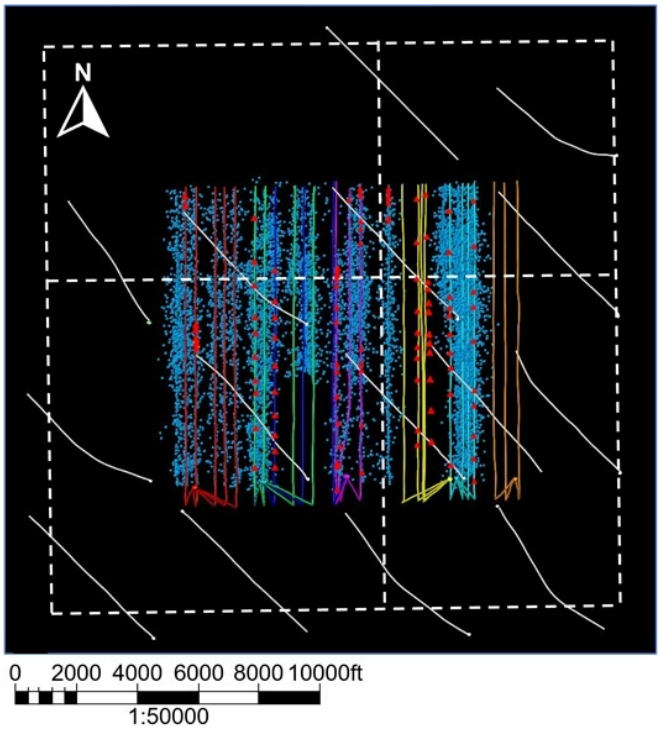
RCP

IN PURSUIT OF NEW IDEAS

RESERVOIR CHARACTERIZATION PROJECT



2019 Fall Sponsors Meeting

November 14th & 15th
COLORADO SCHOOL OF MINES

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RCP FALL 2019 SPONSORS MEETING

Colorado School of Mines, Golden, Colorado
November 14th and 15th, 2019

Thursday, November 14th: Field Studies

Time	Presentation	Presenter
8:00 AM	*Continental Breakfast & Registration*	
8:30 AM	Welcome	Dr. Tom Boyd, Senior Associate Provost for Operations
9:00 AM	RCP Overview and Welcome	Dr. Ali Tura, Co-director RCP
9:25 AM	Eagle Ford	Ufuk Durmus, Dr. Jim Simmons, Adam Tuppen, Gary Binder, and Youfang Liu
10:40 AM	*Coffee Break*	
10:55 AM	Eagle Ford, continued	Abdulrahim Al Mulhim, Kaveh Amini, and Youfang Liu
11:45 AM	Chalk Bluff Development Optimization	Dr. Ge Jin, Co-director RCP
12:15 PM	*Lunch*	
1:15 PM	Raudhatain Field, North Kuwait	Liwei Cheng and Nadima Dwihusna
2:00 PM	Machine Learning	Nadima Dwihusna
2:30 PM	*Coffee Break*	
2:40 PM	Midland Basin Project	Gary Binder and Aleksei Titov
3:45 PM – 5:00 PM	Student Posters	
4:15 PM – 6:00 PM	*Happy Hour*	

Friday, November 15th: Field & Research Studies

Time	Presentation	Presenter
8:00 AM	Welcome	Dr. Paul Sava, Interim Head of the Department of Geophysics
8:15 AM	Fiber Optics Research Program	Aleksei Titov, Kagan Kutun, and Gary Binder
9:05 AM	Laboratory Assessment of Improved Oil Production from Unconventional Shale Reservoirs	Asm Kamruzzaman
9:25 AM	*Coffee Break*	
9:35 AM	Compressive Sensing in Seismic Acquisition	Anna Titova
10:05 AM	Tight Gas Sandstone Reservoirs in Neuquen Basin	Atilas Silva
10:30 AM	Offshore Deepwater Project: Jubarte Field, Brazil	Andrea Damasceno, Max Velasques, and Moacyr Bezerra
12:00 PM	North Sea 4D	Sima Daneshvar and Payson Todd
12:30 PM	*Meeting Adjourns*	

RCP Students

Abdulrahim Al Mulhim
Degree: MS Petroleum Engineering
Hometown: Alahsa, Saudi Arabia
Project: Eagle Ford
Topic: Hydraulic fracture modeling

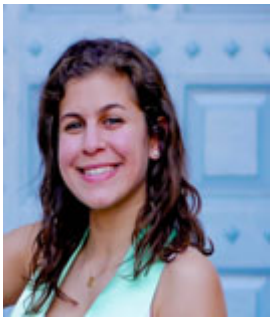
Kaveh Amini
Degree: PhD Petroleum Engineering
Hometown: Parker, Colorado
Project: Eagle Ford
Topic: Reservoir modeling, enhanced oil recovery, hydraulic fracture modeling, multi-phase flow

