UNIVERSITY OF UND NORTH DAKOTA

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Nov 01, 2007

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol – 14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0840

RE: Approval of proposal

Dear Mrs. Fine,

This is to confirm that the research proposal "Geomechanical Study of Bakken Formation in the Nesson Anticline Area, William County, North Dakota" prepared by Dr. Zhengwen Zeng, Assistant Professor in the Department of Geology and Geological Engineering at The University of North Dakota, submitted to you for the research grant at the Oil and Gas Research Council under the North Dakota Industrial Commission, has been reviewed and approved by all related administrative officers in The University of North Dakota. If you have any questions on this proposal, please feel free to contact us.

Thank you very much.

Sincerely,

Barry I. Milavetz, PhD
Associate Vice President for Research
Research Development and Compliance

(USE THIS FORM FOR ALL EXTERNAL FUNDING PROPOSALS)

☐ Earmark ☐ Competitive Proposal ☐ Noncompetitive Proposal ☒ Preproposal ☐ Fellowship ☐ Appendix Attached (e.g. Matching Funds Form, MOU)

UNIVERSITY OF NORTH DAKOTA
Proposal Transmittal Form

Submit 2 copies of signed proposal in final form no fewer than 3 working days prior to proposal deadline to *RD&C , Box 7134, 105 Twamley Hall*

TITLE: (30 Characters or Less) Geomechanical Study of Bakken Formation

FUNDING AGENCY/RFP: Oil and Gas Research Council, North Dakota Industrial Commission

PRINCIPAL INVESTIGATOR(S): Zhengwen Zeng **PHONE:** 701-777-3027
(Name, Title, Department)

PRINCIPAL INVESTIGATOR(S): **PHONE:**
(Name, Title, Department)

PROPOSAL DEADLINE DATE: November 1, 2007 **PROPOSED PROJECT PERIOD:** Jan 1, 2008 To: Dec 31, 2009

TOTAL FUNDS REQUESTED: $180,635 **TOTAL DIRECT COSTS:** $139,766 **TOTAL F & A:** $40,869

Check if your project involves any of the following (review and approval of a proposal may be required by the appropriate committee):

☐ Animals (Institutional Animal Care Committee)
☐ Biohazards or Recombinant DNA (Institutional Biosafety Committee)
☐ Human Subjects (Institutional Review Board)
☐ Radioactive Materials (Radiation Safety & Hazardous Materials Committee)
☐ Controlled Substances/DEA License Required

☒ UNIVERSITY COMMITMENTS ☐ Faculty Release Time beyond Current Allocation ☐ Office/Lab Space beyond Current Allocation ☐ Support Staff

If University Commitments is checked, check corresponding commitment on right and please explain.

☒ Graduate Student Tuition Waivers ☐ Matching Funds ☐ Other

If the response to any of the following is "Yes," please attach documentation.

Has lobbying occurred with respect to this proposal? (Required for Federal projects only)	☐ Yes	☒ No
Does this proposal require modification to existing building utilities, construction of new space, or impact the existing operation of building components?	☐ Yes	☒ No
Does the project have a confidentiality agreement, proprietary information or a material transfer agreement?	☐ Yes	☒ No
Does this proposal involve interdisciplinary or multidisciplinary research?	☐ Yes	☒ No
Will this proposal use resources in the High Performance Computer Center?	☐ Yes	☒ No
Did this proposal result from a Faculty Research Seed Money (FRSM) grant?	☐ Yes	☒ No If so, date of FRSM award:

Conflict of Interest: I have filed with the Dean of my college appropriate, up-to-date Financial Interest Disclosure forms that relate to the University of North Dakota. I understand that these forms indicate that I will cooperate in the development of a Memorandum of Understanding that constitutes a conflict of interest "resolution plan" if a conflict of interest or potential conflict of interest is found to exist that relates to this proposal, and to comply with any conditions or restrictions imposed by the University to manage, reduce or eliminate actual or potential conflicts of interest or forfeit the award.

Zhengwen Zeng 11/01/2007
Principal Investigator(s) Date Principal Investigator(s) Date

APPROVALS:

W.D. Gosnold 11/01/07
Department Chairperson(s) Date

Other Date

School/College - Administration & Finance (as appropriate) Date

Chassi Heuman 11.2.07
Grants & Contracts Administration (G&C) Date

11/02/07
Principal Investigator's Dean Date

12/7/07
Research Development and Compliance (RD&C) Date

Dean of Graduate School (as appropriate) Date

Revised 11/14/2006

Research Proposal

Geomechanical Study of Bakken Formation in the Nesson Anticline Area, William County, North Dakota

Submitted to

Karlene Fine, Executive Director
North Dakota Industrial Commission
State Capitol-14th Floor
600 East Boulevard Ave Dept 405
Bismarck, ND 58505-0804

