Public-Private Partnership
UND College of Engineering & Mines

G-028-58

Request for Budget Revisions

Presented May 21, 2017 by Steve Nordeng and Michael Mann

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Outline

- Original project objectives
- Task layout and project metrics
- Progress update
- Budget request

Overall Objectives

- Enhance the education of students in the field of petroleum geology, petroleum engineering, and related earth sciences
- Increase the research efforts currently conducted by faculty and students in petroleum related fields
- Create new opportunities with industry in North Dakota and elsewhere

General Project Structure

- Endowed Faculty Positions
  - Harold Hamm Distinguished Professor of Petroleum Geology
  - Harold Hamm Distinguished Professor of Petroleum Engineering
  - $7.5 million endowment / $675,000 salaries – CRL and Harold Hamm
- Student Scholarships and Assistantships
  - Undergraduate scholarships / Graduate assistantships - $720,000 NDIC
  - Harold Hamm Leadership Scholarships - $1.35 million endowment
- High Resolution Virtual Core Library
  - Access and analytical tools to high resolution scans of cores, cuttings and thin sections
  - $1.5 million NDIC, $500 CRL and Harold Hamm

General Project Structure – Cont.

- Advanced Laboratories
  - Tools to enhance research that can improve oil and gas recovery strategies, design of drilling methods, and projection of gas and oil flow behavior
  - SEM, XRD, XRF, NMR and vitrine reflectance optical scope
  - $1.5 million from NDIC
- Student Experience Fund
  - Enhance hands of experience and professional development of students
  - Field trips, participation in national and international conferences, and create research opportunities
  - $280,000 NDIC

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Anticipated Results

- At least 50 petroleum engineers and geologists will graduate each year
- Create sustainable pipeline of students attracted to North Dakota
- Distinguished faculty members will be attracted to UND
- Expertise in petroleum related areas enhanced through new hires
- Advanced labs provide state of art equipment for research, education and industry collaboration
- Enhanced student experience – updated curriculum, hands on experience, and field studies
- Greater utilization of Core Library via Virtual Core Library
- Exposure of students to national and international conferences

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Standards of Success - Metrics

- Successful graduation of students
- Placement of students in rewarding careers
- Completion of research that improves methods of extraction
- Successful partnerships with industry
- Utilization of Advanced Laboratories by students, faculty and industry
- Utilization of Virtual Core Library by students, faculty and industry
- Published research by faculty members and students
- Thesis and dissertations completed

Endowed Faculty Positions

- Harold Hamm Distinguished Professor of Petroleum Geology
  - Dr. Stephan Nordeng
- Harold Hamm Distinguished Professor of Petroleum Engineering
  - Dr. Vamegh Rasouli
- Other Faculty Hires:
  - HHSGGE
    - Dr. Dongmei Wang,
    - Dr. Taufique Mahmood,
    - Dr. I'suan Ho
  - P.E
    - Dr. Hui Pu
    - Dr. Minou Rabiei

Student Scholarships and Assistantships

- Typically support 5 graduate assistantships and 2-4 scholarships each semester
- Current Graduate Students
  - Daniel "Burke" Brunson (M.S. ½ time) - Williston Basin Thermal Maturation
  - Mark Dickson (M.S. ½ time) -Parametric study of a Geothermal Snow melting system in North Dakota
  - Kelsey Forward (M.S. ½ time) - Variable-scale Mapping of Groundwater Recharge and Discharge with Satellite and UAS Imagery
  - Jin Zhang (Ph.D., ½ time) - Aqueous Imbibition with Enhanced Contact Area Approaches to Extract Oil for Keeping Bakken/Three Forks Wells Flowing.
  - Fazilatun Nessa Mahmood (Ph.D. ½ time) - Oxygen isotope fractionation in biogenic silica.
  - Benjamin York (M.S. ¼ time) - Fluvial response to glacial rebound in the Red River Valley
- Current Undergraduate Scholarships ($15,000/yr)
  - Stephanie Kitowski
  - Connor Linderberg

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Student Experience Fund: Used by 91 individuals

Activity	80	54	37	Totals
	FY 14	FY 15	FY 16	171
Spring Field trip experience	Belize - 18	Hawaii - 18	California - 10	46
GSA National	20	7	5	32
AAPG National	9	5	9	23
AAPG Rocky Mountain Rendezvous	10	6	1	17
Research Projects	1	7	6	14
Geol 415 field trip	8			8
Geothermal Resources Council	5	3		8
AAPG Sectional	4		10*	4
Senior Thesis	6	2		8
Geothermal Trip	3			3
ND Academy of Science	2	1		3
AGU	2			2
ARMA conference	2			2
GSA Rocky Mountain	2			2

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Oil Generation Rate Prediction Using Arrhenius Equation For Bakken Formation

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Harold Hamm School of Geology and Geological Engineering, University of North Dakota

Abstract

Oil generation rate index is important in considering oil well performance. An oil generation rate index was estimated for two groups of wells in the Bakken Formation in the North Dakota portion of the Williston Basin. Activation energies consistent with a fixed frequency factor ($1x10^{-14}$/sec) and estimates of the current temperature within the Bakken Formation were used to calculate a reaction rate. The reaction rate was converted into a generation rate index by multiplying the reaction rate by the mass of crackable kerogen derived from Rock-Eval S_2 analyses and bulk density logs. The Rock-Eval pyrolysis temperature of 435°C, production index of 0.1 and conversion fraction of 0.1~0.15 are believed to represent the threshold of intense hydrocarbon generation from mature rocks. The calculated reaction rate index appears consistent with this threshold.

