May 2018

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 8 • Number 9

The Epicenter of Geophysical Excellence

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Spring Symposium honoree: Dave Hale

Photo courtesy of Nicola Maitland

EDITOR'S NOTE

To ensure your information reaches the GSH members in a timely manner, please note the following deadlines and plan accordingly. Please submit your articles and any questions to Dmitry Kulakov, editor, at dkulakov@slb.com

GSH JOURNAL DEADLINES

Sept 2018 ..... **July 13**
Oct 2018 ..... **Aug 16**
Nov 2018 ..... **Sept 13**

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A Word from the Board

IT'S ALL ABOUT FAMILY…

BY Denise Dorsey – 2nd VP Elect

Growing up in the Oil & Gas Industry has given me a unique perspective into this family we call Geophysicists. From as early as I can remember, I was attending local Geophysical Society events which my father was an active member. From Crawfish boils in New Orleans to Family Day at Oklahoma City's Frontier City, we followed my father around as he introduced us to the Geophysical family. Leading by example, my father taught me that by being a part of the local Geophysical Society, as well as the national society, the Society of Exploration Geophysicists, one becomes an integral member of an extraordinary group of people. Every city where I have worked, I have found that by being a member of the local Geophysical Society has helped me to understand the pulse of this big industry. The Geophysical Society of Houston is no exception.

When I first moved to Houston 9 years ago, I immediately sought out the local society, joined, began attending functions, and then volunteered my time. I found out that the GSH has 100 plus technical and social events each year! There are plenty of places to learn, share ideas, and socialize with fellow geophysicists.

Six social events are scheduled every year. The fiscal year starts with an Icebreaker event in September, followed by the Fishing Tournament in October, Tennis Tournament in November, Sporting Clays in March, Golf Tournament in April or May, and ending the year with the Honors and Awards Banquet in May. By attending, sponsoring, and supporting these events, you are benefitted by meeting other people in our industry, supporting the local society, and having a great time. It is a win-win all the way around!

This year's Honors and Awards Banquet will be held on Thursday, May 3rd at the Hotel Sorella La Scala Ballroom. Everyone is invited to join us as we honor our colleagues who have milestone GSH and SEG anniversaries, as well as GSH Honorary and Life members. Buy your tickets online on the GSH web site. I can assure you that this event will be one of the most rewarding experiences you will ever attend!

On September 27th we will start the new fiscal year with the annual Icebreaker at Saint Arnold's Brewery located at 2000 Lyons Avenue in Houston. Be sure and put this on your calendar now. It's a great time to connect with old friends and make new ones while you enjoy tasting the different beers brewed locally here in Houston.

The GSH-HGS Annual Saltwater Fishing Tournament will be on Friday, October 5th. You don't want to miss this fun competition. Trophies are given out for the heaviest fish in different categories.

Denise Dorsey

A fantastic place to volunteer and educate the public in the geosciences is with the GSH Community Outreach Committee. Lisa Buckner heads this team of volunteers who spend their evenings and weekends traveling all over the greater Houston area visiting schools, museums, and festivals getting the next generation excited about the family of geoscientists.

Each month the GSH hosts Technical breakfasts, Technical lunches, Webinars, and Special Interest Groups in different places around the Houston area. These provide a perfect opportunity to increase your knowledge, as well as strengthen networking with other geoscientists.

Don't miss out on the many opportunities the GSH has to offer! I promise you won't regret becoming a part of the Geophysical Family. In the end, it's all about family!

Looking for more ways to participate in the Geophysical Society of Houston?

Consider how you can make a difference by volunteering at one of our events!

Contact Nicola Maitland to learn more about this excellent networking opportunity:

nmaitland@resolvegeo.com - 713-972-6209

Dear GSH Journal reader,

Please, feel free to contact any of us with any and all questions or suggestions that you can come up with.

editor@gshtx.org

Sincerely,

Dmitry Kulakov, Editor

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From the Other Side

By Lee Lawyer

Whether the subject is "Hands-Free", "Artificial Intelligence", "Drones", or "Driverless", these terms are all different. Usually, a Drone is maneuvered by a pilot remotely from the Drone. Hands-Free might refer to an automobile that is NOT remotely controlled. I understand that there was a driverless truck that travelled from the West Coast to Florida, without help from a human (but the human was along for rest stops).

I just attended a Tech Breakfast that featured Dave Chalenski, with Shell. His subject was "Rapid Autonomous Marine 4D (RAM4D)". It's a marine system that involves a single small surface vessel towing a small seismic source. It operates without escort, following pre-charted shot-points without human intervention. A later version may have a short cable that will be towed behind the source boat. I really like experiments. Back in the 50's 60's and 70's, we were constantly trying out new ideas. You may say that there is nothing new for experimentation. However, data acquisition is a major exception to that idea.

But why do we want unmanned systems? Consider the oil industry. A drone that places things on the ocean floor 5,000 feet deep sounds like a great idea. It is the only way to do so, but that we know there are more ways to acquire seismic data. In the case of RAM4D, the motive is to acquire 4D data at significantly reduced cost.

First, we have to discuss the value of 4D data in a proven oil field. A lot of things change when we produce large amounts of liquid from a reservoir. Sometimes we change the response to a seismic signal. Ergo, 4D data may be able to detect those changes. Stop there. Let's assume there is an economical return on acquiring 4D data. The research work of Shell is directed toward cutting costs of acquiring that 4D data set. There are interesting possibilities in having a relatively inexpensive way of acquiring 4D data. One big way is being able to increase the frequency of the surveys, and the value of such surveys depend on the frequency of the changes see in the reservoir (Simple sample theory).

You may ask, "Why is Shell publishing these things?" Good question. Dave Chalenski stated it plainly. They come up with the basic principle and conduct experiments to prove viability, and then turn the implementation over to service companies, which will hopefully provide them the ability to gather the data at a significantly lower price. This is similar to the development and usage of 3D surveys in the 70's and 80's, when it was almost impossible to get a 3D survey conducted over a recently discovered oil field. Technology was improving but not getting any less expensive. We sold it to the Production people on the basis of value. It was a difficult sale back then, and I suspect it is still difficult to convince a production engineer to conduct an expensive seismic survey several times to look for small changes in the reservoir.

ExxonMobil conducted electrical surveys in a marine setting to prove its viability. They published it and turned the implementation over to service companies. I can't recall Chevron doing anything like that. Chevron and others closed their Exploration/Development Research departments several years ago. I don't think Shell and ExxonMobil went that way.

Universities often are required to make research results available to the sponsors who donate funds. Often the sponsors have a say in how the research is managed. Maybe that is too strong. Maybe the sponsors can influence the research direction.

Back to the subject of "virtual reality", which is like "hands-free". They were talking about using visual aberrations that make it seem as if you are experiencing something real, thus allowing one to get sea -sick sitting at your desk. I guess all of this is going to happen whether it is "good or bad".

For practical purposes we have pilotless airplanes that can take off, navigate and land without human intervention (unless a problem arises). Ground traffic is a little different than air traffic. Maybe someday we will be free of cars running into other cars. That will put the repair shops out of business and maybe insurance companies. How nice for us. I have a car now that will detect a car in your "blind zone", warn you if you are about to collide with another vehicle, automatically use the wind shield wiper if it rains, allow you to answer your cell phone hands-free, and look backwards when reversing without turning around. There are many more examples, too.

