graduate Research Assistant	2009-2013
Schlumberger DCS, Denver, CO	Geophysics intern	Summer 2011
Atlantic Int. Operation Ltd, Dubai, UAE	Upstream division, Project Manager	2008-2009
CGGVeritas, Massy, France	Geophysics Intern	Winter 2008
Khak Azma Geomechanics Lab, Tehran, Iran	Entry level engineer	2005-2006
National Iranian South Oil Company, Ahwaz, Iran	Petroleum Engineering Intern	Summer 2003
National Iranian Oil Company Exploration Directorate, Tehran, Iran	Geophysics Intern	Summer 2004

3. Media appearance

Silver, A. "Five innovative ways to use 3D printing in the laboratory." Nature 565, no. 7737 (2019): 123.

4. Publications *(* shows graduate students and post-docs)*:

I. Book (refereed):

Ostadhassan M, Liu K*, Li C*, Khatibi S*. Fine Scale Characterization of Shale Reservoirs: Methods and Challenges. Springer; 2018.

II. Book Chapter (refereed):

Ostadhassan M. Geomechanics and Elastic Anisotropy of Shale Formations. New Frontiers in Oil and Gas Exploration: Springer, Cham; 2016. p. 165-207.

III. Journal Publications (refereed):

1. Zhao P, Wang L, Cai J, Kong L*, **Ostadhassan M.** An improved method for the fractal dimension of pore space using NMR and its application in evaluating tight oil reservoirs. Fuel (Accepted).
2. Liu K*, **Ostadhassan M**, Hackley P, Gentzis T, Zou J, Yuan Y, Carvajal-Ortiz H, Rezaee R, Bubach B. Experimental study on the impact of thermal maturity on shale microstructures using hydrous pyrolysis. Energy & Fuels (Accepted).
3. Kong L*, **Ostadhassan M**, Liu B, Eshraghi M, Li C, Navarro M, Zhang Y, Wei H. A Comparison of 3D Printed Porous Rocks with Nano X-ray Computed Tomography: Silica Sand, Gypsum Powder and Resin. AAPG Bulletin. (Accepted)

4. Abarghani A*, Gentzis T, Shokouhimehr M, **Ostadhassan M.** Molecular heterogeneity of organic matter in geomaterials based on AFM nanoIR spectroscopy. International Journal of Coal Geology (Under Review)
5. Liu K*, **Ostadhassan M**, An intensive comparison in fractal dimensions from gas adsorption data in shale. Fuel (Under Review)
6. Lee H*, Shakib FA, Shokouhimehr, M, Bubach B, Kong L*. **Ostadhassan M,** Optimal Separation of CO2/CH4/Brine with Amorphous Kerogen: A Thermodynamics and Kinetics Study. Journal of Physical Chemistry C 2019 Aug 2.
7. Li C, Kong L*, **Ostadhassan M,** Gentzis T. Nanoscale Pore Structure Characterization of Tight Oil Formation: A Case Study of the Bakken Formation. Energy & Fuels. 2019 Jul 1.
8. Zhang K, Lee TH, Bubach, **Ostadhassan M**, Jang HW, Choi JW, and Shokouhimehr M. Layered metal-organic framework based on tetracyanonickelate as cathode material for in situ Li-ion storage. RSC Advances. 2019;9(37):21363-70.
9. Zhang K, Lee TH, Bubach B, **Ostadhassan M**, Jang HW, Choi JW, Shokouhimehr M, New concept for aluminum-ion batteries: graphite carbon-encapsulated metal nanoparticles derived from in-situ grown Prussian blue analogs on natural loofa as cathode materials. Scientific Reports (Accepted)
10. Abarghani A*, **Ostadhassan M,** Hackley P, Pomerantz A, Nejati S. A Chemo-mechanical Snapshot of In-situ Conversion of Kerogen to Petroleum. *Geochimica et Cosmochimica Acta* (Accepted)
11. Liu G, Zeng L, Li H, **Ostadhassan M,** Dong J, Xu X. Natural fractures: the key controlling factor for reservoir quality of metamorphic rock buried hills in the Liaohe Basin, China. Marine and Petroleum Geology (Under Review)
12. Abarghani A*, **Ostadhassan M,** Gentzis T, Khatibi S*, Bubach B. The Effect of Thermal Maturity on Redox-Sensitive Trace Metals Concentration in the Bakken Source Rock, North Dakota, USA. Chemical Geology (Under Review)
13. Lee H*, **Ostadhassan M,** Liu K*, Bubach B. Developing an Amorphous Organic Material Molecular Model Based on Gas Adsorption Isotherms. Computational Geosciences (Under Review)
14. Ozatta O*, **Ostadhassan M**, Liu K*. A Review: Impact of CO2 on Geomechanical Properties of Shale Reservoir. Journal of Petroleum Science and Engineering (Under Review)
15. Mirzaei-Paiaman A, Saboorian-Jooybari H, Chen Z, **Ostadhassan M**. New technique of True Effective Mobility (TEM-Function) in dynamic rock typing: Reduction of uncertainties in relative permeability data for reservoir simulation. Journal of Petroleum Science and Engineering. 2019 Apr 23.
16. Abarghani A*, **Ostadhassan M**, Bubach B, Zhao P. Estimation of thermal maturity in the Bakken source rock from a combination of well logs, North Dakota, USA. Marine and Petroleum Geology. 2019 Apr 9.
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23. Liu K*, **Ostadhassan M,** Sun L, Zou J, Yuan Y, Gentzis T, Zhang Y, Carvajal-Ortiz H, Rezaee R. A comprehensive pore structure study of the Bakken Shale with SANS, N2 adsorption and mercury intrusion. Fuel. 2019.01.174
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25. Abarghani A*, **Ostadhassan M**, Bubach B, Zhao P. Estimation of Thermal Maturity in the Bakken Source Rock from a Combination of Well Logs, North Dakota, USA. Marine and Petroleum Geology (Accepted)
26. Kong L*, **Ostadhassan M,** Zamiran S, Liu B, Marino G, Li C*. Geomechanical Upscaling Methods: Comparison and Verification via 3D Printing. Energies. 2019 Jan;12(3):382.