Purpose of Research

-To provide an understanding of how an integrated approach can improve exploration results

-To experimentally determine the kinetics of source beds within Bakken Formation and provide an avenue for oil generation rate estimation

Map of Study Area

Study Area:
North Dakota Portion of the Williston Basin (Samples picked randomly from different counties)

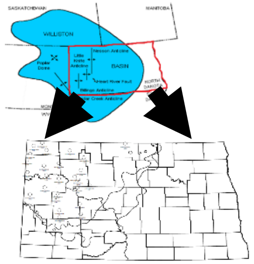


Figure 1: Map of the Study Area

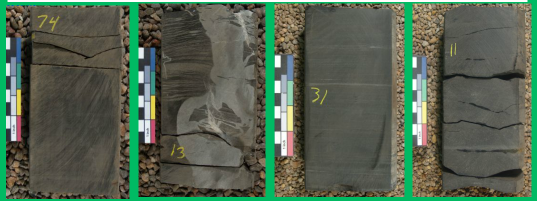
Introduction

The Bakken Formation stratigraphically underlies the Lodgepole Formation and overlies the Three Forks Formation and is defined as two laterally persistent, thin (<20m) organic rich, black shales (Upper and Lower Member) which are separated by a thin (<27m) gray sequence of siliciclastics and carbonates (Middle Member). The black shales containing abundant marine organic material, with a local concentration of up to 40% total organic carbon (TOC) by weight serve as very effective seals, owing to their very low permeability (0.01–20 mD). The middle member is the primary oil-producing member and has low porosity (1%-15%) and permeability (0-20 millidarcies), particularly for a reservoir rock.

Methods

-Study the physical properties of the rock

Figure 2: Core Samples



-Evaluate source beds within each well with regard to the mass of S_2 (crackable hydrocarbon) per unit mass of rock which will be generated by programmed pyrolysis (Rock-Eval)

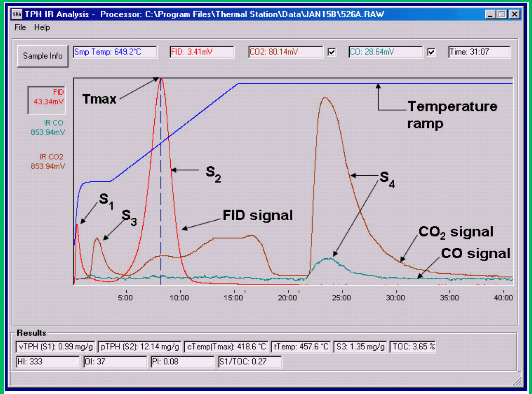


Figure 3: Rock Eval Pyrolysis

Methods

-Estimate the density of the source using Compensated Neutron Density (CND) logs.

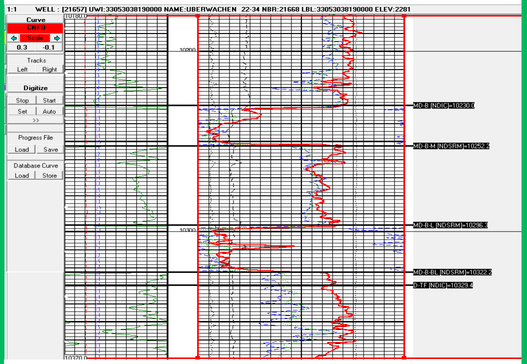


Figure 4: Compensated Neutron Density Log

-Determine Temperature based on heat flow

-Use the Arrhenius equation to combine these variables into an index for comparison with maps of formation pressure.

$(dx/dt = A e^{-Ea/RT} X)$

Results

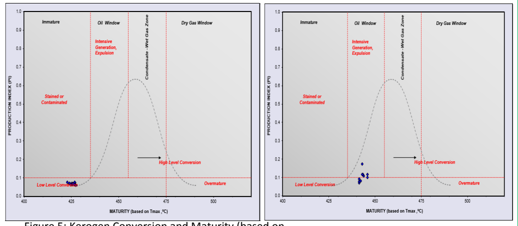


Figure 5: Kerogen Conversion and Maturity (based on Tmax)

API Number	Eac (kJ/mole)	Ln(Ac)	Temp (°K)	expA	R (mol-°K)	Mass of Kerogen	Index	Index Log
33061006530000	222.5178977	63.319	357.05	3.15568E+27	0.008314	226.8603795	0.001997161	-2.699587011
33061004980000	227.5488851	63.319	406.35	3.15568E+27	0.008314	96.98518397	1.7149736	0.234257439

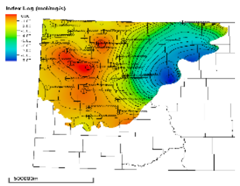


Figure 6: Reaction Rate Index Map

Results

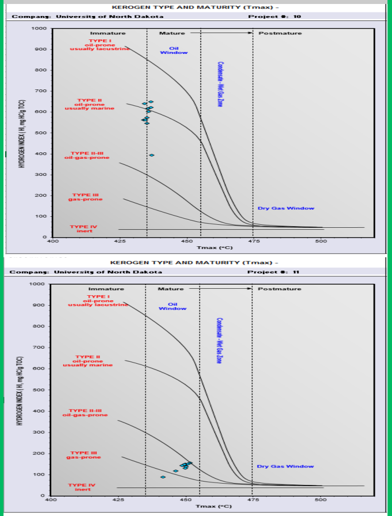


Figure 7: Kerogen Type and Maturity

Discussions

The results shows that Group A wells has the highest reaction rate 1.715 mol/mg/s^{-1} which detects they are over-pressurized and tend to exhibit better porosity than would be predicted while Group B wells has the least reaction rate of 5.0E-6 mol/mg/s^{-1}. The mechanism causing over-pressure might be intense hydrocarbon generation from thermally matured and excellent quality source rock.. The rate of reaction do not wholly depend on the amount of organic matter but also the conversion temperature.