Artificial Intelligence (AI) seems to be different than "hands-free". It is said that the definition of insanity is repeating the same experiment, but expecting a different result each time. Happily, computer algorithms give the same answer over and over. Artificial Intelligence is just the opposite. In AI, if you get the same answer each time, something is not working correctly.

I don't know where I am going with all of this, but it is interesting, don't you think?

Technical Luncheons

What We've Learned From 3 Years of Doing ISM: Five Big Lessons That Can Help Oil and Gas Operators Better Mitigate Risk

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Dario Baturan

Speaker(s): Dario Baturan, Nanometrics Passive Seismic Monitoring Services division

Westside

Tuesday, May 15, 2018
11:00 a.m. – 1:00 p.m.

Location: Norris Conference Center (City Centre)
816 Town & Country Blvd.
Houston, TX 77024
(Free parking garage off Sam Houston Tollway/Beltway-8 northbound feeder or Town & Country Blvd)

Downtown

Wednesday, May 16, 2018
11:00 a.m. – 1:00 p.m.

Location: Petroleum Club of Houston Total Building
1201 Louisiana St,
Floor 35
Houston, TX 77002
($10 valet parking with discount – entrance is off of Milam Street)

Abstract:

Earthquakes can be induced by human activities such as mining, reservoir or dam impoundment, geothermal reservoir stimulation, wastewater injection, hydraulic fracturing or CO2 sequestration. Such events are predominantly small in magnitude, and are rarely felt locally or detected regionally. In certain areas of Canada and the US, the rates of seismicity characterized as induced or triggered have been increasing over the past several years; most concerning is the increase in the number and frequency of potentially damaging magnitude 3.0+ events. In Oklahoma, for example, the USGS reported more than 500 magnitude three or larger events in 2014, compared to only 53 between 1970 and 2005. As a result, states such as Oklahoma, Texas, Colorado, Ohio, Arkansas, California and others are investing an increasing amount of attention and resources into the issue. Responses have included closer investigation into specific events, requiring more extensive monitoring, developing regulations or even area-wide moratoriums in an attempt to mitigate risks associated with induced seismicity.

In this talk, I present key insights gained from three years of doing induced seismic monitoring (ISM) as well as results of the research done with ISM-generated seismic data. First, I discuss the key characteristics of observed induced seismicity and the benefits of high-quality ISM data sets with emphasis on how their value largely depends on appropriate instrument selection, sound seismic network design and data processing techniques utilized. Using examples from recent research studies, I illustrate the key role of robust modeling of regional source, attenuation and site attributes on the accuracy of reported event magnitudes, ground motion estimation and induced seismicity hazard assessment. Finally, acknowledging that the ultimate goal of ISM networks is in assisting operators to manage induced seismic risk, I share some examples of how ISM data products can be potentially used to measure the effectiveness of implemented risk mitigation protocols in near-real time.

Biography:

Dario Baturan has led mission-critical seismic monitoring projects worldwide for over a decade and has worked closely with academic researchers, governments, United Nations, and oil and gas operators. He has a wealth of expertise ranging from seismic network design, deployment, operations and data outcomes. As the Director of Technical Operations for Nanometrics Passive Seismic Monitoring Services division, Dario is identifying, developing and implementing the most client-focused and cutting-edge monitoring solutions available. He leads a diverse group of professionals in scientific research, geophysical data analysis, network operations and field operations. Dario has a B.Eng. in Computer Systems Engineering from Carleton University.

ANNOUNCING THE 2018

GEOPHYSICAL SOCIETY OF HOUSTON HONORS & AWARDS BANQUET

Thursday, May 3rd, 2018
Cocktails - 6:00 pm, Dinner - 7:15 pm

Hotel Sorella
La Scala Ballroom
800 Sorella Ct
Houston, TX 77024

Please join us as we honor our colleagues,
SEG and GSH Milestone Recipients,
and GSH Honorary and Life Members.

Spouses and guests are welcome.
Register online at www.gshtx.org.

For more information, contact Kat Pittman at
281-615-3339 or kpittman@resolvegeo.com

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SHEARWATER REVEAL

Technical Breakfasts

Delaware Basin PSDM Seismic Data: Why Near Surface Velocity Inversion Affects Image Integrity

Register for Tech Breakfast North

Register for Tech Breakfast West

Speaker(s): Bruce Karr, FairfieldNodal
Co-authors: Scott Tiefenthaler, Julie Schneider and Dong Li, FairfieldNodal, Houston TX

Bruce Karr

North

Tuesday, May 1, 2018
7:00 – 8:30 a.m.

Sponsored by Anadarko Petroleum and Lumina Reservoir Inc.

Location: Anadarko Petroleum
1201 Lake Robbins Drive
The Woodlands, TX 77380

West

Wednesday,May 9, 2018
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

Location: Schlumberger
Q Auditorium
10001 Richmond Ave.
Houston, TX 77042

Abstract:

Pre-Stack Depth Migration (PSDM) for Permian Basin seismic data has not been widely adopted. However a few companies began adopting PSDM starting about 4 years ago. PSDM is most commonly associated with complex structural overburden, typical in the Gulf of Mexico Tertiary section where advances in hardware and software have allowed for significant advances in image quality. This paper presents data comparisons in the central Delaware Basin where a deceptively simple structural overburden but a complex lateral velocity profile provides the motivation to use PSDM to improve image quality.

Generally, time to depth conversion using a simple velocity function will result in a mis-tie due to lateral velocity changes in the overburden. In processing we would say that is a "depth problem". A typical example is the case of a salt dome where sediments with a velocity of 10,000 feet per second rest unconformably against an intrusive salt with a velocity of 20,000 feet per second. Time migration is not adequate in this case due the limiting assumption of slowly changing lateral velocities. Depth migration, however, improves imaging by iteratively ray tracing through a velocity model until the CDP gathers are flat thus providing the clearest stack possible. The land data shown in this paper exhibit a shallow, high velocity layer of interbedded evaporates and anhydrites overlaying relatively lower velocity sediments. This high velocity, near surface inversion creates the ray path distortions similar to the offshore case of extreme lateral velocity changes.

The presentation starts with a look at the PSDM data and the ray bending caused by a near surface velocity inversion. (Figure 1). A quick look at a few wells confirms the near surface high velocity inversion. The wells also confirm the velocity and the complexity of not just anhydrite but slower salts within the anhydrite rock and their changing thickness. Both the anhydrites and salts are higher velocity than the underlying shales and sands in the immediate Delaware section. It is this zone immediately below the high velocity layers that is improved from a depth imaging. As we move deeper in the section from the Delaware group into the Bone Spring Group and eventually to the Wolfcamp section, the problem begins to heal itself. Unfortunately, depending on the thickness and complexity of the velocity changes from above, the Bone Spring Group through the top of the Wolfcamp section can be affected.

Biography:

Bruce Karr, Technical Sales Manager for Fairfield Seismic Technologies, has worked for FairfieldNodal since 1994 as a Geophysicist. Mr. Karr's processing expertise includes 3D and 4D multi-component land data, with particular focus on geophysical problems including long wave length statics, spectral enhancement, noise, depth-time issues, multi-component data and field technology.