Nurbol Bekbossinov
Degree: MS Petroleum Engineering
Hometown: Almaty, Kazakhstan
Project: Chalk Bluff
Topic: Integrated characterization of northern DJ Basin, Colorado; Reservoir modeling with hydraulic fracturing optimization

Dwaipayan Chakraborty
Degree: MS Geophysics
Hometown: Kolkata, India
Project: Eagle Ford
Topic: Near-real time automatic microseismic event classification and location in downhole fiberoptic data using machine learning

Liwei Cheng
Degree: PhD Geophysics
Hometown: Taipei, Taiwan
Project: Middle Marrat, North Kuwait
Topic: Integrated reservoir characterization of the Raudhatain field

Andrea Damasceno
Degree: MS Geophysics
Hometown: Natal, Brazil
Project: Offshore Deepwater: Jubarte Field, Brazil
Topic: Deepwater Turbidite reservoir characterization using a PRM Seismic Dataset



Sima Daneshvar
Degree: MS Geophysics
Hometown: Houston, Texas
Project: North Sea 4D
Topic: 4D simultaneous PP PS pre-stack inversion in the Edvard Grieg oil field, Norwegian North Sea

Moacyr De Souza Bezerra
Degree: PhD Geophysics
Hometown: Espito Santo, Brazil
Project: Offshore Deepwater: Jubarte Field, Brazil
Topic: Time-lapse (4D) and multi component seismic processing for enhanced reservoir characterization

Ali Downard
Degree: MS Geophysics
Hometown: Paw Paw, Michigan
Project: Chalk Bluff
Topic: Integrated characterization of northern DJ Basin, Colorado; Machine learning applications to reservoir characterization

Ufuk Durmus
Degree: MS Geophysics
Hometown: Istanbul, Turkey
Project: Eagle Ford
Topic: Rock Physics Modeling for Eagle Ford shale

Nadima Dwihusna
Degree: MS Geophysics
Hometown: Bakersfield, California
Project: Machine Learning
Topic: Lithology classification using supervised and unsupervised Machine Learning (ML); seismic inversion and integrated reservoir characterization and modelling through ML

Owen Huff
Degree: MS Geophysics
Hometown: Macomb, Illinois
Project: Eagle Ford
Topic: Processing and interpretation of microseismic and VSP distributed acoustic sensing data; hydraulic fracturing time-lapse analysis

Asm Kamruzzaman
Degree: PhD Petroleum Engineering
Hometown: Dhaka, Bangladesh
Project: Enhanced Oil Recovery
Topic: Enhanced Oil Recovery in unconventional resources

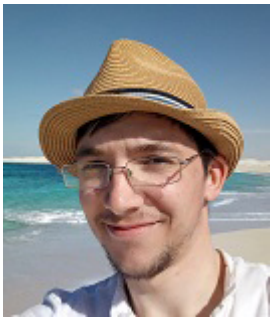
Kagan Kutun
Degree: PhD Petroleum Engineering
Hometown: Mersin, Turkey
Project: Fiber Optics Research Program
Topic: Experimental and numerical investigation of distributed temperature data

Youfang Liu
Degree: PhD Geophysics
Hometown: Jiujiang, China
Project: Eagle Ford
Topic: Multicompont time-lapse seismic analysis for hydraulic fracturing monitoring

Balnur Mindygaliyeva
Degree: MS Petroleum Engineering
Hometown: Aktobe, Kazakhstan
Project: Chalk Bluff
Topic: Integrated reservoir characterization of northern DJ Basin, Colorado; Reservoir modeling

Harrison Schumann
Degree: MS Geophysics
Hometown: San Antonio, TX
Project: Chalk Bluff
Topic: Integrated characterization of northern DJ Basin; Machine learning applications to well log and seismic data analysis

Atilas Silva
Degree: MS Geophysics
Hometown: Brasilia, Brazil
Project: Tight Sands - Neuquen
Topic: Quantitative seismic interpretation, seismic characterization of natural fractures, seismic inversion, high pressured gas reservoirs, tight gas



Aleksei Titov
Degree: PhD Geophysics
Hometown: St. Petersburg, Russia
Project: Fiber Optics Research Program
Topic: Laboratory and numerical modeling for quantitative analysis of distributed acoustic sensing (DAS) data

Anna Titova
Degree: PhD Geophysics
Hometown: Omsk, Russia
Project: Compressive Sensing in Seismic Acquisition
Topic: Seismic acquisition, compressive sensing, data interpolation, matrix completion