By

Zhengwen Zeng (PhD, Asst Prof.)
Project Applicant and Principal Investigator
Department of Geology and Geological Engineering
University of North Dakota

Amount of the request: $180,635

Date of application: November 1, 2007

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Abstract

We proposed geomechanical study on the Bakken Formation at the Nesson Anticline areas in William County, North Dakota. We plan to investigate the in-situ stress field through well logging analysis, core observation, geologic analysis, and numerical modeling, and to experimentally measure geomechanical properties of the Bakken Formation rocks through laboratory tests. Successful completion of this project will generate important geomechanical parameters, including (1) in-situ stress orientation, (2) in-situ stress magnitude, (3) formation rock tensile strength, (4) formation rock uniaxial compressive strength, (5) Young's modulus and Poison's ratio, (6) bulk modulus and rock compressibility, (7) triaxial strength, cohesion and angle of internal friction, and (8) P- and S-wave seismic velocities, and dynamic Young's modulus and Poison's ratio.

Knowing the above mentioned in-situ stress and geomechanical properties of the Bakken Formation will greatly improve the rate of success in drilling horizontal wells and hydraulic fracturing the targeted formation. Due to the large amount of investment in drilling horizontal wells, improved rate of success will attract more companies to North Dakota, resulting in new investment, jobs, more productions, and many other indirect economic impacts.

Completion of this project will also indirectly benefit the North Dakota economy in many other ways. Facilities will be improved for teaching geomechanics-related lab courses, thus graduating more students for the North Dakota petroleum industry. Enhanced lab capacity will allow us to serve the local and regional demand for geomechanical tests, thus not only keeping federal money to be spent in North Dakota, but also attracting outside funds to the state.

Project description

Objectives

1. Determine the in-situ stress field of the targeted formation for better design of horizontal wells and hydraulic fracturing;
2. Measure the geomechanical properties, such as rock strength, to improve well stability during both drilling and production stages;
3. Develop local geomechanical laboratory capacities to serve the state and the regional demand; and
4. Establish lab facilities to teach lab classes for courses that include geomechanics components.

Methodology

1. In-situ stress field (Zeng, 2002; Zeng et al, 2004)
    a. Well logging analysis (current data indicates 14 wells have been drilled in the targeted area),
    b. Minor and micro structural analysis from core sample observations (core samples are stored in the North Dakota Geological Survey's Core Library located about 100 ft away from the PI's office building on UND campus),
    c. Data from regional and world stress map project conducted by Zoback and his team (the data is now managed by a research team in Karlsruhe University, Germany), and
    d. Analytical solutions: using the measured Geomechanical properties, vertical and horizontal stresses can be estimated using some simple models due to the fact that Williston Basin is tectonically inactive.

2. Geomechanical parameters (Zeng, 2002; Zeng et al, 2004)
    a. Formation rock tensile strength and uniaxial compressive strength: point load test method ,
    b. Young's modulus and Poison's ratio: triaxial compression with very accurate measurement of volumetric strain,
    c. Bulk modulus and rock compressibility: triaxial compression with very accurate measurement of volumetric strain,
    d. Triaxial strength: triaxial compression with very accurate measurement of volumetric strain,
    e. Cohesion and angle of internal friction: failure envelope from Mohr's circles by three or more triaxial compression tests, and
    f. P- and S-wave seismic velocities, and dynamic Young's modulus and Poison's ratio: triaxial core holder with acoustic transducers.

Expected results

1. In-situ stress field (orientation and magnitude) in the Bakken Formation in the Beaver Lodge Field along the N-S trending Nesson anticline in Williams County, North Dakota;
2. Geomechanical properties of the Bakken Formation rocks from the Beaver Lodge Field: (1) tensile strength, (2) uniaxial compressive strength, (3) Young's modulus and Poison's ratio, (4) bulk modulus and rock compressibility, (5) triaxial strength, cohesion and angle of internal friction, and (6) P- and S-wave seismic velocities, and dynamic Young's modulus and Poison's ratio;
3. Local capacity for geomechanical experiments;

4. Laboratory classes for several UND courses that has rock mechanics components, including
    a. GeoE 455 Geomechanics;
    b. GeoE 323 Engineering Geology;
    c. Geol410 Site Characterization; and
    d. GeoE 352 Petroleum Development Engineering;
5. New geomechanical experimental method using un-conventional triaxial cell; and
6. Integrated method for in-situ stress determination which can be applied to other formations and oil fields in the future.

Duration: 2 years

January 1 2008 – December 31, 2009.