Mr. Karr received a BS in Geophysical Engineering and a minor in Geology from the Colorado School of Mines in 1988, and began his career with GSI shortly after graduation. After two years of field work in Saudi Arabia, and after GSI was purchased by Halliburton, Mr. Karr was transferred to Midland, Texas, where he began processing seismic data. By the early 1990s, West Texas was a prolific region for 3D surveys, and Mr. Karr learned his trade on 3D projects in the Midland and Delaware basins. Five years later, after Halliburton sold their geophysical services, Mr. Karr moved to Denver to begin work for Golden Geophysical, which was later purchased by Fairfield Industries.

Data Processing & Acquisition SIG

Improving Mini-basin and Subsalt Imaging with Reflection Full Waveform Inversion

Register for Data Processing

Katarina Jonke

Speaker(s): Katarina Jonke, CGG

Co-authors: Zhan Fu, Brad Wray and Hao Shen, CGG

Sponsored by Schlumberger

Location: Schlumberger
Q Auditorium
10001 Richmond Ave.
Houston, TX 77042

Tuesday, May 8, 2018
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

Abstract:

Reflection-based full waveform inversion (RFWI) is increasingly used to recover long wavelengths of the background velocity model and provide updates that extend beyond the reach of diving waves. In our case study, we use an RFWI method that first updates the density using the high-wavenumber components of the decomposed full waveform inversion (FWI) gradient and then updates the velocity using the low-wavenumber components. We show on a deep water example from the Mexican side of the Perdido fold belt that RFWI improves the velocity inside sediment mini-basins and thus the interpretability of the underlying salt. We also apply this method for the intra-salt and subsalt velocity updates and show how it can improve imaging of the deep targets.

Biography:

Katarina Jonke received her engineering degree in Applied Geophysics from the University of Belgrade (2000) and her Master's degree in Geophysics from the University of Houston (2004). Katarina started her career with NIS Naftagas in Serbia as a geophysicist in land acquisition crews. She joined CGG in 2005 and currently holds the position of a Senior Imaging Team Leader. She works predominantly on deep-water GOM projects with a focus on velocity model building, salt tectonics, and subsalt imaging.

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A Live Webinar

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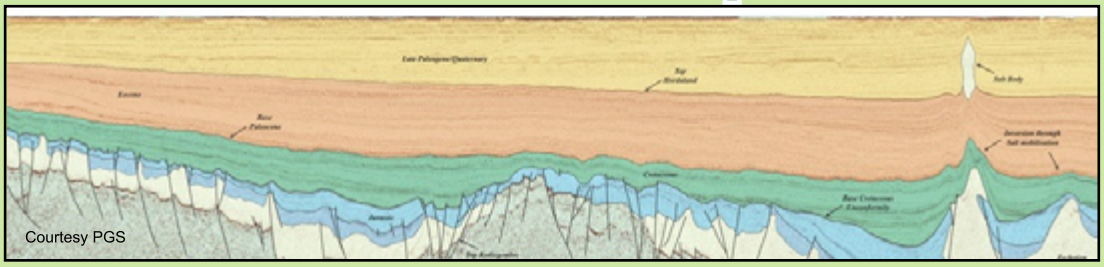
SOCIETY OF EXPLORATION GEOPHYSICISTS

Basic Seismic Interpretation



Four Half-days (10 AM - 2 PM) May 8-11, 2018

Presented by

Don Herron & Bob Wegner

The course consists of lectures on fundamental topics including basics of petroleum geology, seismic response, velocity, resolution, seismic migration, seismic correlation and mapping techniques, and quantified interpretation. Lectures are supported by hands-on exercises, and the second half of the course includes two practical correlation & mapping projects.

Session 1
- ·Introduction to Petroleum
- ·Petroleum Geology
- ·What is Seismic Exploration
- ·Intro to Seismic Interpretation

Session 2
- ·Seismic response
- ·Velocity
- ·Resolution
- ·Seismic migration

Session 3
- ·Fault interpretation
- ·Horizon interpretation
- ·Correlation and mapping exercise (3D seismic grid)

Session 4
- ·Quantified interpretation
- ·Bright Spot Interpretation
- ·Course summary

Don Herron received a BS degree (with honors) in geological sciences from Brown University & a Master of Science degree in geological sciences from the California Institute of Technology. He was a seismic interpreter at Texaco, Gulf, & Sohio/BP. Following retirement from BP he was a geoscience consultant for PGS and a seismic interpretation instructor for several major oil companies. He was co-instructor for the SEG Continuing Education course “Seismic Interpretation in the Exploration Domain”, a member of the Editorial Board of The Leading Edge (TLE) (chairman 2006–2007), & currently is an Assistant Editor for the joint SEG-AAPG journal Interpretation. He writes TLE’s “Interpreter Sam” column.

Robert C. Wegner received a BS in geology from Queens College, a M.S. in geophysics from Lehigh University, & a Ph.D. in geophysics from Rice University. Bob retired from ExxonMobil's Upstream Research Company after developing quantitative seismic interpretation tools and techniques. He has taught petroleum exploration at Rice University and the University of Texas' Continuing Education Department, is a short course instructor for the SEG & AAPG in Basic Seismic Interpretation, has been a member and chairman of the SEG Continuing Education Committee. & is a reviewer for the special session of the joint SEG-AAPG journal Interpretation dealing with seismic Interpretation pitfalls.

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Potential Fields SIG

Tackling Magnetic Remanence Problem Using a Novel Machine Learning-based Inversion Method

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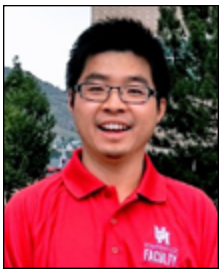

Dr. Jiajia Sun

Speaker(s): Dr. Jiajia Sun,
Assistant Professor of Geophysics,
Department of Earth and Atmospheric Sciences at University of Houston

Thursday, May 17, 2018
5:30 p.m. - 8:00 p.m.

Location: HESS Club
(Houston Engr. & Science Society)
5430 Westheimer
Houston, TX 77056

Abstract:

Magnetic data is among the most widely used geophysical data for characterizing the crustal structures which is of critical relevance to achieving societal goals. For example, in oil industry, the magnetic data is frequently collected for reconnaissance explorations in frontier areas, providing insights into the basin structures. For mineral exploration, magnetic data contains important information about the location and size of iron and sulfide deposits, as well as hydrothermal alternation zones. Magnetic data are also used for understanding the crustal structures and geodynamic evolutions underneath volcanoes and geothermal sites. Despite the cost-effectiveness and widespread use of magnetics in petroleum and mineral explorations as well as volcanic and geothermal studies, interpretation of magnetic data has been long hindered by the pervasive existence of remanence.