Payson Todd
Degree: PhD Geophysics
Hometown: Evergreen, Colorado
Project: North Sea 4D
Topic: How well do we know what we think we know? Uncertainty in seismic data interpretation

Max Velasques
Degree: MS Geophysics
Hometown: Rio de Janeiro, Brazil
Project: Offshore Deepwater Project: Jubarte Field, Brazil
Topic: Impact of simultaneous source acquisition on 4D seismic response

Isabel White
Degree: PhD Geophysics
Hometown: New York City, New York
Project: Pouce Coupe
Topic: Pouce Coupe microseismic processing: shear wave splitting and tomography

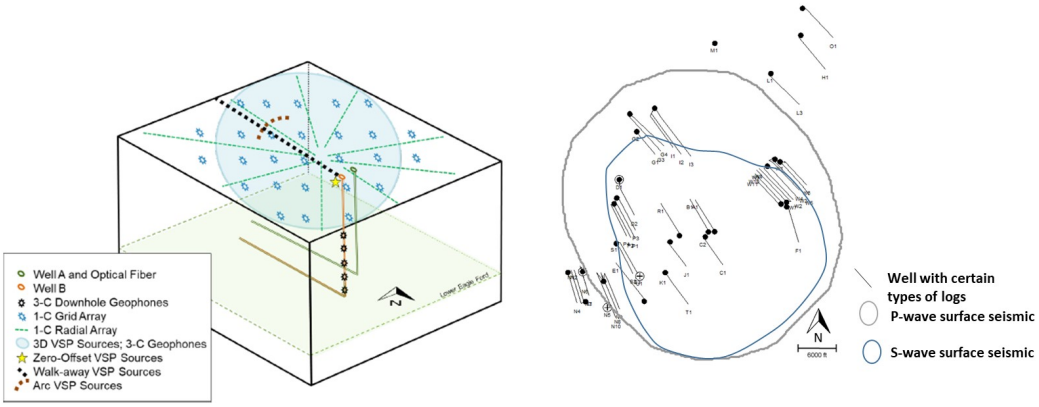
Eagle Ford Project

Kaveh Amini, Gary Binder, Dwaipayan Chakraborty, Owen Huff, Youfang Liu, Abdulrahim Al Mulhim, and Ufuk Durmus

Project Goals

The Eagle Ford team seeks to understand hydraulic fracturing practices by analysis of well log and time-lapse datasets available in the project. An integrated workflow has been designed to create static and dynamic models of the reservoir to study the processes occurring during stimulation and production. The knowledge gained through this work improves field development through better well placement, stimulation design and new methods.

Data



Objectives

- Create novel rock physics model to characterize the effects of mineralogy, kerogen content and porosity on seismic and geomechanical properties
- Develop an AVA inversion algorithm using 9 component surface seismic data for P-impedance, S-impedance and density estimation
- Create the static model using well log and surface seismic data for reservoir simulation
- Improve the microseismic analysis from combination of DAS and surface geophone array to potentially update the dynamic model
- Develop an algorithm for near-realtime auto-detection of microseismic events during 15 stages of hydraulic fracturing in Eagleford Shale using downhole DAS and surface 3C data
- Optimize future treatments within landing zones in the studied area using hydraulic fracture modeling for certain wells
- Integrate the static model (well log and seismic) and dynamic model for reservoir simulation
- Perform sensitivity analysis for optimizing well-spacing