27. Kong L*, **Ostadhassan M,** Tamimi N, Samani S, Li C. Refracturing: well selection, treatment design, and lessons learned—a review. Arabian Journal of Geosciences. 2019 Feb 1;12(4):117.
28. Liu K*, **Ostadhassan M**, Xu X, Bubach B. Abnormal behavior during nanoindentation holding stage: Characterization and explanation. Journal of Petroleum Science and Engineering. 2018 Oct 23.
29. Li C*, **Ostadhassan M,** Kong L*, Bubach B. Multi-scale assessment of mechanical properties of organic-rich shales: A coupled nanoindentation, deconvolution analysis and homogenization method. Journal of Petroleum Science and Engineering. 2018 Nov 2.
30. Li C*, **Ostadhassan M,** Abarghani A*, Fogden A, Kong L*. Multi-scale evaluation of mechanical properties of the Bakken shale. Journal of Materials Science. 2019 Feb 1;54(3):2133-51.
31. Kong L*, **Ostadhassan M**, Li C*, Liu K*, Multifractal characteristics of MIP-based pore size distribution of 3D printed gypsum-powder rocks. Transport in Porous Media. 2018:1-20.
32. Khatibi S*, **Ostadhassan M**, Xie ZH, Gentzis T, Bubach B, Gan Z, Carvajal-Ortiz H. NMR relaxometry a new approach to detect geochemical properties of organic matter in tight shales. Fuel. 2019 Jan 1;235:167-77.
33. Li C*, **Ostadhassan M**, Guo S, Gentzis T, Kong L*. Application of PeakForce tapping mode of atomic force microscope to characterize nanomechanical properties of organic matter of the Bakken Shale. Fuel. 2018 Dec 1;233:894-910.
34. Khatibi S*, **Ostadhassan M,** Aghajanpour A, Kovaleva Y*, Mohammed RA*. Various effect of faults on mechanical earth models: A case study of integrated study. InGeomechanics and Geodynamics of Rock Masses 2018 May 24 (pp. 617-621). CRC Press.
35. Khatibi S*, Aghajanpour A, **Ostadhassan M,** Kovaleva Y*. Drilling deviated wells in a highly unstable gas field in southern part of Iran. InGeomechanics and Geodynamics of Rock Masses-Volume 2 2018 May 20 (pp. 1387-1393). CRC Press.
36. Li C*, **Ostadhassan M**, Gentzis T, Kong L*, Carvajal-Ortiz H, Bubach B. Nanomechanical characterization of organic matter in the Bakken formation by microscopy-based method. Marine and Petroleum Geology. 2018 Sep 1;96:128-38.
37. Kong L*, **Ostadhassan M,** Li C*. Porosity measurement of 3-D printed gypsum rock by means of X-ray computed tomography. InGeomechanics and Geodynamics of Rock Masses-Volume 2 2018 May 20 (pp. 1401-1406). CRC Press.
38. Liu K*, **Ostadhassan M**, Zou J, Gentzis T, Rezaee R, Bubach B, Carvajal-Ortiz H. Nanopore structures of isolated kerogen and bulk shale in Bakken Formation. Fuel. 2018 Aug 15;226:441-53.
39. Liu K*, **Ostadhassan M**, Bubach B. Application of nanoindentation to characterize creep behavior of oil shales. Journal of Petroleum Science and Engineering. 2018 Aug 1;167:729-36.
40. Zamiran S, Rafieepour S, **Ostadhassan M**. A geomechanical study of Bakken Formation considering the anisotropic behavior of shale layers. Journal of Petroleum Science and Engineering. 2018;165:567-74.
41. Liu K*Q, **Ostadhassan M**, Zou J, Gentzis T, Rezaee R, Bubach B, Carvajal-Ortiz H. Multifractal analysis of gas adsorption isotherms for pore structure characterization of the Bakken Shale. Fuel. 2018;219:296-311.
42. Liu K*, **Ostadhassan M**, Kong L*. Multifractal characteristics of Longmaxi Shale pore structures by N 2 adsorption: A model comparison. Journal of Petroleum Science and Engineering. 2018;168:330-41.
43. Liu K*, **Ostadhassan M**, Bubach B, Ling K, Tokhmechi B, Robert D. Statistical grid nanoindentation analysis to estimate macro-mechanical properties of the Bakken Shale. Journal of Natural Gas Science and Engineering. 2018;53:181-90.
44. Liu K*, **Ostadhassan M**, Bubach B, Dietrich R, Rasouli V. Nano-dynamic mechanical analysis (nano-DMA) of creep behavior of shales: Bakken case study. Journal of Materials Science. 2018;53(6):4417-32.
45. Liu K*, **Ostadhassan M**, Kong L*. Fractal and Multifractal Characteristics of Pore Throats in the Bakken Shale. Transport in Porous Media. 2018:1-20.
46. Kong L*, **Ostadhassan M**, Li C*, Tamimi N. Can 3-D Printed Gypsum Samples Replicate Natural Rocks? An Experimental Study. Rock Mechanics and Rock Engineering. 2018:1-14.
47. Kong L*, **Ostadhassan M**, Li C*, Tamimi N. Pore characterization of 3D-printed gypsum rocks: a comprehensive approach. Journal of Materials Science. 2018;53(7):5063-78.
48. Khatibi S*, **Ostadhassan M**, Tuschel D, Gentzis T, Carvajal-Ortiz H. Evaluating Molecular Evolution of Kerogen by Raman Spectroscopy: Correlation with Optical Microscopy and Rock-Eval Pyrolysis. Energies. 2018;11(6):1-19.
49. Khatibi S*, **Ostadhassan M**, Tuschel D, Gentzis T, Bubach B, Carvajal-Ortiz H. Raman spectroscopy to study thermal

maturity and elastic modulus of kerogen. International Journal of Coal Geology. 2018;185:103-18.