Conclusions

-The two groups of wells are both producing ranging from immature to thermally matured.

-With increased production, temperature and pressure which are factors that drives the conversion of organic matter to oil are thereby increased.

-Evaluating the generation rate could better define the limits of resource play and in turn aid in search of new resources

Petroleum Related Theses

- 2013 Skitt, Troy J.D., (M.S.) Lithological and Sequence Stratigraphic Examination of the Madison Group Marker Beds, Eastern Williston Basin Margin, North Dakota. Chairman: R.D. LeFever
- 2014 Alcorn, Zachary P., (M.S.) Lithostratigraphic Investigation of a Late Devonian Carbonate-Evaporite Sequence; The Duperow Formation, Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2014 Ashu, Richard A., (Ph.D.) Stratigraphy, Depositional Environments, and Petroleum Potential of the Three Forks Formation—Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2014 Bosshart, Nicholas W., (M.S.) Characterization, Diagenesis, and Geocellular Modeling of Winnipegosis Formation Pinnacle Reefs in the Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2014 Murphy, Brian R., (M.S.) Elemental Chemostratigraphy of the Three Forks Formation, Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2014 Sebade, Matthew J., (M.S.) The Depositional Environment and Diagenetic Effects on Sand Bodies within the Unconventional Resource Play of the Spearfish Formation (Triassic) in North Central North Dakota. Chairman: R.D. LeFever.
- 2015 Engelman, Benjamin L., (M.S.) Lithostratigraphic Investigation and Components of a Complete Petroleum System within an Upper Devonian Carbonate-Evaporite Sequence; The Birdbear Formation, Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2015 Hartig, Caitlin M., (M.S.) Interplay of Porous Media and Gracture Stimulation in Sedimentary Enhanced Geothermal Systems; Red River Formation, Williston Basin, North Dakota. Chairman: W.D. Gosnold.
- 2015 Ricker, Faye N., (M.S.) Geothermal Regime of the Williston Basin in North Dakota. Chairman: W.D. Gosnold.
- 2015 Sigler, Mitchell V., (M.S.) Reservoir Analysis of the Birdbear Formation (Devonian) in Northwestern North Dakota. Chairman: R.D. LeFever.
- 2016 Ekwenta, Sunny O., (M.S.) Diagenesis and Reservoir Analysis of the Birdbear Formation, Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2016 Lord, Emma M., (M.S.) Ice Fluctuations in Moraine Canyon, Antartica Dated with Cosmogenic ^{26}Al, ^{10}Be, and ^{21}Ne. Chairman: J. Putkonen.
- 2016 Nwachukwu, Francis C., (M.S.) Depostition, Diagenesis and Porosity of Birdbear Formation, Williston Basin, North Dakota. Chairman: R.D. LeFever.
- 2016 Oster, Benjamin S., (M.S.) Reservoir Characterization and Modeling; Winnipegosis Formation, Temple Field, Williston Basin, North Dakota. Chariman: M. Ostadhassan.
- 2016 Sandberg, Kilynn F., (M.S.) Depostitional Environment of the Top Four Members of the Three Forks Formation in Northwestern North Dakota, Williston Basin and its Relation to Variables in Oil Production. Chairman: R.D. LeFever.

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High Resolution Virtual Core Library

- High Resolution Images
  - 85 Wells
  - 21 Formations
  - 8900 ft. imaged
- New directions
  - Hyperspectral Scanning
    - High resolution images and textures
    - Maps of select minerals
  - Rock fabric recognition - currently using the Caffe Convolutional Neural Network

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Hyperspectral Scanning

- Proposed
  - 9,400 ft of core (cut or broken)
  - Planned for Fall 2017

Hyperspectral Imaging

Spectral range:	450nm to 2500nm (VNIR + SWIR)
Spectral resolution:	4nm (~520 spectral bands)
Spatial resolution:	0.5mm

Core Photography

Sensor:	3 x CCD, high resolution colour RGB camera
Spatial resolution:	~50 micron (0.05mm)

Laser Profiler

Height resolution:	~20 micron
Spatial resolution:	~200 micron

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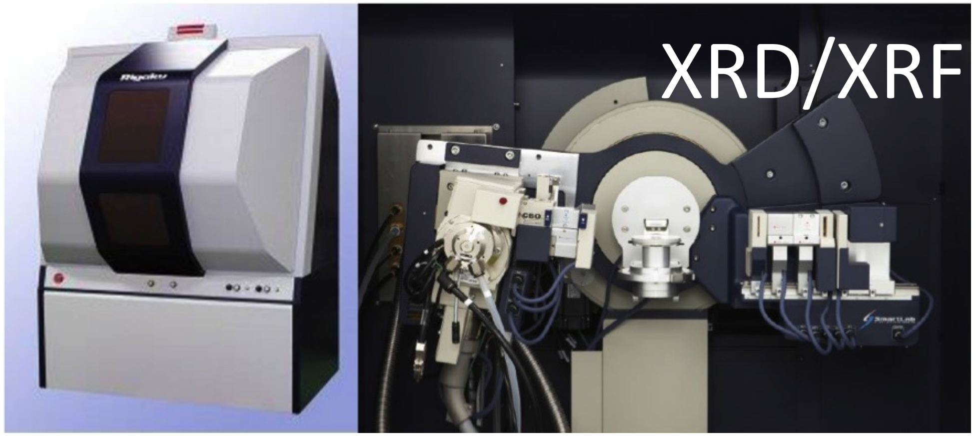
Advanced Laboratories