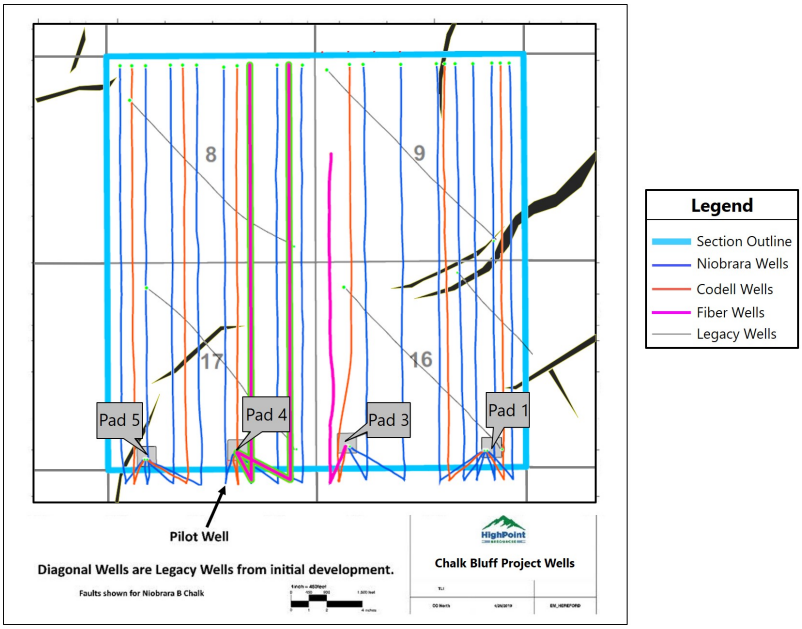
Chalk Bluff Development Optimization

Ali Downard, Harrison Schumann, Balnur Mindygaliyeva, and Nurbol Bekbossinov

Project Goals

The ultimate goals of the project are to increase recovery and optimize hydraulic fracturing operations for cost-effective development of this unconventional reservoir in the Hereford Field. This reservoir is being re-developed by HighPoint Resources, so understanding how pre-existing legacy wells impact optimal well spacing, fracture orientation and width, and well-to-well connectivty will be key to reaching these goals.

Data



- Geophysics: 3D seismic, surface microseismic, tiltmeter, and DAS
- Engineering: DTS, pressure analysis, and completion/treatment
- Geology: geochemical data, full log suite, and image logs

Objectives

- Understanding drivers and processes of vertical and horizontal connectivity
- Understanding legacy development effects and how to mitigate them
- Determining stage and cluster spacing that maximizes DSU economics
- Examining how fractures respond to existing faults and subsurface heterogeneity
- Developing new reservoir analysis methods (fiber optics, geochemistry, etc.)
- Integrating the subsurface static, geomechanical fracture, and dynamic models to provide predictive capability
- Understanding value of EOR for field implementation in a future phase of the project

Raudhatain Field, North Kuwait

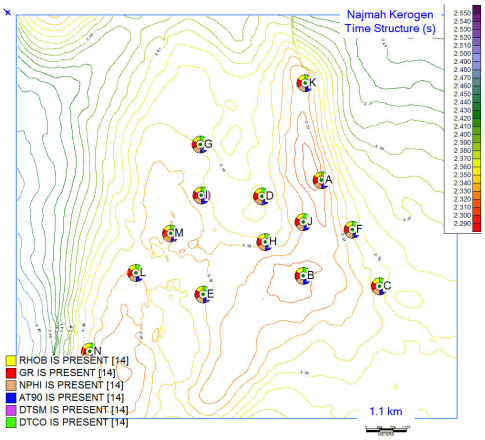
Liwei Cheng and Nadima Dwihusna

Project Goals

The Raudhatain field project has two sub-projects leading to better reservoir development and management. The first sub-project aims to improve the seismic imaging at deep Jurassic reservoirs through attenuating inter-bed multiples, caused by the high velocity carbonate and anhydrite overburden, in both pre- and post stack domain. The second sub-project is to use the seismic and well logs at the shallow reservoir level for machine learning based facies inversion and lithology characterization. The goal is to better understand the depositional setting, fractures, and facies. This method will rely on many wells and a good quality of seismic data that matches the well when modeled. The integrated rock facies inversion results from the machine learning analysis will be used to characterize the fracture sweet spot and subsurface interpretation.

Data

The data include 3D wide-azimuth P-wave surface seismic data, four wells of VSP data and fourteen wells with well logs.



Objectives

Deep Jurassic reservoir characterization and multiple attenuation project

- Predict the multiples and evaluate the multiple attenuation methods used in the industry
- Attenuate inter-bed multiples and improve imaging at deep Jurassic reservoir intervals
- Characterize fractures from the multiple-attenuated seismic data for the reservoir development

Seismic and facies inversion through machine learning project

- Apply machine learning in well logs for facies inversion
- Employ machine learning in seismic trace surrounding each well log
- Utilize machine learning for the seismic and facies inversion for the entire field