50. Khatibi S*, **Ostadhassan M**, Aghajanpour A. Raman spectroscopy: an analytical tool for evaluating organic matter. J Oil Gas Petrochem Sci. 2018;1(1):28-33.
51. Abarghani A*, **Ostadhassan M**, Gentzis T, Carvajal-Ortiz H, Bubach B. Organofacies study of the Bakken source rock in North Dakota, USA, based on organic petrology and geochemistry. International Journal of Coal Geology. 2018;188:79-93.
52. Liu K*, **Ostadhassan M**, Zhou J, Gentzis T, Rezaee R. Nanoscale pore structure characterization of the Bakken shale in the USA. Fuel. 2017;209:567-78.
53. Liu K*, **Ostadhassan M**, Gentzis T, Carvajal-Ortiz H, Bubach B. Characterization of geochemical properties and microstructures of the Bakken Shale in North Dakota. International Journal of Coal Geology. 2017.
54. Liu K*, **Ostadhassan M**. Microstructural and geomechanical analysis of Bakken shale at nanoscale. Journal of Petroleum science and Engineering. 2017; 153:133-44.
55. Kovaleva Y*, ***Ostadhassan M**, Tamimi N, Kovalev A. A preliminary optimization of borehole microseismic array design with a multiple criteria decision analysis. Journal of Applied Geophysics. 2018 Jul 11.
56. Liu K*, **Ostadhassan M**. Multi-scale fractal analysis of pores in shale rocks. Journal of Applied Geophysics. 2017; 140:1-10.
57. Liu K*, **Ostadhassan M**. Quantification of the microstructures of Bakken shale reservoirs using multi-fractal and lacunarity analysis. Journal of Natural Gas Science and Engineering. 2017; 39:62-71.
58. Liu K*, **Ostadhassan M**, Bubach B. Applications of nano-indentation methods to estimate nanoscale mechanical properties of shale reservoir rocks. Journal of Natural Gas Science and Engineering. 2016;35:1310-9.
59. **Ostadhassan M**, Zamiran S, Jabbari H, Osouli A, Bubach B, Oster B. Study analyzes high-density well pads. The American Oil & Gas Reporter. Vol. 59, No. 8, pp. 50-53, August, 2016.
60. Mirzaei-Paiaman A, Sabbagh F, **Ostadhassan M**, Shafiei A, Rezaee R, Saboorian-Jooybari H, Chen Z. A further verification of FZI* and PSRTI: Newly developed petrophysical rock typing indices. Journal of Petroleum Science and Engineering. 2019 Apr 1;175:693-705.
61. Xu Z, Zhao P, Wang Z, **Ostadhassan M**, Pan Z. Characterization and Consecutive Prediction of Pore Structures in Tight Oil Reservoirs. Energies. 2018 Oct 11;11(10):2705.
62. Semnani A, Wang L, **Ostadhassan M**, Nabi-Bidhendi M, Araabi BN. Time-frequency decomposition of seismic signals via quantum swarm evolutionary matching pursuit. Geophysical Prospecting.
63. Zhao P, **Ostadhassan M,** Shen B, Wenhui L, Abarghani A*, Liu K*, Luo M, Cai J. Estimating thermal maturity of organic-rich shale from well logs: Case studies of two shale plays. Fuel. 2019 Jan 1;235: 1195-1206.
64. Zhao P, Cai J, Huang Z, **Ostadhassan M**, RAN F. Estimating permeability of shale gas reservoirs from porosity and rock compositions. Geophysics. 2018 Jun 7;83(5):1-36.
65. Mirzaei-Paiaman A, **Ostadhassan M**, Rezaee R, Saboorian-Jooybari H, Chen Z. A new approach in petrophysical rock typing. Journal of Petroleum Science and Engineering. 2018;166:445-64.
66. Khatibi S*, Aghajanpour A, **Ostadhassan M**, Farzay O. Evaluating Single-Parameter parabolic failure criterion in wellbore stability analysis. Journal of Natural Gas Science and Engineering. 2018;50:166-80.
67. Jabbari H, Afsari K, Rabiei M, Monk A, **Ostadhassan M**. Thermally-induced wettability alteration from hot-water imbibition in naturally fractured reservoirs—Part 2: 2D models, sensitivity study & heavy oil. Fuel. 2017;208:692-700.

IV. *Selected* Conference Papers (refereed)

1. Kong L*, **Ostadhassan M**, Fereshtenejad S, Song JJ, Li C*. Anisotropy Analysis of 3D Printed Gypsum Rocks Integrating Pulse-Transmission, Nanoindentation and Micro-CT Techniques. In52nd US Rock Mechanics/Geomechanics Symposium 2018 Aug 21. American Rock Mechanics Association.
2. Khatibi S*, **Ostadhassan M**, Aghajanpour A. Geomechanical and Geochemical Characterization of Organic Matter by Raman Spectroscopy. 52^{nd} US Rock Mechanics/Geomechanics Symposium 2018 Aug 21. American Rock Mechanics Association.
3. Liu K*, Ostadhassan M, Wang H. Creep Behavior of Shale-Nanoindentation Experiments. In52nd US Rock Mechanics/Geomechanics Symposium 2018 Aug 21. American Rock Mechanics Association.
4. Li C*, **Ostadhassan M**, Kong L*. Effect of Organic Matter on Nano-Mechanical Properties of Organic-Rich Shale. In52nd US Rock Mechanics/Geomechanics Symposium 2018 Aug 21. American Rock Mechanics Association.