We have recently developed a new approach to interpreting magnetic data complicated by remanence. This new method is a direct outcome of cross-fertilization between classical geophysical inverse theory and an unsupervised machine learning technique, fuzzy c-means (FCM) clustering. This new inversion method, termed magnetization clustering inversion (MCI), directly inverts the measured magnetic total-field anomaly for a distribution of magnetization vectors, and constrains the magnetization directions to show region-wise consistency in spatial domain and tight clusters in the crossplot of inclinations against declinations. We have obtained very encouraging results from our preliminary studies. Compared with existing methods, this new method does not perform any data transform (e.g., component conversion and amplitude calculation), does not require isolation of magnetic anomalies, and represents a direct and generally applicable approach to the remanence problem.

In this presentation, I will explain the concepts and thought process involved in developing MCI. The audience can expect to develop a conceptual understanding of how this new inversion method works. I will also briefly talk about the optimization algorithm that we have developed to solve the inverse problem. The focus of my presentation will be on several practical application examples using data sets from Australia and Brazil.

Biography:

Dr. Jiajia Sun is Assistant Professor of Geophysics in the Department of Earth and Atmospheric Sciences at University of Houston. He obtained his B.Sc. in Geophysics from China University of Geosciences (Wuhan) in 2008 and his Ph.D. in Geophysics from the Colorado School of Mines in 2015. His current research focuses on (1) solving magnetic remanence problem by integrating geophysics and machine learning, and (2) developing joint interpretation and inversion methods for multiple geophysical data sets. He is Active Member of SEG, member of AGU and EAGE, and serves in the SEG Gravity and Magnetics Committee. He received honorable mention for Best Paper in GEOPHYSICS in 2015, and Best Paper in the Mining sessions at the 2016 SEG Annual Meeting.

Niobrara Discrete Fracture Networks: From Outcrop Surveys to Subsurface Reservoir Models

Alena Grechishnikova, Energy & Geoscience Institute, University of Utah*

Summary

The Niobrara unconventional play is one of the main reservoirs in the Denver Basin where well performance depends on the size and efficiency of the interconnected fracture "plumbing system" developed during multistage hydraulic fracturing. A complex natural fracture network can significantly increase the size of stimulated reservoir volume, provide additional surface area contact and enhance permeability. The purpose of this study is to characterize the natural fracture networks and to determine the drivers that influence fracture trends and distributions. The findings are integrated into a reservoir model through DFN (Discrete Fracture Network) for further use in reservoir simulations. Fracture analysis was first done at the active mine site that provided a Niobrara exposure creating a perfect natural laboratory to gain insight into the reservoir. For better statistical representation multiple digital surveys comprised of a ground-based LIDAR and photogrammetry were collected. The lessons learned were carried into the subsurface to construct fracture networks based on the structural and lithology drivers seen at the outcrop. The statistical fracture data sets from the surface were calibrated and compared to the available subsurface fracture data to ensure the information gained from the

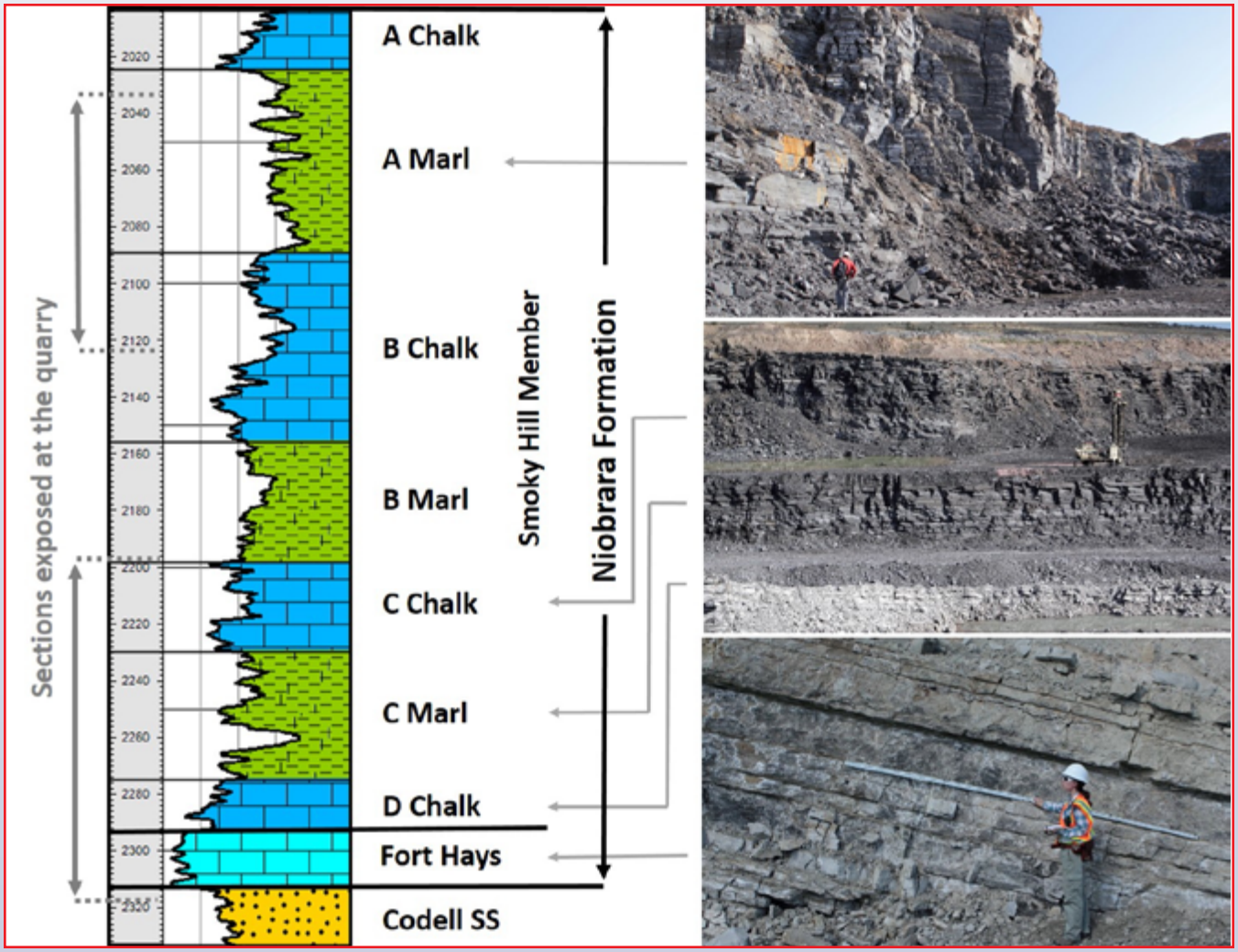

Figure 1: Gamma Ray log and examples of corresponding rock types of the Niobrara Formation (Grechishnikova, 2016b)

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outcrop exposures is a valid analogue for the Niobrara reservoir in the Wattenberg Field. Overall this research aims to help improve reservoir characterization in the subsurface at a sub-seismic scale and result in better well planning and placement.

Introduction

In tight reservoirs, the presence of natural fractures is an important attribute that can have a significant impact on production. Understanding and predicting the fracture network in these settings affects optimized well placement, reservoir stimulation planning, and production. One of the approaches to describe the fluid flow in the naturally fractured reservoir is DFN modeling which allows the construction of an interconnected three-dimensional system of fracture planes. Accurate fracture network mapping requires a better understanding of fracture drivers and thus the understanding of the distributions of lithologies and the role and behavior of faults. Some of the fracture parameters (such as fracture length, height, aspect ratio) can only be measured at the surface exposure.