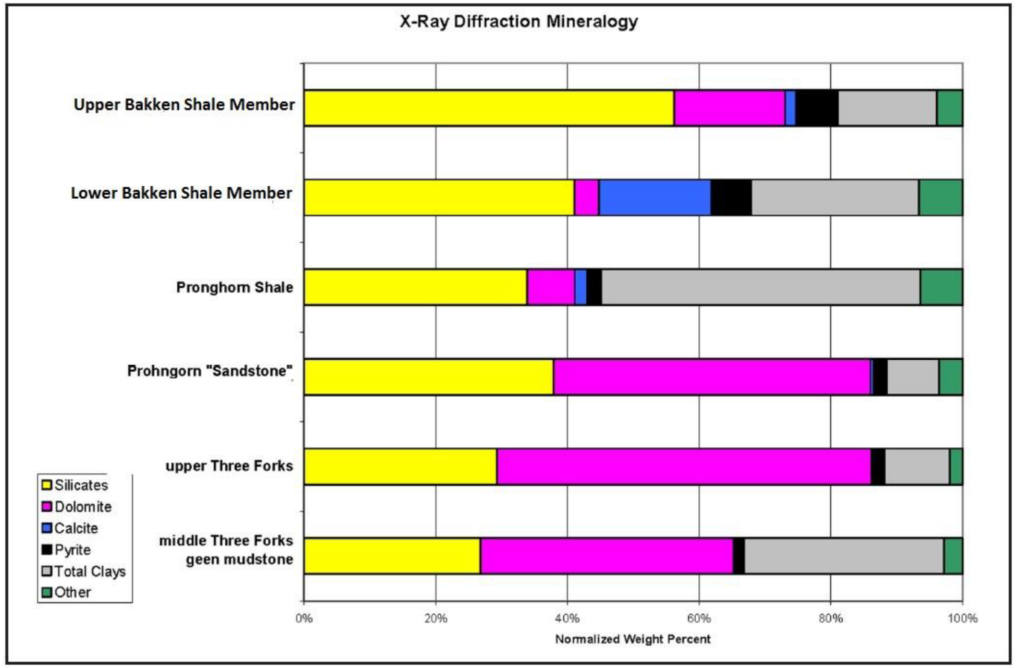
- Direct Purchases: SEM, XRD, XRF, NMR, virtinite reflectance
- Administered through the Institute for Energy Studies / available for use by students, faculty, EERC, and industry
- Core Gamma Ray, SRA lab, located in the Wilson Laird Core Library
- 3-D microscope
- Software / Simulation capabilities – Petra® 40 seats, Petrel®, CMG, Agisoft