5. Liu K*, **Ostadhassan M**, Li C*, Alexeyev A*., Fracture Toughness Measurement of Shales Using Nano-Indentation: The Bakken Case Study. 51st US Rock Mechanics/Geomechanics Symposium; 2017: American Rock Mechanics Association.
6. Liu K*, **Ostadhassan M**, Kong L*, Pore structure heterogeneity in Middle Bakken formation. 51st US Rock Mechanics/Geomechanics Symposium; 2017: American Rock Mechanics Association.
7. Li C*, **Ostadhassan M**, Kong L*, editors. Nanochemo-mechanical characterization of organic shale through AFM and EDS. 2017 SEG International Exposition and Annual Meeting; 2017: Society of Exploration Geophysicists.
8. Kovaleva Y*, ***Ostadhassan M**, Tamimi N., Optimizing microseismic design using multiple criteria decision analysis. 2017 SEG International Exposition and Annual Meeting; 2017: Society of Exploration Geophysicists.
9. Alexeyev A*, **Ostadhassan M**, Mohammed RA, Bubach B, Khatibi S*, Li C*., Well log based geomechanical and petrophysical analysis of the bakken formation. 51st US Rock Mechanics/Geomechanics Symposium; 2017: American Rock Mechanics Association.
10. Liu K*, **Ostadhassan M**, Bubach B, Jabbari H., Bakken Formation Shales Nano-Scale Analysis Understand Mechanical Parameters. 50th US Rock Mechanics/Geomechanics Symposium; 2016: American Rock Mechanics Association.
11. **Ostadhassan M**, Jabbari H, Zamiran S, Osouli A, Bubach B, Oster B., Probabilistic Time-Dependent Thermo-chemo-poroelastic Borehole Stability Analysis in Shale Formations. 49th US Rock Mechanics/Geomechanics Symposium; 2015: American Rock Mechanics Association.
12. **Ostadhassan M**, Tamimi N., Mechanical Behavior of Salt Rock at Elevated Temperature. 48th US Rock Mechanics/Geomechanics Symposium; 2014: American Rock Mechanics Association.
13. **Ostadhassan M**, Benson S, Zamiran S, Bubach B., Stress analysis and wellbore stability in unconventional reservoirs. 47th US Rock Mechanics/Geomechanics Symposium; 2013: American Rock Mechanics Association.

i. *Selected* Conference Papers (non- refereed)

1. Khatibi S*, Aghajanpour A, **Ostadhassan M**, Ghanbari E, Amirian E., Evaluating the Impact of Mechanical Properties of Kerogen on Hydraulic Fracturing of Organic Rich Formations. SPE Canada Unconventional Resources Conference; 2018: Society of Petroleum Engineers.
2. Liu K*, **Ostadhassan M**, Li C*., Quantifying the nano-mechanical signature of shale oil formations by nanoindentation2017: Unconventional Resources Technology Conference (URTEC).
3. Liu K*, **Ostadhassan M**, Gentzis T, Carvajal-Ortiz H, Bubach B., Microstructures and Geochemical Characteristics of Bakken Shale Formations2017: Unconventional Resources Technology Conference (URTEC).
4. Liu K*, **Ostadhassan M**, editors. Quantification of the Microstructure Heterogeneities of Bakken Shale Reservoirs from Multi-Fractal Analysis. SPE Oklahoma City Oil and Gas Symposium; 2017: Society of Petroleum Engineers.
5. Anderson J, Rice J, Said A, Mehrer C, **Ostadhassan M**, Alexeyev A*., Comprehensive Study of the Charlson Oil Field, Williston Basin, ND. SPE Annual Caspian Technical Conference and Exhibition; 2017: Society of Petroleum Engineers.
6. Alexeyev A*, **Ostadhassan M**, Bubach B, Boualam A, Djezzar S., Integrated Reservoir Characterization of the Middle Bakken in the Blue Buttes Field, Williston Basin, North Dakota. SPE Western Regional Meeting; 2017: Society of Petroleum Engineers.
7. Kong L*, **Ostadhassan M**, Sarout J, Ling K, Li C*, Wang H. Impact of Thermal Maturation on Wave Velocity in the Bakken Shale. InSPE Western Regional Meeting 2018 Apr 20. Society of Petroleum Engineers.
8. Liu K*, **Ostadhassan M**, Jabbari H, Bubach B., Potential Application of Atomic Force Microscopy in Characterization of Nano-pore Structures of Bakken Formation. SPE Low Perm Symposium; 2016: Society of Petroleum Engineers.
9. Liu K*, **Ostadhassan M**, Bubach B., Pore Structure Analysis by Using Atomic Force Microscopy2016: Unconventional Resources Technology Conference (URTEC).
10. **Ostadhassan M**, Zamiran S, Jabbari H, Osouli A, Bubach B, Oster B., Stability analysis of multilateral high density pad wells in the three forks formation. SPE Western Regional Meeting; 2015: Society of Petroleum Engineers.
11. Le T, **Ostadhassan M**., A Multidisciplinary Study of Stimulation Designs in the Three Forks Formation, ND. Unconventional Resources Technology Conference; 2015: Unconventional Resources Technology Conference.
12. **Ostadhassan M**, Jabbari H, Zamiran S, Osouli A, Oster B, Lentz N., Wellbore Instability of Inclined Wells in Highly Layered Rocks—Bakken Case Study. SPE Eastern Regional Meeting; 2014: Society of Petroleum Engineers.
13. Zamiran S, Salam S, Osouli A, **Ostadhassan M**., Underground Disposal of Fine Coal Waste. 49th US Rock Mechanics/Geomechanics Symposium; 2015: American Rock Mechanics Association.

14. Jabbari H, **Ostadhassan M**, Salehi S., Geomecanical Modeling in CO 2 Enhanced Oil Recovery. 49th US Rock Mechanics/Geomechanics Symposium; 2015: American Rock Mechanics Association.
15. Zamiran S, Osouli A, **Ostadhassan M**., Geomechanical modeling of inclined wellbore in anisotropic shale layers of Bakken formation. 48th US Rock Mechanics/Geomechanics Symposium; 2014: American Rock Mechanics Association.
16. Jabbari H, **Ostadhassan M**, Rabeie M., Geomechanics Modeling in CO2-EOR: Case Study. SPE/CSUR Unconventional Resources Conference; 2015: Society of Petroleum Engineers.
17. Jabbari H, **Ostadhassan M**, Khavanin M, Lentz N, Johnson S., Uncertainty Assessment of Stimulation Design—Bakken Case Study. SPE Eastern Regional Meeting; 2014: Society of Petroleum Engineers.