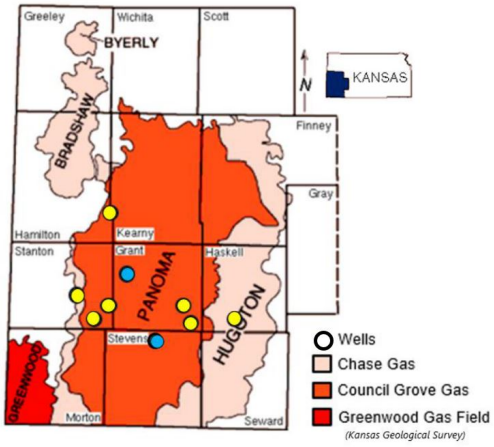
Machine Learning

Nadima Dwihusna and Harrison Schumann

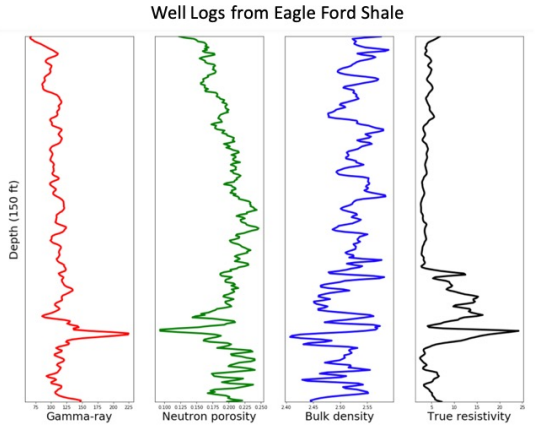
Project Goals

The growth of both data volume and data types in the development of a modern oilfield is stretching the capabilities of traditional manual workflows. Machine learning methods allow us to make sense of large volumes of data with many variables while avoiding the biases that humans can bring to such analysis. This project focuses on developing automated well log QC and lithology classification algorithms. A standardized workflow is being developed to test a large variety of machine learning algorithms and hyperparameter combinations to find the best performing model. Various types of DNN and CNN models are also tested to seek better prediction performance.

Data



The data used for lithology classification are in the Hugoton and Panoma Field in the South of Kansas with 9 total wells: 7 training wells (yellow) and 2 blind test wells (blue) (Kansas Geological Survey, 2019).



The well log data from Eagle Ford Shale are used for automated well log QC and classification.

Objectives

- Develop a machine learning model that automatically performs facies inversion for Hugoton and Panoma Field Kansas project.
- Compare the performance of different DNN and CNN structures in facies recognition.
- Develop a workflow for automated well log QC and classification.
- Implement feature selection through Random Forest Feature Importance and Principal Component Analysis (PCA).

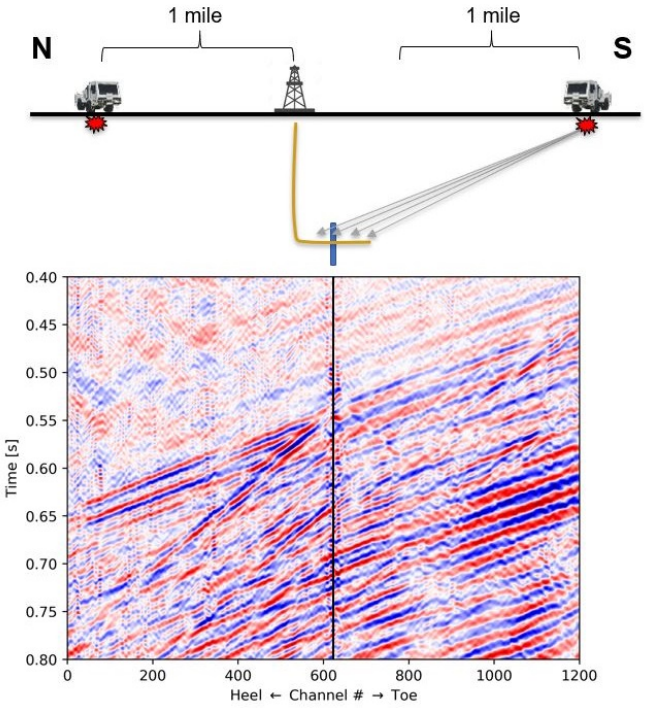
Midland Basin Project

Gary Binder and Aleksei Titov

Project Goals

The Midland Basin Project centers around the use of Distributed Acoustic Sensing (DAS) to conduct vertical seismic profiling (VSP) surveys after each stage of hydraulic fracturing. It is a continuation of the previous Phase XVII Wolfcamp Project, and for Phase XVIII, Apache has provided an improved dataset acquired with engineered fiber optic cable technology in the Midland Basin. The goal of the project is to characterize the stage-by-stage geometry and evolution of the stimulated rock volume (SRV) through analyzing time shifts and scattered waves observed after each survey.

Data



A difference record from the right vibroseis source showing a PS conversion as the incident P-wave scatters off the stimulated rock from a single stage

Objectives

- Use scattered waves and time shifts to estimate the height, elastic rock properties, and leak-off behavior of the stimulated rock volume
- Understand the interference of other wells in a zipper group on the time-lapse seismic response and what that can say about horizontal and vertical connectivity between wells
- Design future acquisition geometries to better characterize properties of the SRV