Vitrinite Reflectance



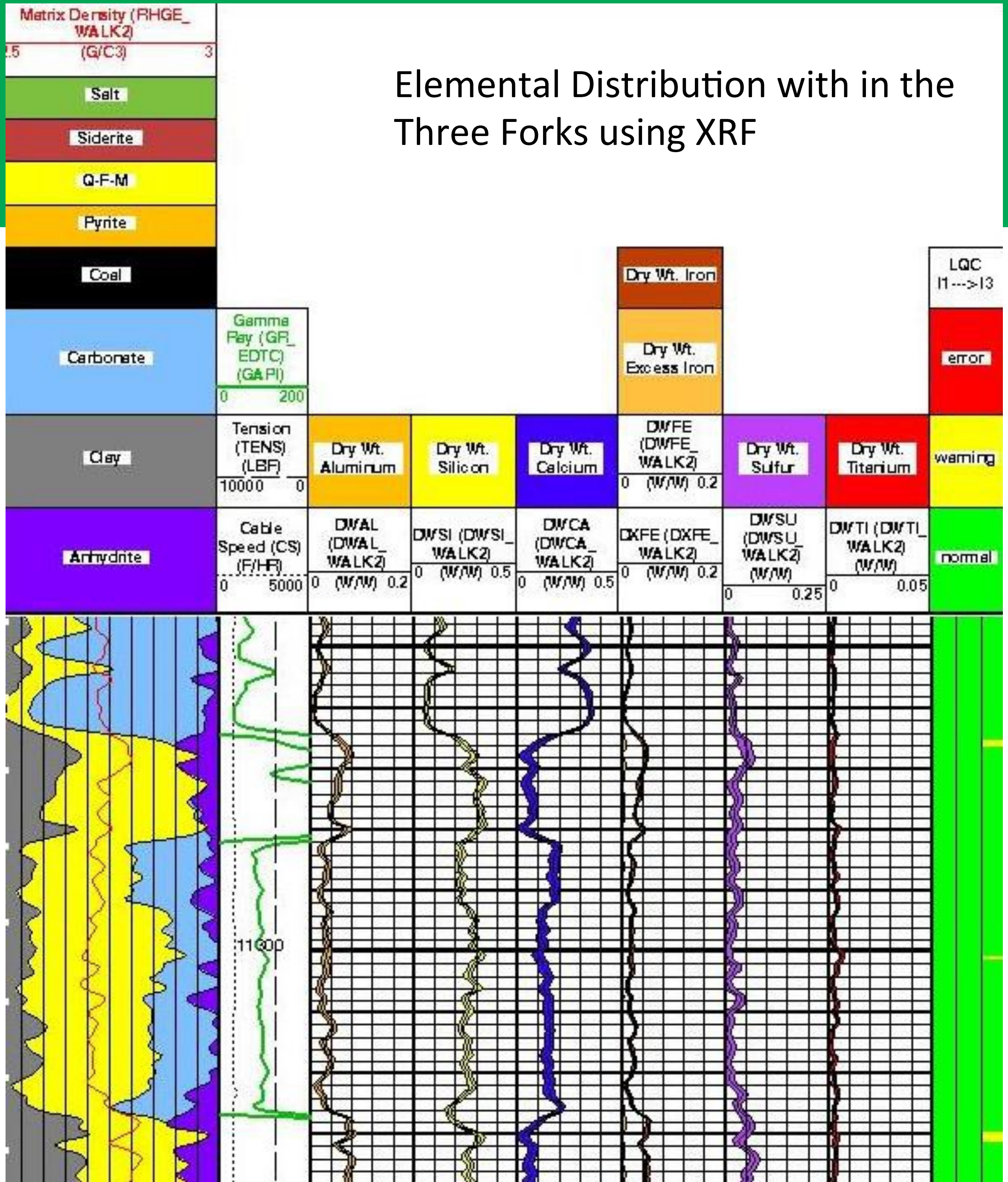
Advanced Laboratories

- Brian Murphy (2014-M.S.) – Chemostratigraphy of the Three Forks



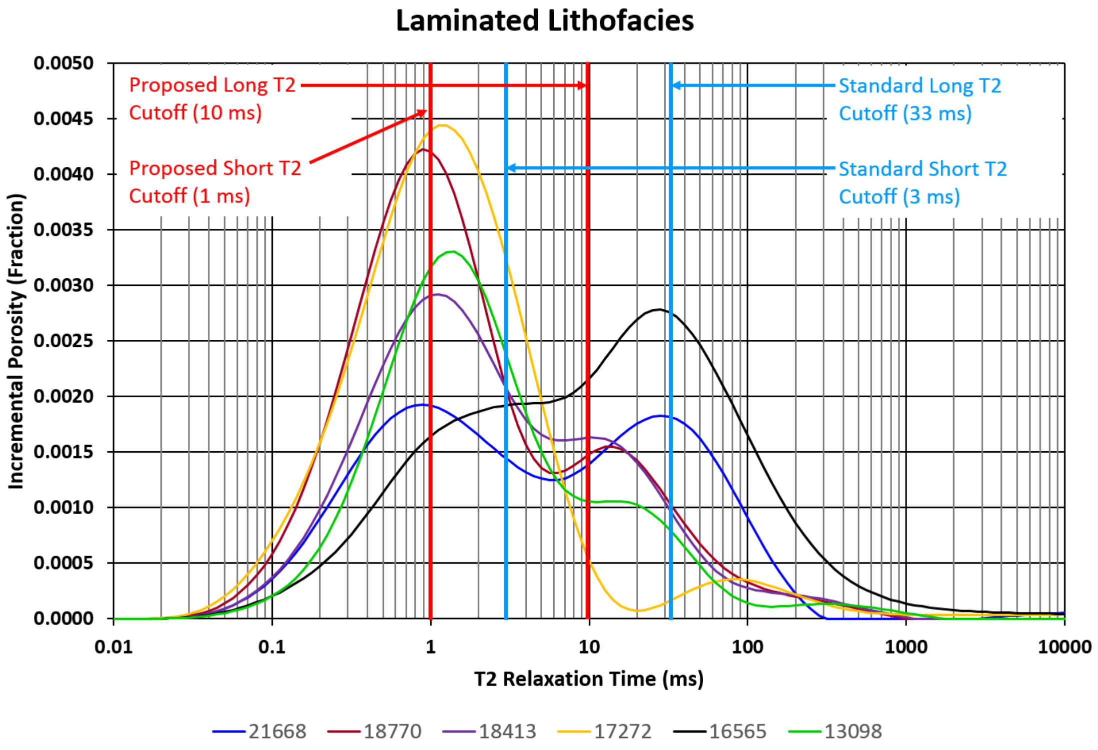
Three Forks Composition from XRD

Elemental Distribution with in the Three Forks using XRF



NMR Determination of Pore Size Distribution

- Three Forks laminated lithofacies
- Duel pore system
  - Clay bound and immobile fluid.
  - Free fluid
- Oil appears to be restricted to free fluid pore-space.
- Kyle Peterson