V. *Selected* Presentations and Abstracts (non-refereed)

1. Liu K*, **Ostadhassan M**. Characterize the pore microstructures of shale formation by using AFM. InInternational Geophysical Conference, Qingdao, China, 17-20 April 2017 2017 May 31 (pp. 1064-1066). Society of Exploration Geophysicists and Chinese Petroleum Society.
2. Liu K***, Ostadhassan M**, Xu X, Multiscale characterization of pore structures of shale: quantification from SEM image analysis. 2016 Workshop: Rock Physics and Borehole Geophysics, Beijing, China, 28-30 August 2016; 2016: Society of Exploration Geophysicists.
3. Kong, L., **Ostadhassan, M.,** Li C*, Petrophysical Characterization of 3-D Printed Rock and its Substitution in the Validation Experiment, in: June 2018: AAPG Annual Convention and Exhibition.
4. Kong L*, **Ostadhassan M,** Tamimi N, Li C*, Alexeyev A*. Laboratory measurements of P-and S-wave anisotropy in synthetic rocks by 3D printing. In AGU Fall Meeting Abstracts 2017 Dec.
5. Kong L*, **Ostadhassan M**, Li C*, Elastic Properties and Size effect of 3-D Printed Rocks, in: American Chemical Society (ACS) 2017 Great Lakes Regional Meeting (GLRM). American Chemical Society
6. Kong L*, Xu Z, **Ostadhassan M,** Li C*. Geomorphology Classification and Architecture Characterization of Braided River Reservoir: A Case Study From Guantao Upper Formation of Gudong Oilfield, Bohai Bay Basin, China., in: April 2017 AAPG Annual Convention and Exhibition.

5. Patent

U. S. Pending Patent (provisional): " **Configuration and Method for Condensate Stabilization Process in Gas Processing Facilities",** as of January 2019.

6. Mentorship

I. undergraduate:

- I have advised around 50 undergraduate students since my appointment and have been in charge of Senior Design Course (the capstone course) for the past 3 years, supervised a large number of projects every semester (fall, spring and summer). The outcome has been:
  - *Le T, Ostadhassan M., A Multidisciplinary Study of Stimulation Designs in the Three Forks Formation, ND. Unconventional Resources Technology Conference; 2015: Unconventional Resources Technology Conference.*
  - ***2017 Doosan Bobcat Outstanding Senior Process Design Award*** *"Comprehensive Study of the Charlson Oil Field" by Jordan Anderson, Cody Mehrer, Joseph Rice and Abdulkadir Said which was published as: Anderson J, Rice J, Said A, Mehrer C, Ostadhassan M, Alexeyev A*. Comprehensive Study of the Charlson Oil Field, Williston Basin, ND. In SPE Annual Caspian Technical Conference and Exhibition 2017 Nov 1. Society of Petroleum Engineers.*

II. graduate:

- The following is the list of committees that I have served on as primary and sole adviser:
  - Kouqi Liu, PhD (Graduated Summer 2018)
  - Rehan Ali Mohammed, MS (Graduated Summer 2018)
  - Cody Brown, MS (Graduated Spring 2018)
  - Alan Alexeyev, MS (Graduated Fall 2017)
  - Ben Oster, MS (Graduated Spring 2016)
  - Lingyun Kong, PhD (Graduated Summer 2019)

- Seyedalireza Khatibi, PhD (Graduated Summer 2019)
- Yulia Kovaleva, MS (Fall 2019)
- Chunxiao Li, former PhD (switched to the geology program)
- Arash Abarghani, PhD (Fall 2019)
- Hyeonseok Lee, PhD (Spring 2021)
- Mousa Abusurra, PhD (Summer 2021)
- Minh Le, MENG, (Graduated Fall 2018)
- Cristina Goodrich MENG (Spring 2020)
- Kyle Pierskalla, MENG (Summer 2019)

III. Post-docs and Researchers

- Dr. Kouqi Liu- Since 2018
- Dr. Shilpi Jain- Since 2019
- Dr. Linag Wang, 2017-2018 (Associate Professor, Southwest Petroleum University, China)
- Dr. Peiqiang Zhao, 2017-2018 (Assistant Professor, China University of Geosciences, China)
- Guoping Liu, PhD student- Since 2018 (China University of Petroleum, China)
- Jin Dong, PhD student- Since 2018 (China University of Petroleum, China)
- Menglu Wang, undergraduate student, Since 2019 (China University of Petroleum, China)

7. Other Experience and Professional Memberships

2001	Member, Society of Petroleum Engineers (SPE)
2008	Member of Society of Exploration Geophysicists (SEG)
2010	Member of American Association of Petroleum Geologists
2015	Faculty adviser to UND SPE student chapter
2008	Faculty adviser to UND SEG student chapter
2016	Associate Editor, Journal of Oil, Gas and Petrochemical Sciences
2018	Guest Editor, Journal of Marine Science and Engineering
2019	Lead Guest Editor, Journal of Chemistry

8. Honors and Awards

2001-2005	Iran Petroleum Ministry Full Scholarship Award
2005-2009	Iran Petroleum Ministry Full Scholarship Award
2011	ExxonMobil Scholarship Award
2012	Chevron/SEG Scholarship Award
2014	SPE New faculty career enhancement award
2015	SPE New faculty career enhancement award
2017	Open Educational Resource development award by UND office of the provost
2015	UND Faculty Instructional Development Grant award
2016	UND Faculty Instructional Development
2018	NIH I-Corps program graduate

9. Funded Competitive Research Supports (Completed/Ongoing)

I. Research

PI- $450K- (Pending)
ND Department of Commerce
Role of the Bakken Region Microbiome in Oil Production and H_2S Associated Antimicrobial Resistance

PI- $140K- 2019/03/1-2021/03/1
ND office of Vice President for Research Grant
Using bacterial RNA to solve the Bakken H_2S problems and increase oil production

CoPI- $2.7M- (Pending)
National Institute of Health
Contribution of Fn-binding Proteins to Borrelia Burgdorferri Pathogenesis

CoPI- $1.2M - 2018/05/16-2022/05/15
ND Industrial Commission/ND Geological Survey
An integrative study of the Bakken Formation: OOIP estimation, redesign of Hydraulic Fracturing through laboratory and ML methods and chemical treatments for increased productivity.