Fiber Optics Research Program

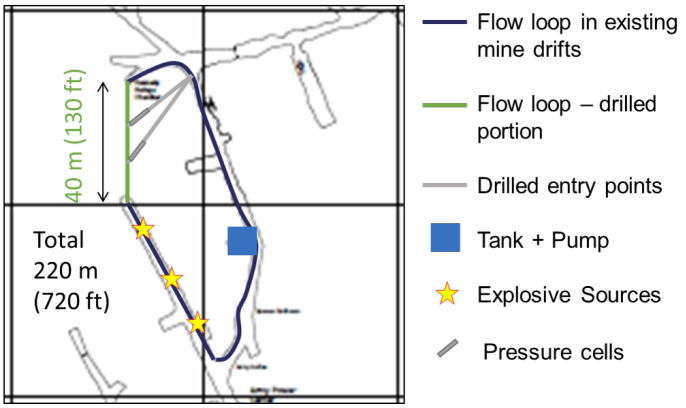
Gary Binder, Aleksei Titov, Kagan Kutun, Dwaipayan Chakraborty, and Owen Huff

Project Goals

The Fiber Optics Research Program (FORP) aims to improve the acquisition, processing, modeling, and interpretation of Fiber-Optic Sensing (FOS) data, which includes Distributed Acoustic Sensing (DAS), Distributed Temperature Sensing (DTS), and Distributed Strain Sensing (DSS). We are developing applications including fracture-strain monitoring, DAS-based 4D VSP, DAS-based microseismic monitoring, and FOS-based production logging.

Data

Edgar Research Mine Flow Loop Equipped with DAS and DTS



Objectives

- Design and execute laboratory tests by deploying fiber-optic cable in multi-phase flow loops on the Mines campus and in the Edgar Research Mine. Investigate the generation and propagation of thermal and acoustic energies in the borehole and their interaction with fiber-optic fiber with various installation methods. Use FOS data to estimate flow regime, flow rate, and holdup.
- Use DAS to monitor microseismic. Develop algorithms for event detection, locating, and moment tensor inversion. Investigate the potentials of using microseismic for imaging purposes.
- Develop algorithms to analyze DTS warmback data. Develop algorithms to invert for near-wellbore rock property and hydraulic fracture density.
- Develop geomechanics models to quantitatively analysis cross-well low-frequency DAS measurement. Develop algorithms to further constrain fracture geometry.

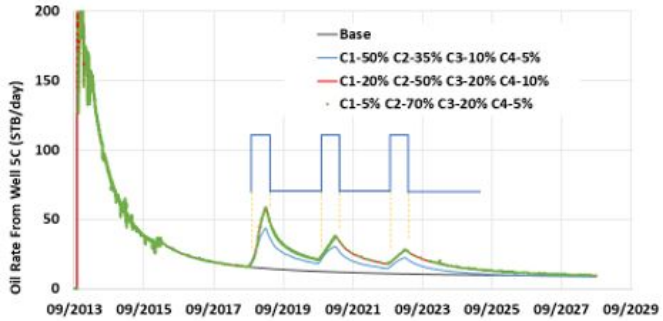
Laboratory Assessment of Improved Oil Production from Unconventional Shale Reservoirs

Asm Kamruzzaman

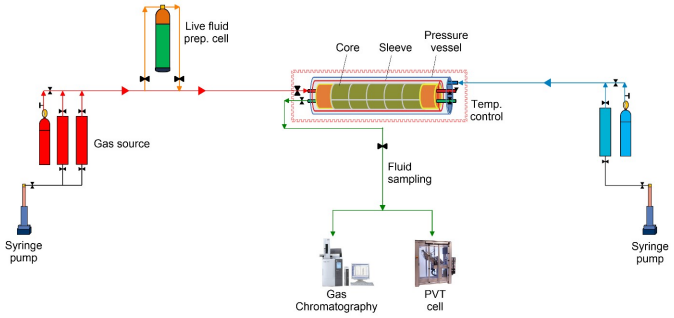
Project Goals

The cumulative oil production from liquid-rich unconventional shale reservoirs is around 6%; thus, there is a need to search for new ideas to increase the current level of oil recovery from shale to higher levels. The goal of this study is to understand and quantify the fundamentals of gas injection EOR in shale reservoirs in the laboratory.

Data



Production performance of a Niobrara Wattenberg well after gas injection at 1.0 MMscf/d



Schematic of the proposed shale EOR laboratory setup

Objectives

- Determine incremental oil recovery in unconventional shale cores at reservoir pressure and temperature conditions.
- Address pressing questions about the micro- and macro-scale EOR processes that control the mobility of hydrocarbons in fractured and unfractured shales.
- Use in-house reservoir model to evaluate gas injection EOR, and scale laboratory results to field.