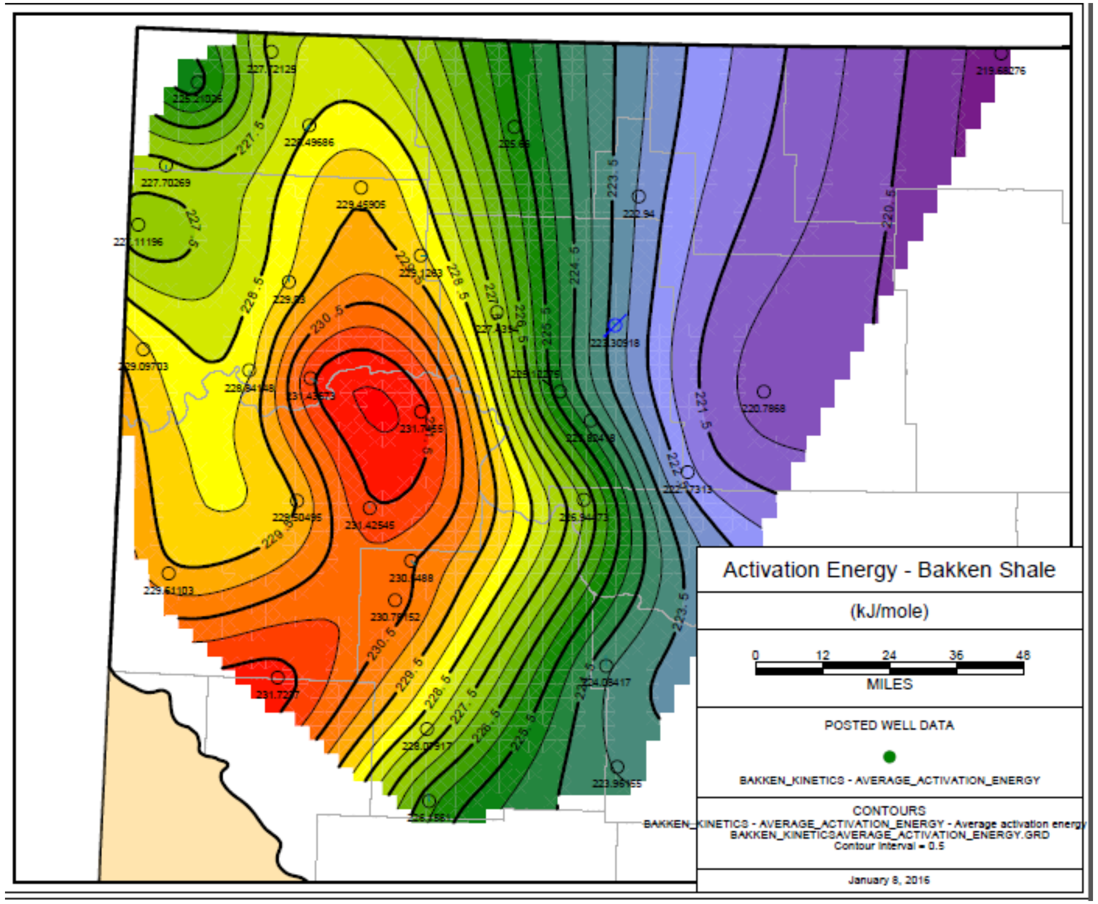


Source Rock Analyzer Lab

- Programmable Micropyrolysis
  - Mass free oil
  - “Crackable” kerogen mass
  - Organic oxygen mass
  - Total Organic Carbon (TOC)
  - Hydrogen Index (HI)
  - Oxygen Index (OI)
  - Thermal Maturation (T_{max})
  - Activation Energy
  - Custom analysis
- Purchased from Weatherford Labs
- Installed and operational

SRA: Current Applications

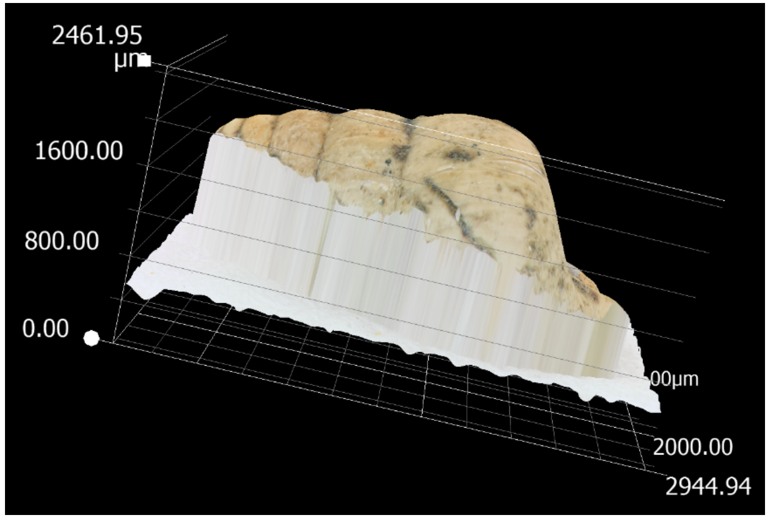
- Bakken
  - Assay the “live” kerogen content.
  - Use with kinetics and formation temperature to produce a modern reaction rate index. Chioma Onwumelu
- Red River
  - Use with stratigraphic analysis by Spencer Wheeler
  - Use kinetics to differentiate between kerogen “types”.
  - Relate kinetics to T_{max}
- Tyler
  - Use to evaluate source rock type(s), richness and quality.
  - Dilyn Stevenson & Michael Farzaneh
- Madison (Collaboration with NDGS)
  - Use to prospect for potential source beds



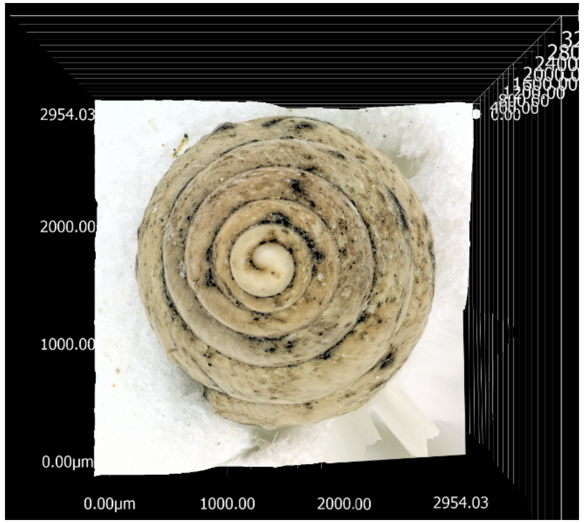
Hydrobia anthonyi (Meek and Hayden), 1856

USNM-PAL 2149

Keyence VHX-5000 HDR 3d digital image. Image can be rotated and measured in three dimensions, both in relief color or in normal light.