PI - $356K - 2018/05/12-2019/11/12
ND Department of Commerce
A Path to a Quantitative Clinical Method for Early Diagnosis of Cancer Based on Cell Mechanics

CoPI- $35K- 2017/12-2018/08
National Institute of Health (NIH)-NCI
Big data from Small RNA

PI - $20K- 2018/02/15-2019/02/15
UND Early Career Award Program
Nanomechanical Evolution of Organic Matter during Hydrocarbon Generation

PI- $50K/Yearly (Recurring)- 2018/03/15
US Geological Survey
Advanced Characterization of Source Rocks via nanoIR, microRaman and Force Spectroscopy

PI - $35K/Yearly (Recurring)- 2018/01/01
ND School of Medicine and Health Sciences
Understanding Mechanobiology of Cells During Hyperbaric Oxygen Therapy

CoPI- $60K- 2016/03/01-2018/03/01
UND Post-Doctoral Funding Program
Re-fracturing extending the life of Unconventional Oil Shale Reservoirs under Low Oil Prices.

PI- $56K - 2015/03/15-2016/03/15
UND Collaborative Seed Grant
Fine scale characterization of the Bakken with focus on Imaging and gas adsorption methods

II. Scholarly

2014	SPE faculty career enhancement award ($2000)
2015	SPE faculty career enhancement award ($2000)
2016	UND Office of Instructional Development ($2000)
2016	UND Faculty Instructional Development ($6000)
2017	UND office of the provost for Open Educational Resource development ($6000)

10. Top Collaborators and Projects Supporters

- Core Laboratories, Houston, TX, USA
- Oasis Petroleum, Williston, ND
- Credence Energy Services, Minot, ND
- Lillestol Research, Fargo, ND
- Marino Engineering Associate, Saint Louis, MOChina University of Petroleum, Beijing, China
- Northeast Petroleum University, Daqin, China
- China University of Geosciences, Wuhan, China
- China Academy of Science, Guangzhou Institute of Geochemistry, Laboratory of Organic Geochemistry
- United States Geological Survey, Reston, VA, USA

- North Dakota Geological Survey, Bismarck, ND, USA
- Southwest Petroleum University, Chengdu, China
- China Spallation Neutron Source, Guangdong, China
- Department of Petroleum Engineering, National Iranian South Oil Company, Ahvaz, Iran
- NeuDax, CO, USA
- Schlumberger-Doll Research, MA, USA
- University of Nebraska Lincoln, NE, USA
- Northwestern University, NUANCE Center, IL, USA
- Stanford University, CA, USA
- California State University, CA, USA
- Curtin University, Perth, Australia
- Asylum Research Oxford Instruments, CA, USA
- Bruker Nanosurfaces, CA, USA
- Itasca Consulting Group, MN, USA
- Seoul National University, Seoul, South Korea

Hui Pu, Ph.D.
Assistant Professor
Department of Petroleum Engineering
University of North Dakota
Grand Forks, ND 58202
701-777-6861; hui.pu@und.edu

EDUCATION

2010 Ph.D. Petroleum Engineering, University of Wyoming

2006 M.S. Petroleum Engineering, Daqing Petroleum Institute, Daqing, China

2003 B.S. Petroleum Engineering, Daqing Petroleum Institute, Daqing, China

PRINCIPAL AREAS OF EXPERTISE

- **Reservoir Engineering, Modeling & Simulation**
- Strong experience and solid knowledge of petroleum engineering, especially reservoir engineering, modeling & simulation, and unconventional reservoirs;
- Simulated waterflood, CO_2 flood, and polymer flood;
- Worked on enhanced recovery in unconventional reservoirs;
- Strong experience in pressure/rate transient analysis, decline curve analysis, material balance, and volumetric analysis;
- Set up pattern models, sector models and large reservoir models from scratch;
- Wrote programs to process data and generate the required formats of data for different reservoir simulators.
- **Enhanced/Improved Oil Recovery, CO_2 Sequestration**
- Studied CO_2 EOR and storage, and evaluated CO_2 EOR potential in some of fields in Wyoming;
- Worked on chemical flood (polymer, surfactant, surfactant-polymer flood) – mechanism study, field evaluation, and pilot test;
- Conducted study on low salinity waterflood;
- Conducted study on waterflooding – evaluated performance, well pattern optimization, designed surveillance, and studied feasibility in for non-fractured and naturally fractured low permeability reservoirs.
- **PVT Analysis, and SCAL**
- Was responsible for the PVT tests simulation, equation of state (EOS) tuning, and minimum miscibility pressure (MMP) study on oil samples from Bell Creek oilfield;
- Worked on the core analysis in lab;
- Planned special core analysis testing programs, analyzed lab data, and utilized SCAL data in the simulation models.
- **Laboratory Studies**
- Conducted experimental study on surfactant flood, surfactant-polymer flood, polymer flood, and low salinity waterflood;
- Applied low-field Nuclear Magnetic Resonance (NMR) and Magnetic Resonance Imaging (MRI) to recovery mechanisms study of low salinity waterflood;
- Evaluated, screened and optimized the properties of surfactant, surfactant-polymer, polymer solutions, low salinity brine, and optimum formulations for field applications;
- Investigated wettability, spontaneous imbibition, chemical-based EOR processes, crude oil/brine/rock interactions, and interfacial tension;
- Conducted coreflood, core analysis, measurement and evaluation of different types of chemicals for EOR experiments.

WORK EXPERIENCE

Aug 2016 – Assistant Professor, Department of Petroleum Engineering, Univ. of North Dakota

- Teach petroleum engineering courses
- Conduct research in the areas of EOR, tight formations, reservoir engineering, modeling and simulation.

2015 Reservoir Engineer, InPetro Technologies Inc, Houston, TX

- Enhanced recovery, reservoir engineering; CO_2 EOR and storage mechanisms;
- Reservoir modeling and simulation, and field development plan.