This research focused on the integration of statistical outcrop fracture data into subsurface fracture interpretations (formation imaging tools, microseismic analysis, and core descriptions) through geological modeling. The method outlined here takes us from the outcrop studies, into the well bore, and to the large scale of seismic data. The geological model proved to be a critical tool allowing the utilization of the drivers controlling fracture distributions and address the differences in resolution provided by multi-scale data sources.

Geological Background

The Niobrara Formation was deposited during the Late Cretaceous in the Western Interior Seaway. Mountain building on the west side of the Seaway produced an asymmetric foreland basin (Longman et al., 1995). The Late Cretaceous to Early Eocene (65-40 Ma) Laramide Orogeny partitioned the large foreland basin into smaller basins, including the Denver Basin (O'Neal, 2015). Haberman (1983) and Davis (1985) described low angle listric, normal fault geometries in upper Cretaceous rocks including the Niobrara Formation. The Niobrara Formation is a low-porosity, low-permeability chalk and marl self-sourcing reservoir (O'Neil, 2015; Sonnenberg, 2011). The natural fractures are thus considered to be one of the important components of sweet spot identification as they can play a significant role in reservoir permeability and connectivity. The matrix porosity has been reduced to 1-10 % and permeability to < 0.1 mD (Longman et al., 1995). The three main chalk beds of the Smoky Hill Member are often referred to by the oil and gas industry as A, B, and C chalks,

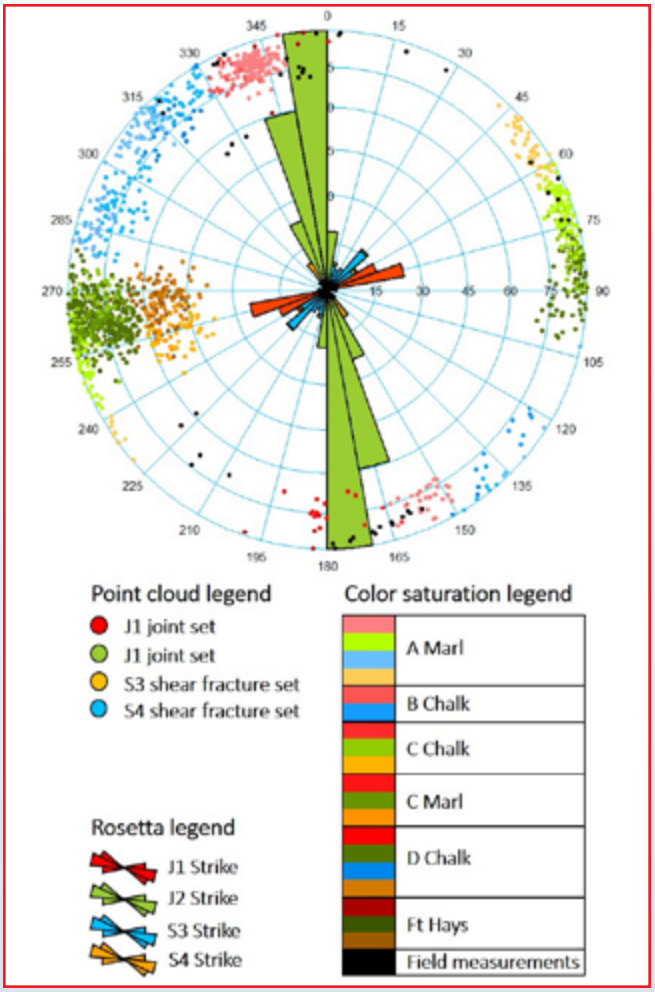

Figure 2: Upper hemisphere equal-area Schmidt Stereonet of all orientation trend measurements in the Niobrara Formation at the quarry (modified from Grechishnikova, 2016b)

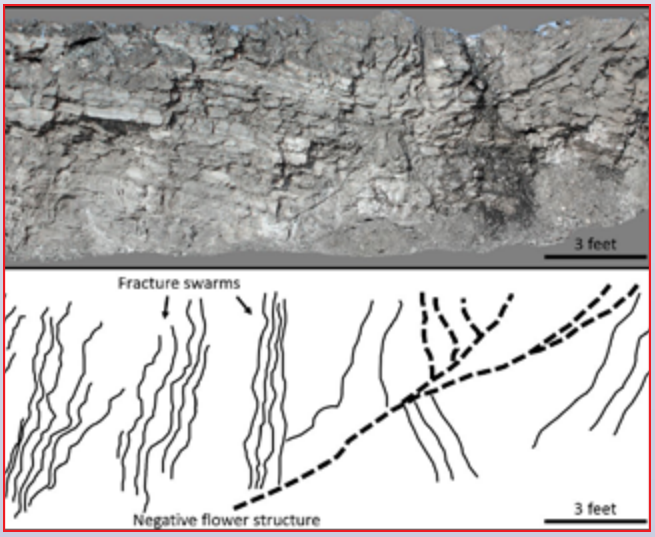

Figure 3: Photogrammetry 3D mesh: fracture swarms and listric faults in a negative flower structure (modified from Grechishnikova, 2016b).

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while the major interbedded marl beds are called A, B, and C marls respectfully. In this work, an additional chalk bed overlaying the Fort Hays Limestone is called D Chalk *(Figure 1)*.

Fracture Analysis at the Outcrop

The study revealed the complexity of fracture sets and distributions. The analysis at the quarry allowed the differentiation between four major fracture and joint sets including J1 compressional joints (red), J2 extensional joints (green), and S3 (orange) and S4 (blue) conjugate shear fracture sets *(Figure 2)*.

The differences in character and nature of the fracture sets suggest the presence of multiple fracture episodes.

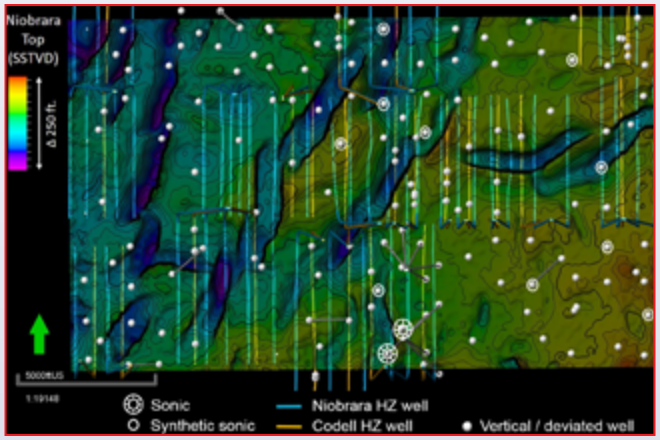

Figure 4: Seismic survey, vertical, deviated, and horizontal wells.