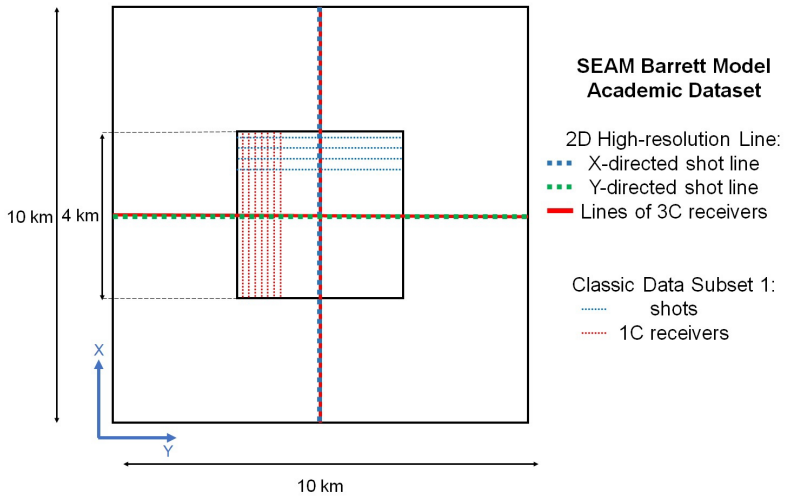
Compressive Sensing for Seismic Acquisition

Anna Titova

Project Goals

The project aims to understand the value and limitations of the Compressive Sensing (CS) sampling paradigm for seismic data acquisition by testing existing and new CS methods on synthetic and field data.

Data



Objectives

- Analyze currently existing CS sampling strategies in terms of reconstruction accuracy
- Search for metrics that guide CS-based survey design and guarantee an adequate range of the reconstruction error
- Detemine sparsity level of seismic data under different sparse transforms
- Study how noise influences the seismic sparsity level
- Investigate matrix completion reconstruction technique

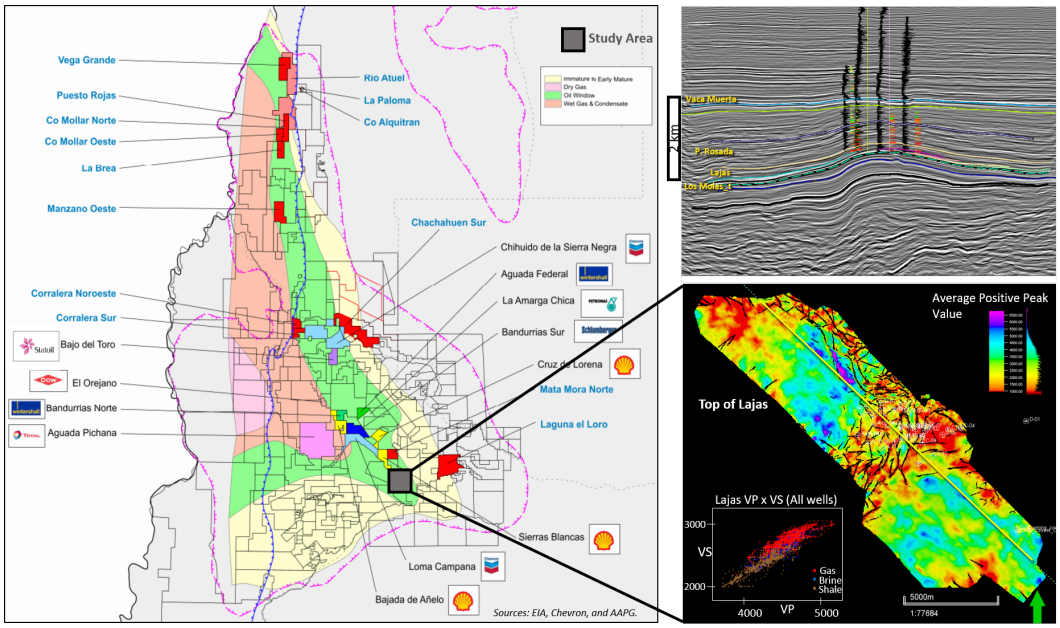
Tight Gas Sandstone Reservoirs in Neuquen Basin

Atilas Silva

Project Goals

The goal of this project is to use a rock physics model to understand the seismic response of the tight gas sandstones of the Lajas and Punta Rosada formations. The seismic response of high porosity sandstones is mainly controlled by mineral composition, porosity, and fluid type. In contrast, in tight sandstone reservoirs, pore structure is likely the property that most greatly influences seismic impedance. An increase in velocity is mainly due to the closure of micro-cracks and compliant pores. Hence, for tight rocks, to accurately represent the seismic impedance variation, it is necessary to apply a rock physics model in which the pore aspect ratio is considered as an input.

Data



Left: Study area on the Vaca Muerta thermal maturity map. Upper right: Seismic section. Sonic Log in black. Gas saturation log shows gas zones in red. Lower right: Average Positive Peak Value within Lajas Formation. Fractures are represented as black lines.