Total project cost: $392,595

Total cost: $392,595

NDIC: $180,635 (46.01%)

UND: $211,960 (53.99%)

Participants

1. Matthew L. Belobraydic, PhD student in Geology;
2. Xuejun Zhou, PhD student in Geological Engineering;
3. Hong Liu, part time UND Petroleum Engineering Lab technician; and
4. Benjamin J. Mooney, undergraduate student in Geological Engineering.

Facilities

The PI spent almost all his new faculty startup fund in the past two years and has successfully built a Petroleum Engineering Lab (http://www.und.edu/dept/pelab/) with the capacity of running high pressure high temperature experiments with automation in experimental control and data acquisition. Adding an ISCO pump and a triaxial core holder to the exiting system will allow the realization of measuring the Geomechanical parameters proposed in this project.

Impacts

The method developed in this proposal will also be used to test rock formations for CO2 sequestration under the UND EERC's PCOR Partnership. From this aspect, this project will have huge positive environmental impact, if funded.

The economic impact could be appreciated from several aspects. First, data generated from this project this project will greatly improve the success rate of drilling horizontal well in and hydraulically fracturing the Bakken Formation, which will attract more companies to come. Second, the methods can be applied to other areas in the Williston Basin, and thus more oil in the Bakken Formation can be recovered. Thirdly, the PCOR CO2 sequestration partnership has to send their geomechanical test assignments to other places at commercial price. The proposed project would allow the establishment of local capacity for this type of tests, and thus keeping the federal money in North Dakota.

Standards of success

1. Data generated and accepted by the industry;
2. Methods developed;

3. Technical team trained;
4. Students taught; and
5. Technology transferred through papers, reports and conference presentations.

Background/Qualifications

Qualifications

The PI has been trained and practiced in laboratory geomechanical experiments, hydraulic fracturing, drilling and general petroleum engineering for more than 20 years. A more detailed introduction of his background and publications can be found at his web page in UND (http://www.geology.und.edu/zeng/index.html).

Management

The project will be divided into three tasks: (1) in-situ stress analysis, (2) geomechanical tests, and (3) technology transfer. In situ stress analysis will start from the beginning the first quarter of the first year. Geomechanical tests will begin with equipment improvement and sample drilling. Once preparation is completed, tests will start. This part is scheduled to last from the second quarter of the first year to the third quarter of the second year. The technology transfer will undergo in the whole project period.

Each part of the task will have a major person. Belobraydic will focus on geomechanical tests. Zhou will focus on in-situ stress analysis. Zeng will be in charge of the whole project while focus on technology transfer. Liu will help data process and lab maintenance. Mooney will help in information collection and sample preparation.

Timetable

The time table below shows the schedule.

Task	2008				2009			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
In-situ stress	———	———	———	———	———			
Geomechanical tests		———	———	———	———	———	———	
Technology transfer	———	———	———	———	———	———	———	———

Budget plan

The following tables are the budget plan for the proposed 2-year research project, one for each year.

Year 1: Jan 1 2008 - Dec 31, 2008

Item	Rate ($)	Quantity	NDIC ($)	UND ($)
Personnel				
Salary				
PI	6,597/mo	4-mo[a]	13,194	13,194
Lab technician	1,250/mo	12-mo	15,000	
Graduate-1	1,500/mo	12-mo		18,000
Graduate-2	1,500/mo	12-mo		18,000
Undergraduate	1,000/mo	6-mo	6,000	
Tuition waiver				
GRA-1 Tuition	14,795/2-term(2008)	2-term		14,795
GRA-2 Tuition	14,795/2-term(2008)	2-term		14,795
Fringe benefits				
PI	20%(Su), 27% (F & Sp)	2-mo	2,639	3562
Lab technician	Non-benefited			
Graduate-1	625/12-mo(2008)	12-mo		625
Graduate-2	625/12-mo(2008)	12-mo		625
Undergraduate	10% in summer	3-mo	300	
Sub total			37,133	83,596
Operational				
Hardware				
ISCO pump	10,000/piece	1	10,000	
Miscellaneous			1,000	
Software				
PFC3D	16,500/set	1-set	16,500	
PETREL	372,400/set (donated)	1-set		1000[b]
ECLIPSE	4,3000,000/set (donated)	1-set		1000[b]

Interactive Petrophysics	331,560/set (donated)	1-set		
Travel			6,000[c]	
Sub total			33,500	2000
Total direct cost			70,633	85,596
F & A	35%			
Total indirect cost			21,222[d]	19,602[e]
Year 1 Total			**197,053**	
NDIC (46.61%)			91,855	
UND (53.38%)				105,198