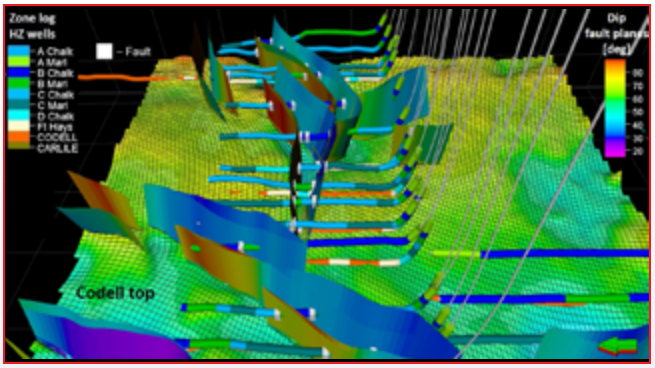

Figure 5: Faults in the structural framework honoring fault picks in the horizontal wells.

The first episode is thought to have happened during the Laramide subhorizontal compression creating wrench fault zones (WFZ) (Weimer, 1996) and causing basement block rotation (Weimer et. al., 1998) along with an en echelon of Riedel shear faults which are known to develop in the WFZ (Burg, 2015). This first episode created J1 compressional joints, and S3 and S4 Mode II conjugate shear fracture sets. The second episode was a post-Laramide extension. It resulted in a new J2 extensional set and reactivated some of the existing faults and fractures, transforming them into Mode III shear fractures and creating negative flower structures (Grechishnikova, 2016b). The data set was incorporated into a reservoir model consisting of structural framework, a lithofacies model, and a DFN model. The study showed that local tectonic variations, such as folds and faults, result in varying fracture intensities. There is a distinct presence of fracture swarms of increased intensity

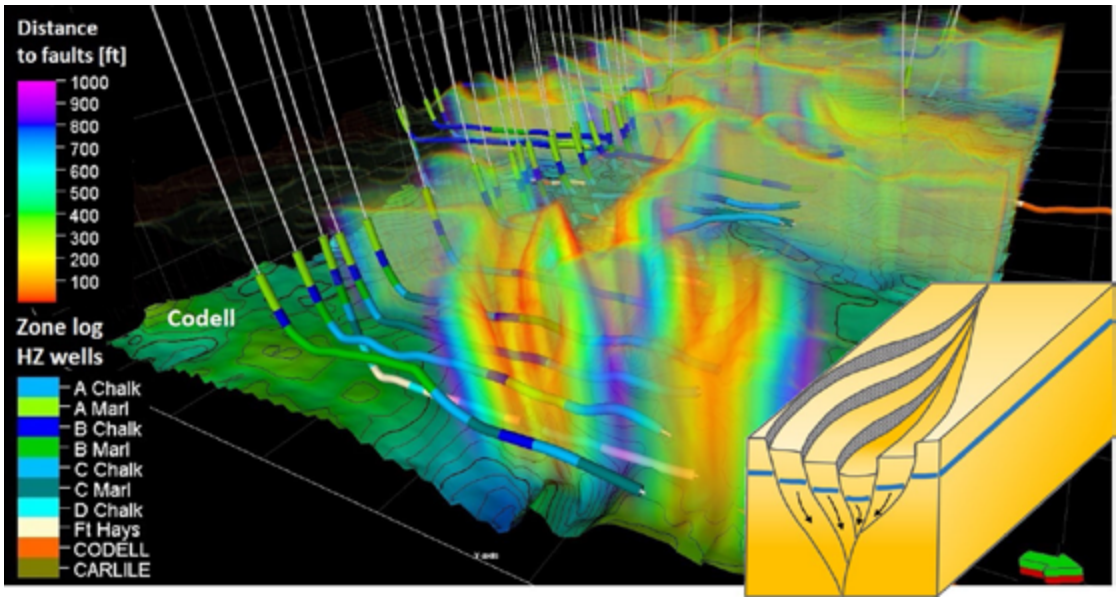

Figure 6: Complex faulting styles in the structural framework exhibited by a distance from the fault property. The conceptual model from the outcrop in on the bottom right.

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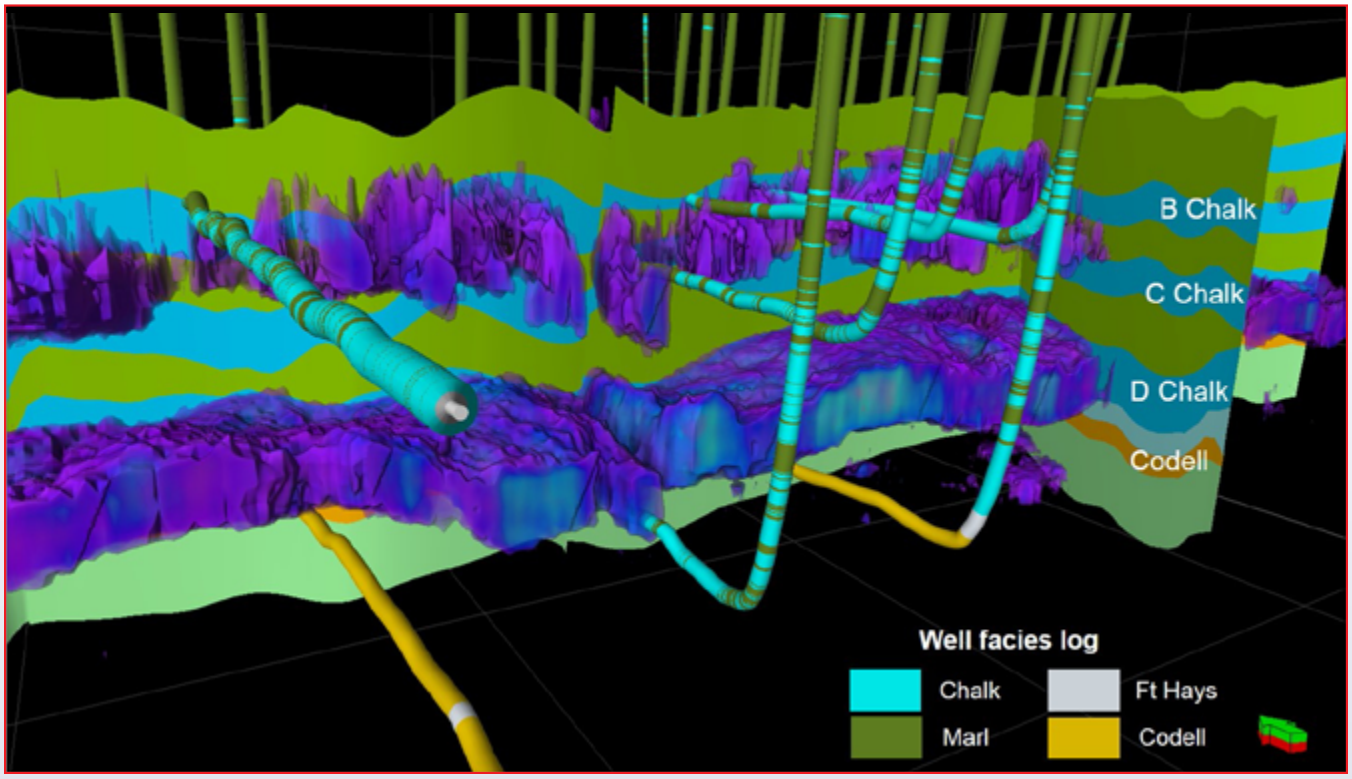

Figure 7: Geobodies from inverted acoustic and elastic impedance volumes cross plots showing chalk distributions. The well logs show Gamma Ray-based facies.

accompanying listric faults in the negative flower structures *(Figure 3)*. The orientations of the fracture sets remain consistent throughout the interbedded chalks, marls, and limestones. There is, however, an apparent variability of fracture spacing associated with changes in lithology. Fracture styles were characterized at several scales: lithofacies-bound fractures are more common in chalks, strata-bound fractures are more common in limestones, and throughgoing fractures frequently happen in swarms crosscutting multiple benches of the Niobrara Formation (chalks, marls, and limestone) (Grechishnikova, 2016b). These throughgoing fracture swarms are expected to contribute to vertical connectivity between individual Niobrara benches.