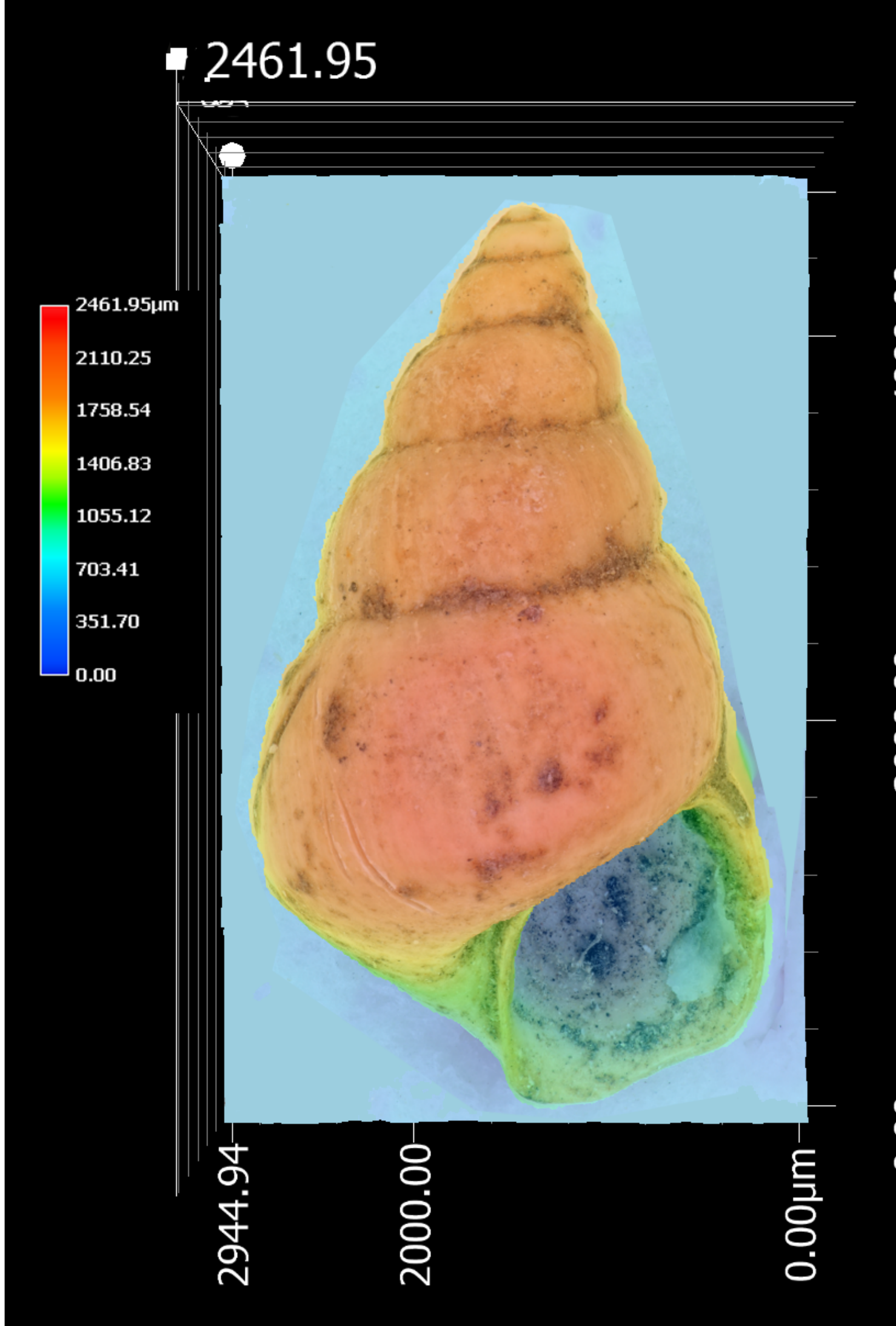


Left lateral view



Apical view

Hartman, March 17, 2017, Lens: Z20-x200, Mag: x76.6.
National Museum of Natural History, Paleobiology Collection.



Laboratory Upgrades

- The Collaborative Energy Complex and the expanded Wilson M. Laird Core Library provide additional laboratory space for student training and expanded research opportunities.
- The Petroleum Computer Laboratory, Chemical Analytical Laboratory, Core Preparation Lab, and the Materials Characterization Laboratory have been augmented with software and hardware to provide better support for student and faculty research associated with the Bakken Petroleum System.
- Chemical Analytical Laboratory (CAL) upgrades primarily used for student and faculty research associated with the Bakken Petroleum System.
- Petroleum Computer Lab (PCL) maintains software contributions from Schlumberger (Petrel) and IHS (Petra) and a second reservoir modeling package donated by CMP. Primarily used by upper level undergraduate and graduate students.

Computer Applications

- PETRA (IHS)
  - 40 seats (multiple computer labs)
  - Available online through Citrix
- PETREL (Schlumberger)
  - Multidisciplinary integrated system
- GPT Geological Reservoir Modelling.
- Caffe Convolutional Neural Network
- Agisoft (image processing)
- Surfer
- Schlumberger Applications
  - Eclipse
  - GEOX
  - Steady State
  - Merak
  - OLGA
  - PipeSIM
  - Petromod
  - Intersect