2010 – 2014 Reservoir Engineer, Energy & Environmental Research Center, Univ. of North Dakota

- Responsible for reservoir engineering studies for large-scale injection of carbon dioxide into the Bell Creek oil field for CO_2 EOR and long-term CO_2 storage, sponsored by DOE NETL and Denbury Resources;
- Planned PVT and special core analysis testing programs and analyzed lab data;
- Conducted MMP, PVT simulation, EOS (equation of state) tuning, and slimtube;
- Co-Authored 8 Bell Creek project reports as a principal contributor for DOE NETL and Denbury Resources;
- Worked on "Denbury Sequestration Project Phase 2b – Evaluation of Selected CO_2 EOR and Sequestration Sites, funded by Denbury Resources" project, the results were utilized by Denbury's decision making for Bakken Sale and Asset Exchange with Exxon;
- Worked on "Optimizing and Quantifying CO2 Storage Resource in Saline Formations and Hydrocarbon Reservoirs", funded by U.S. DOE NETL.

2006–2010 Graduate Assistant, Department of Chemical & Petroleum Engineering, Univ. of Wyoming

- Worked in Petrophysics & Surface Chemistry Lab: coreflood, evaluation of fluids, petrophysics, mineralogy, lithology, capillary pressure, IFT, and imbibition test;
- Investigated the mechanisms of low salinity waterflood, and evaluated its potential application in Tensleep, Minnelusa and Cottonwood reservoirs in Wyoming;
- Taught and graded students of *Rock and Fluids* course.

Grants and Funding

- "Functional Nanoparticle-Augmented Surfactant Fluid for Enhanced Oil Recovery in Williston Basin", North Dakota Industrial Commission Oil and Gas Research Program Fund, $1,439,810, May 1, 2017-April 30, 2020, PI
- "Development of Novel Nanoparticle-Surfactant based Fluid for Enhanced Oil Recovery in Bakken Formation", UND Post-Doctoral Research Program, $120,000, January 1, 2018-December 31, 2019, Co-PI
- "Detailed Characterization of Rock Samples from Bakken Formation in North Dakota" $1,740, October 26, 2016, PI

PUBLICATIONS

Papers Published in Refereed Journal Papers

- Zhou, Y., Wu, X., Zhong, X., Sun, W., Zhao, J., **Pu, H.**, Modified Silica Nanoparticle and its Nano fluid for Enhanced Oil Recovery under Higher Temperatures and Salinity, submitted to ACS Applied Materials & Interfaces on 11 April 2019
- Sun, R., **Pu, H.**, Yu, W., Miao, J., Zhao, J., Simulation-Based Enhanced oil recovery Predictions from Wettability Alteration in the Middle Bakken Tight Reservoir with Hydraulic

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- Zhang, S., **Pu, H.**, Zhao, J., Experimental and Numerical Studies of Spontaneous Imbibition with Different Boundary Conditions: Case Studies of Middle Bakken and Berea Cores, Energy & Fuels, 2019, 33, 6, 5135-5146, https://doi.org/10.1021/acs.energyfuels.9b00909
- Li, C., **Pu, H.**, Zhao, J., Molecular Simulation Study on the Volume Swelling and the Viscosity Reduction of n-Alkane/CO2 Systems, Industrial & Engineering Chemistry Research, 2019, 58, 20, 8871-8877, https://doi.org/10.1021/acs.iecr.9b01268
- Gao, S., Chen, S., **Pu, H.**, Gong, L., Ma, S., Luo, Q., Wang, X., Gao, A., Zhang, B., Fine Characterization of Large Composite Channel Sandbody Architecture and Its Control on Remaining Oil Distribution: A Case Study of Alkaline-Surfactant-Polymer (ASP) Flooding Test Area in Xingshugang Oilfield, China, Journal of Petroleum Science and Engineering, Volume 175, April 2019, Pages 363-374, https://doi.org/10.1016/j.petrol.2018.12.033
- Zhong, X., **Pu, H**., Zhou, Y., Zhao, J., Comparative Study on the Static Adsorption Behavior of Zwitterionic Surfactants on Minerals in Middle Bakken Formation, Energy & Fuels, 2019, 33, 2, 1007–1015, https://doi.org/10.1021/acs.energyfuels.8b04013
- Sun, R., Yu, W., Xu, F., **Pu, H.**, Miao, J., Compositional simulation of CO_2 Huff-n-Puff process in Middle Bakken tight oil reservoirs with hydraulic fractures, Fuel 236 (2019) 1446–1457, https://doi.org/10.1016/j.fuel.2018.09.113
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- Li, W., Zhao, H., **Pu, H**., Zhang, Y., Wang, L., Zhang, L., Sun, X., Study on the Mechanisms of Refracturing Technology Featuring Temporary Plug for Fracturing Fluid Diversion in Tight Sandstone Reservoirs, Energy Science & Engineering, 2019; 7:88-97, https://doi.org/10.1002/ ese3.259
- Wu, X., **Pu, H.**, Zhu, K., Lu, S.: “Formation Damage Mechanisms and Protection Technology for Nanpu Nearshore Tight Gas Reservoir”, Journal of Petroleum Science and Engineering, 158 (2017) 509–515, https://doi.org/10.1016/j.petrol.2017.07.033
- **Pu, H.**, Wang, Y., Li, Y.: "How CO_2 Storage Mechanisms Are Different in Organic Shale: Characterization and Simulation Studies", SPE Journal, 23 (3), June 2018, https://doi.org/10.2118/180080-PA
- Rui, Z., Han, G., Zhang, H., Wang, S., **Pu, H.**, Ling, K.: “A New Model to Evaluate Two Leak Points in a Gas Pipeline”, Journal of Natural Gas Science and Engineering, 46 (2017) 491-497, https://doi.org/10.1016/j.jngse.2017.08.025
- **Pu, H.**, Yin, D., “A Numerical Simulation Study on Surfactant Flooding and Its Field Application in Daqing's Pilot Test”, Journal of Petroleum Science and Technology, Vol. 27(5), 2009
- Yin, D., **Pu, H.**, “Numerical Simulation Study on Surfactant Flooding for Low Permeability Oilfield in the Condition of Threshold Pressure”, Journal of Hydrodynamics, Ser. B, Vol.20(4), 2008
- Wang, W., **Pu, H.**, Yin, D., Gao, P., “The Study on Reasonable Infilling Method for Low Permeability Reservoir”, Small Hydrocarbon Reservoirs, Vol.12(2), 2006
- Yin, D., **Pu, H.**, Wu, Y., “Numerical Simulation of Imbibition Oil Recovery for Low Permeability Fractured Reservoir”, Journal of Hydrodynamics, Ser. A, Vol.19(4), 2004