Subsurface Fracture Modeling

In the Wattenberg Field, Denver Basin, creating and propping fractures in the marlstones can be problematic, and the effectiveness of these completions can vary substantially (R. Johnson, personal communication, 2016). For improved reservoir characterization a modeling approach, capable of tracking fracture-connectivity structures with high resolution, provides essential information of fault and fracture-connectivity which could affect the fluid flow. The implementation of structural and lithological fracture drivers requires going beyond the seismic resolution to create a comprehensive and detailed geological model. Horizontal well data drilled within the seismic survey area are a valuable input providing an insight on intercepted benches and faults *(Figure 4)*. Horizontal wells were reinterpreted for the formation tops and zones. Data used for interpretations included: mud log data (gamma ray, gas shows, ROP, cuttings descriptions) and depth converted 3D seismic to "re-geosteer" the wells and to analyze relative bench geospatial positioning. Both 3D seismic and horizontal well data were used to interpret fault structures *(Figure 5)*. The seismic resolution at reservoir depth only allows for gross scale fault interpretation. The negative flower structure model with multiple "stair-step" faults previously interpreted at the outcrop was used as an analogy to complement the simple graben concept. Fault picks in the horizontal wells validated the multiple listric fault structure concept and enhanced the structural model with more complex faulting styles *(Figure 6)*.

The complex interbedded nature of the Smoky Hill Member exists at a finer scale than represented by the zone/bench model. The facies model is targeting to capture the finer scale of detail than suggested by the benches classification. For a better facies analysis and modeling, multiple inputs were used, including: elastic seismic inversion volumes, core analysis and facies descriptions, well and mud logs from wells within the seismic survey. Horizontal wells can be an important

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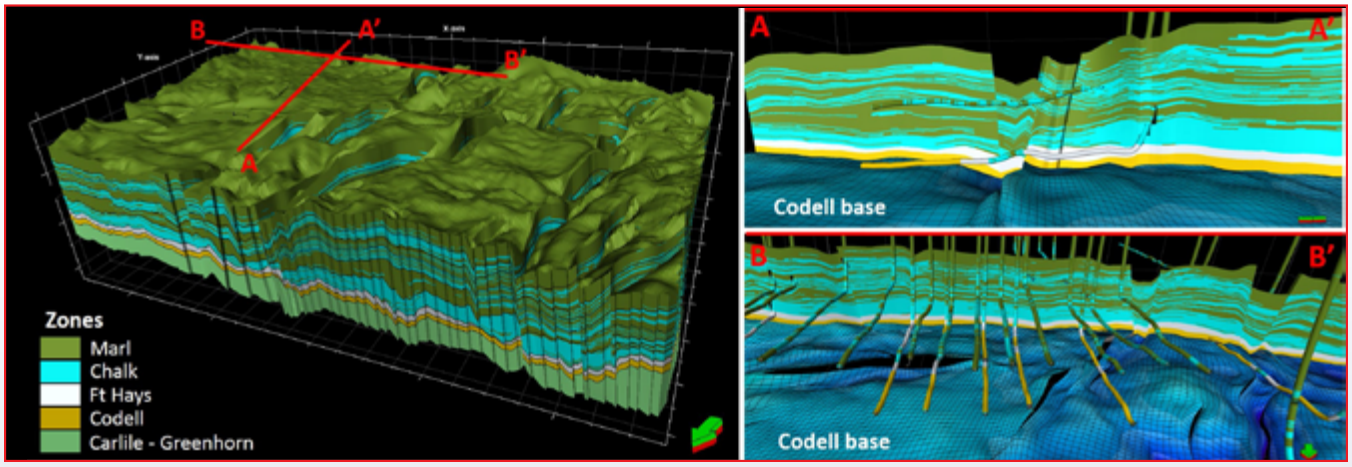

Figure 8: Facies model cross sections and Gamma Ray-based facies logs in the horizontal wells.

data source when attempting to build a detailed facies model when combined with seismic inversion results. Because of the limited data availability in the horizontal wells, a simple cutoff value for the Gamma Ray was used as a proxy for lithology. Core interpretations were used to verify whether a single Gamma Ray log was able to differentiate between chalk and marl stringers of meaningful thickness (based on the tool resolution). Seismic inversion products were utilized through geobodies application as a low frequency trend due to the seismic resolution limitations *(Figure 7)*. This insured that the continuous nature of facies stringers was preserved within the facies model. The simplified chalk/marl facies model classification was used to implement the lithology fracture drivers. The facies model was developed for each zone individually by performing a Truncated Gaussian Simulation driven by probabilities from the facies logs calculated based on the GR cutoffs *(Figure 8)*.

Fracture sets interpreted from image logs appear to be similar to some of those observed at the outcrop

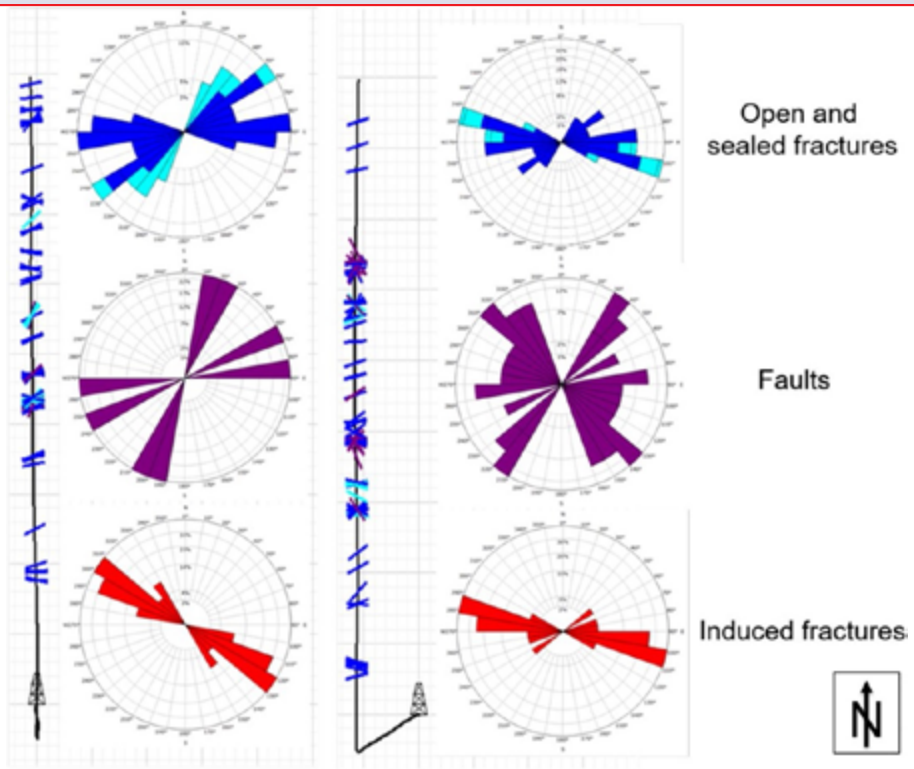

Figure 9: Image logs interpretations (Dudley, 2015)