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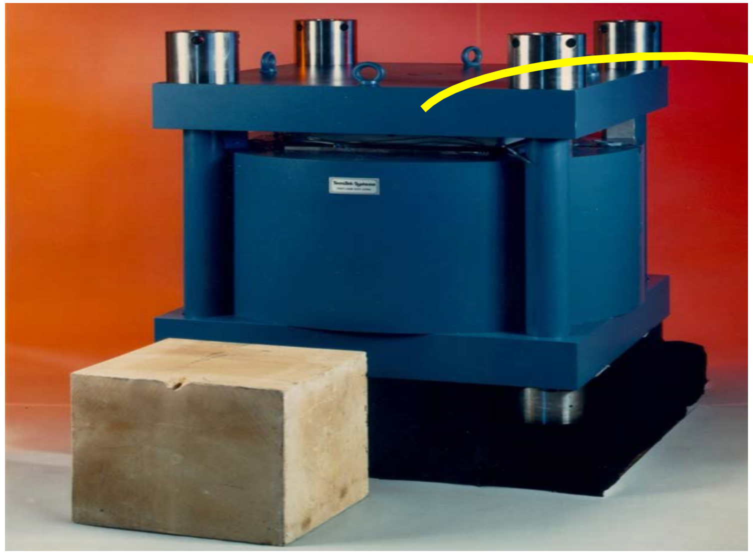
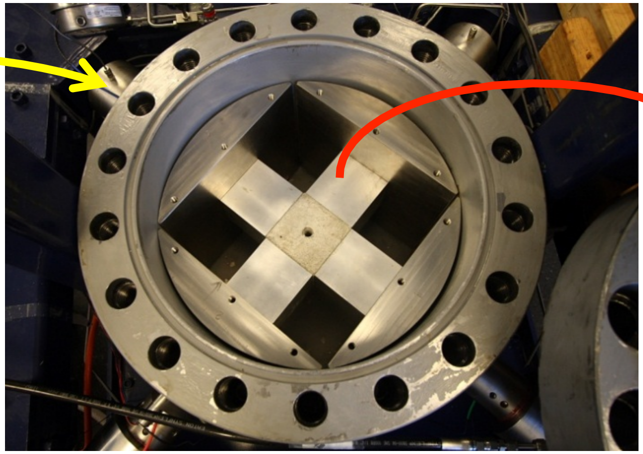
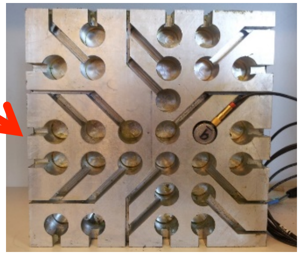
Proposed Polyaxial Cell

Lab scale reservoir simulation using a cubical rock sample as large as 5” under pore pressure, temperature and three independent stresses to simulate Hydraulic Fracturing, Sand production, depletion and injection etc.

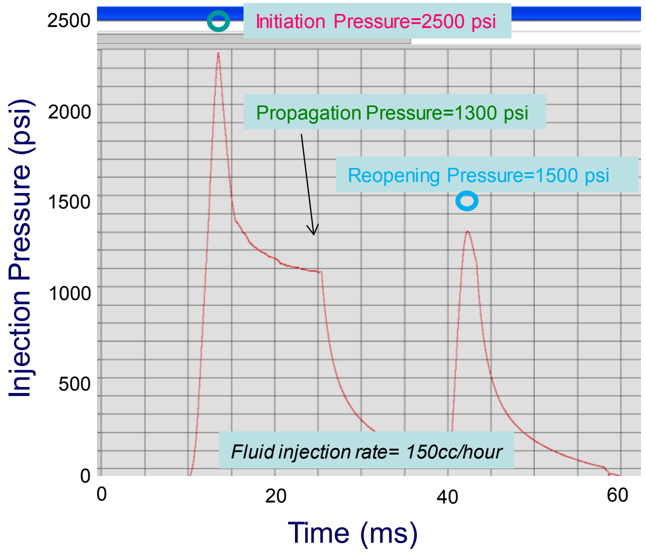


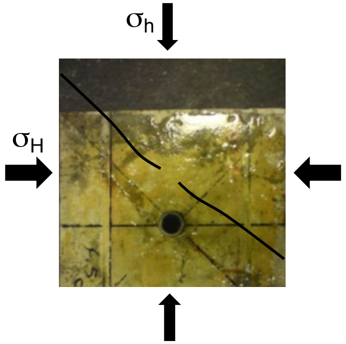


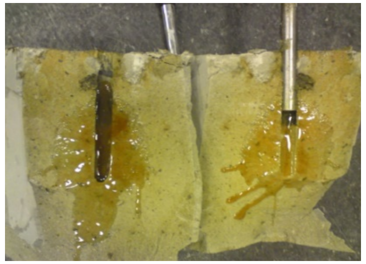
A 5”rock tested for HF



Seismic transducers placed in designed spacers to monitor fracture geometry







Interaction of HF with Natural Fractures. P-t curve (right) and images after the experiment

Summary: Significant Progress Achieved

- 211 students currently enrolled in Petroleum Engineering and 20 in Petroleum Geology/Geological Engineering. 35 MS/PhD students.
- 34 students graduated with BS degree 2016-17 academic year
- 75% students placed in petroleum-related industry
- 67% students with experiential learning experience including internships
- 8 petroleum engineering faculty / 4 petroleum geology/geology engineering
- Established working Industrial Advisory Board (22 members)
- Curriculum modernized with input from Industrial Advisory Board
- 15 thesis and dissertations and many publications and conference proceedings
- Analytical laboratory and virtual core available for student, faculty, EERC and industry use

Budget

	Original Budget	Current Balance
Virtual Core Library	$1,500,000	$349,000
Student Experience	$280,000	$173,000
Assistantships / Scholarships	$720,000	$314,000
Advanced Laboratory Equipment	$1,500,000	$0
Total	$4,000,000	$836,000

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Summary of Proposed Changes

- Transfer $170,000 from the Assistantship/Scholarship fund and $275,000 from subcontracts in the Virtual Core Library account to equipment to support the purchase of the polyaxial tester. A total of $450,000 will be committed to the purchase of this equipment. The remaining cost of the polyaxial tester will be paid from UND funds
- Utilize a portion of the Assistantship/Scholarship fund to pay student salaries (either as direct salary of through stipends) to support core facies analysis and to make the software/hardware upgrades necessary to support this work.
- Award graduate assistantships in excess of the annual $90,000 limit if funding is available
- Pay scholarships and graduate assistantships through December 31, 2017.
- Allow UND to receive and pay for the polyaxial tester if delivered after September 30, but before December 31, 2017.

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