Papers Published in Conference Proceedings

- Zhang, S., Li, C., **Pu, H**., Ling, K., Sun, R., Zhao, J., SPE 197080 Experimental Study of Surfactant-Assisted Oil Recovery in the Middle Bakken Cores, to be presented at 2019 SPE Liquids-Rich Basins Conference and Exhibition–North America, Odessa, Texas,7 - 8 Nov 2019

- **Pu, H.**, Wang, Y., Li, Y.: SPE 180080 "How CO_2 Storage Mechanisms are Different in Organic Shale: Characterization and Simulation Studies", to be presented at SPE Europec featured at 78th EAGE Conference and Exhibition held in Vienna, Austria, 30 May–2 June 2016
- **Pu, H.**, Li, Y.: SPE 179533 "Novel Capillarity and Adsorption Quantification Method in IOR Process in Bakken Shale Oil Reservoirs", SPE Improved Oil Recovery Conference, Tulsa, OK, 11-13 April 2016
- **Pu, H.**, Li, Y.: SPE 178943 "Study of Condensate Blockage and Its Remedy in Eagle Ford Gas-Condensate Zone", to be presented at SPE International Conference & Exhibition on Formation Damage Control, Lafayette, Louisiana, USA, 24–26 February 2016
- **Pu, H.**, Li, Y.: CMTC 439769 "CO_2 EOR Mechanisms in Bakken Shale Oil Reservoirs", Carbon Management Technology Conference, Sugarland, Texas, 17–19 November 2015
- Li, Y., **Pu, H.**, CMTC 439561 "Modeling Study on CO_2 Capture and Storage in Organic-Rich Shale", Carbon Management Technology Conference, Sugarland, Texas, 17–19 November 2015
- Jin, L., **Pu, H.**, Wang, Y., Li, Y., SPE 178507/URTeC-2148314 "The Consideration of Pore Size Distribution in Organic-rich Unconventional Formations May Increase Oil Production and Reserve by 25%, Eagle Ford Case Study", Unconventional Resources Technology Conference, San Antonio, TX, 20-22 July 2015
- **Pu, H.**, Xie, X., Yin, P., Morrow, N. R., SPE 134042 "Low-Salinity Waterflooding and Mineral Dissolution", 2010 SPE Annual Technical Conference and Exhibition
- **Pu, H.**, Wang, G., Han, G., SPE 120127 "Production Enhancement Through Pattern Modification: Analysis and Field Results", 2009 SPE Production and Operations Symposium
- **Pu, H.**, Xu, Q., SPE 118746 "An Update and Perspective on Field-Scale Chemical Flood in Daqing Oilfield, China", 2009 SPE Middle East Oil & Gas Show and Conference
- **Pu, H.**, Wang, G., Li, Y., SPE 118836 "Reservoir Simulation Study on Improvement of Waterflooding Effect for a Naturally Fractured Low Permeability Field in Daqing, China: a Successful Case", 2009 SPE Middle East Oil & Gas Show and Conference
- **Pu, H.**, Yin, D., SPE 109546 "Study of Polymer Flooding in Class III Reservoir and Pilot Test", 2008 16th SPE/DOE Improved Oil Recovery Symposium
- **Pu, H.**, Yin, D., SPE 114200 "Field Practice of Improvement of Waterflooding Effect for Mature Naturally Fractured Low-Permeability Field", 2008 SPE Western Regional Meeting
- **Pu, H.**, Yin, D., Chen, Y., Yang, F., SPE 111720 "Feasibility Study and Pilot Test of Polymer Flooding in Third Class Reservoir of Daqing Oilfield", 2008 SPE North Africa Technical Conference and Exhibition
- **Pu, H.**, Xie, X., Yin, P., Morrow, N., SPE 113410 "Application of Coalbed Methane Water to Oil Recovery from Tensleep Sandstone by Low-Salinity Waterflooding", 2008 16th SPE/DOE Improved Oil Recovery Symposium
- Xu, Y., **Pu, H.**, Shi, L., SPE 114199 "An Integrated Study of Mature Low-Permeability Reservoir in Daqing Oil Field, China", 2008 SPE Western Regional Meeting
- Yin, D., **Pu, H.**, SPE 112424 "A Numerical Simulation Study on Surfactant Flooding and Its Field Application in Daqing Oilfield", 2008 SPE EUROPEC Conference
- Xie, X., **Pu, H.**, Morrow, N., "Aspects of Coalbed Natural Gas Water and Oil Recovery", 2007 National Meeting of the American Society of Mining and Reclamation

TRAININGS

- Modern Production Data Analysis for Unconventional Reservoirs by Fekete, September, 2013
- Fundamentals of Geostatistics by Prof. Clayton Deutch, August 2013
- OilField Manager (OFM) Fundamentals by Schlumberger, July 2012

- CO_2-Based EOR (Miscible Flood) and CMOST by CMG, February 2011
- Fundamentals of Reservoir Simulation by Mike Carlson, September, 2011
- Petrel Reservoir Engineering by Schlumberger, September 2011

HONORS/AWARDS

- Featured in the article of supplement to February 2014 *JPT (Journal of Petroleum Technology)*: “Daqing: an Old Field is at the Center of New EOR Testing”
- SPE Scholarship by Denver Section, 2007-2008, 2008-2009
- Graduate Assistantship, University of Wyoming, 2006-2010
- National Scholarship for M.S. Study, China Ministry of Education, 2003-2006
- Outstanding Undergraduate Student of Year 2003, Daqing Petroleum Institute, China