Year 2: Jan 1 2009 – Dec 31, 2009

Item	Rate ($)	Quantity	NDIC ($)	UND ($)
Personnel				
Salary				
PI	6,597/mo	4-mo[a]	13,194	13,194
Lab technician	1,250/mo	12-mo	15,000	
Graduate-1	1,500/mo	12-mo		18,000
Graduate-2	1,500/mo	12-mo		18,000
Undergraduate	1,000/mo	6-mo	6,000	
Tuition waiver				
GRA-1 Tuition	15,535/2-term(2009)	2-term		15,535
GRA-2 Tuition	15,535/2-term(2009)	2-term		15,535
Fringe benefits				
PI	20%(Su), 27% (F & Sp)	2-mo	2,639	3,562
Lab technician	Non-benefited			
Graduate-1	656/12-mo(2009)	12-mo		656
Graduate-2	656/12-mo(2009)	12-mo		656
Undergraduate	10% in summer	3-mo	300	
Sub total			37,133	85,138
Operational				
Hardware				
Triaxial cell	13,000/piece	1	13,000	
Miscellaneous			1,000	
Software				
FLAC3D	12,000/set	1-set	12,000	
PETREL	372,400/set (donated)	1-set		1000[b]
ECLIPSE	4,3000,000/set (donated)	1-set		1000[b]
Interactive Petrophysics	331,560/set (donated)	1-set		
Travel			6,000[c]	
Sub total			32,000	2000
Total direct cost			69,133	87,138
F & A	35%			

Total indirect cost			19,647[d]	19,624[e]
Year 2 Total			**195,542**	
NDIC (45.40%)			88,780	
UND (54.60%)				106,762

Budget notes

a. PI is a UND faculty member appointed for 9-mo each year, of which 40% is allocated for research. PI contributes 4-mo in total to this proposed project, of which 2-mo from the above mentioned research time, and the other 2-mo from summer months.

b. This is third-party annual fee.

c. Travel includes trips to NDIC, the oil field(s), the operator's field office, other necessary locations, and attending annual conferences of Society of Petroleum Engineers (SPE), American Association of Petroleum Geologists (AAPG) and American Association of Rock mechanics (ARMA).

d. Equipment above $5000 is not charged for F & A.

e. Tuition waiver is not charged for F & A.

The PI has spent all his new faculty startup fund in the past two years on building up the Petroleum Engineering Lab at UND (http://www.und.edu/dept/pelab/). This lab is now equipped with two (2) ISCO pumps and ready to serve the fundamental petrophysical experiments, such as measuring density, porosity, permeability, etc.

A regular triaxial loading machine would cost anywhere from $200K to multiple million dollars. A previous faculty member and the PI have tried several times for NSF's major research instrument fund, but never succeed----this partly drove that faculty member to Texas A & M University where he was offered enough fund to build/purchase a new triaxial loading machine. Realizing the fact that UND is not likely to get the federal fund

in a short period of time to build a conventional triaxial loading machine, the PI have developed an alternative solution to this problem. By adding an ISCO pump and a triaxial acoustic core holder, as proposed in the budget plan, to the current core flooding system in the UND Petroleum Engineering Lab, the geomechanical properties routinely measured in a conventional triaxial loading machine can also be measured using this modified triaxial core flooding system.

However, if less funding is available than requested, the PI would adjust the project's objectives based on the available fund.

Tax liability affidavit

This is to affirm that I, Zhengwen Zeng, the applicant and PI of this research project, residing at 5366 W Lanark Drive, Grand Forks, North Dakota 58203, and working and a tenure track Assistant Professor for the Dept of Geology and Geological Engineering at The University of North Dakota, do not have an outstanding tax liability to the State of North Dakota or any of its subdivisions.

Zhengwen Zeng

Nov. 1, 2007

Confidential information

None

Patents and Rights to Technical Data

None

Appendices

None

References

1. Zeng, Z., Roegiers, J-C. and Grigg, R. B., 2004: "Experimental Determination of Geomechanical and Petrophysical Properties of Jackfork Sandstone – A Tight Gas Formation," paper ARMA/NARMS04-562, *Proc. 6th North America Rock Mechanics Symposium*, Houston, Texas, USA, June 5 – 9.
2. Zeng, Z. 2002: "Laboratory Imaging of Hydraulic Fractures Using Microseismicity," *Ph.D. Dissertation*, University of Oklahoma, Norman, Oklahoma, USA.
3. Zeng, Z., Scott, T.E. Jr. and Roegiers, J.-C. 1999: "Simulation of Hydraulic Fracturing Dynamics," Rock Mechanics Institute, University of Oklahoma, Norman, Oklahoma, USA.
4. Zhang, L., Xu, J., Gao, P., Zhou, Y., Gao, X., Zeng, Z., Wang, C. Liu, S., Huang, J., and Qu, G. 1996: "Reservoir Development Optimization through Fracture Characterization and Geomechanical Research in Liaohe Oil Field," Institute of Geology, State Seismological Bureau, Beijing, China.