Objectives

- Choose a rock physics model that can best represent the seismic response of the tight sand of the study area
- Construct rock physics templates aiming to quantitatively predict the seismic response as a function of key rock properties (porosity, pore aspect ratio, gas saturation, anisotropy, fracture density, pore pressure, etc.)
- Identify sweet spots in the seismic inversion data

Offshore Deepwater Project (Jubarte Field, Brazil)

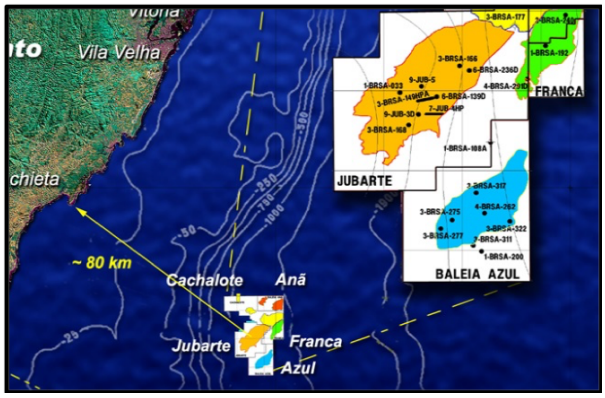
Andrea Damasceno, Max Velasques, and Moacyr Bezerra

Project Goals

The studies related to this project comprise areas of seismic acquisition, processing, and reservoir characterization. The data is being used to better understand the post-salt reservoir dynamic properties, and as a background for further analysis involving the feasibility of 4D simultaneous sources acquisitions and seismic sensors orientation correction with 4D consistency.

Data

Discovered in 2001, Jubarte is an oil accumulation with excellent permo-porosity conditions. The seismic data for this project are a PRM (Permanent Reservoir Monitoring) 4D-4C acquisition.



Jubarte field geographical location map

Objectives

- In the reservoir characterization part of the project, we are using this rich dataset to perform a 4D quantitative interpretation, integrating seismic (4D inversion and time-shifts), rock physics models, and fluid flow simulation data;
- The seismic acquisition branch of the project is using synthetic and field data to analyze how simultaneous source acquisitions would affect the 4D signal for post-salt and sub-salt reservoirs.
- In terms of seismic processing, horizontal component energy leakage into the vertical component is a problem that has been studied by both the industry and academy for a long time with very good results, and the proposal is to include both anisotropy and 4D consistency in order to avoid artifacts in the 4D signal.

North Sea 4D

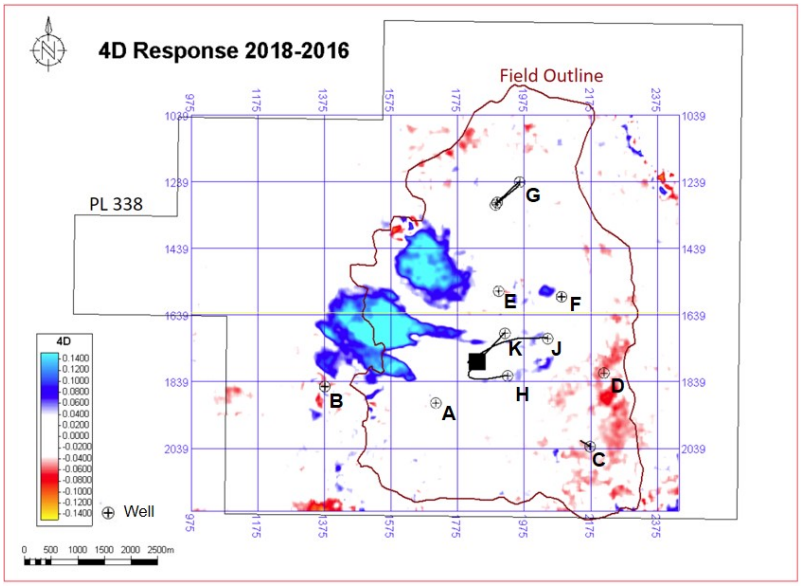
Sima Daneshvar and Payson Todd

Project Goals

Reservoir characterization challenges arise from the depositional complexity of the Edvard Grieg reservoir and overburden; consequently, detailed analysis must be done to plan for future development. This project evaluates potential benefits of using multicomponent data to better understand reservoir geometry, heterogeneity, and effects of production and injection.

Data

The operator of the field, Lundin Norway, has provided PP and PS processed gathers from 2016 and 2018, along with 12 well logs.



Objectives

- Analyze rock properties of the reservoir to determine potential benefits of PS data
- Evaluate AVA response in reservoir and overburden to better characterize the reservoir and identify challenges in the dataset
- Perform 4D joint PP-PS inversion to improve the S-impedance, Vp/Vs, and potentially density estimates to ultimately aid in interpretations of reservoir heterogeneity, quality, and response to development

Notes