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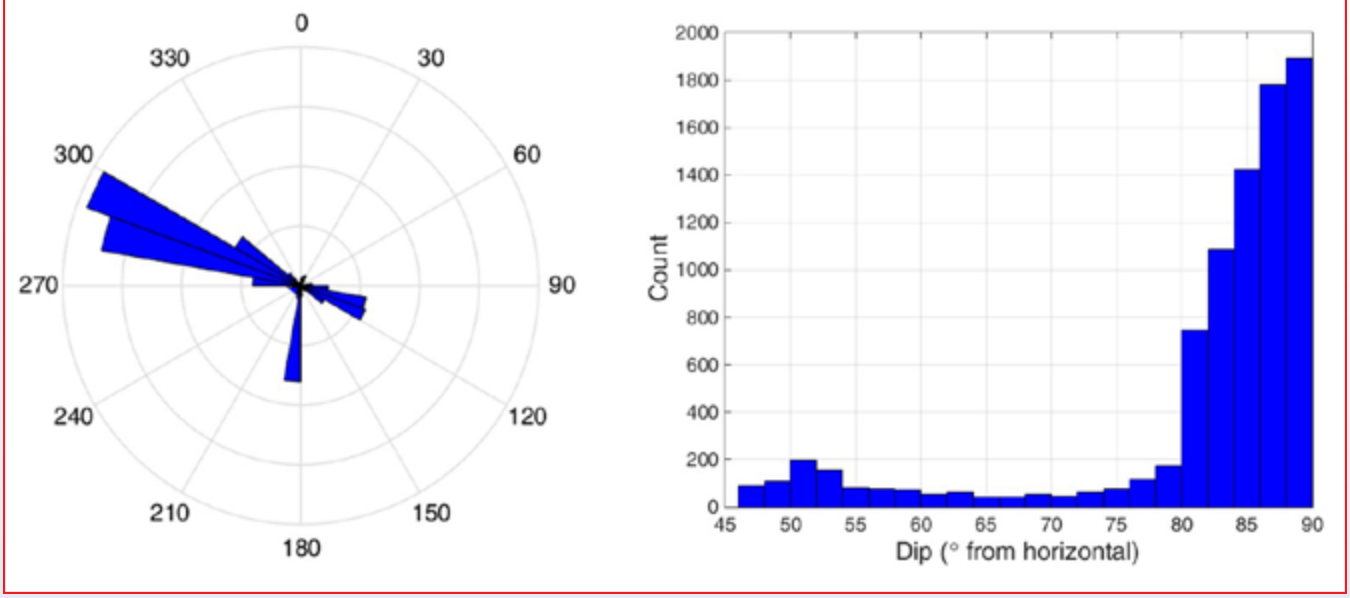

Figure 10: Microseismic events' orientations (strike) and event counts (rose diagram). Microseismic events' dip values (histogram) (I. White, personal communication, 2016).

(Figure 2). *Figure 9* shows fracture orientations from image logs acquired in horizontal wells corresponding to the J1 fracture set measured at the surface. It is important to note that fracture sets identified based on well information could be limited due to the horizontal well orientations restricted to North-South potentially missing the J2 fracture set also striking North-South. Microseismic interpretations *(Figure 10)* show two sets of fractures correlating with J1 and J2 sets observed at the quarry *(Figure 2)*. Core analysis, though missing directional information, reveals the nature of the observed fractures (D. Brugioni, personal communication, 2017) which supports the interpretation of shear fracture types and multiple tectonic regimes made at the outcrop. Both the outcrop study and analysis of image logs suggest the occurrence of increased

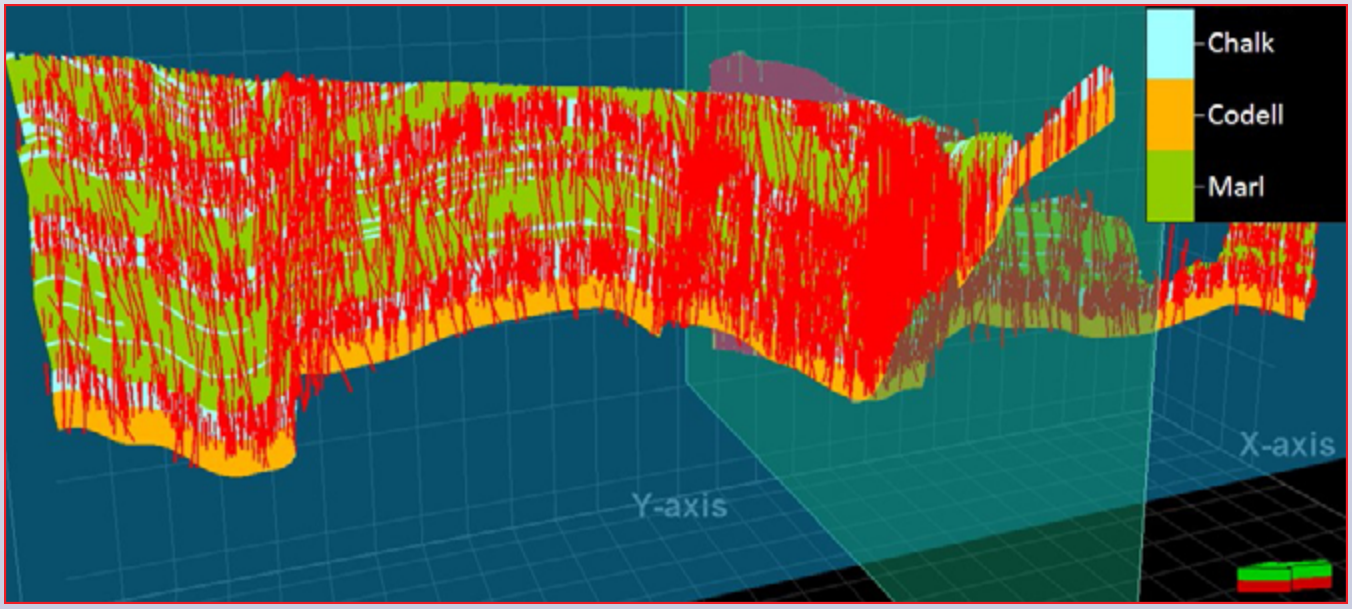

Figure 11: Example of the DFN model cross sections showing increased fracture intensities in chalk facies and around fault zones (modified from Grechishnikova, 2016a).

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fracture intensity near faults. Additionally, recent work on microseismic data supports this observation. Finally, the fracture drivers, fracture sets and orientations, and fracture aspect ratio data are utilized in a multi-step process of fracture intensity volume creation which guides the DFN distributions *(Figure 11)*.

Conclusions

Natural fracture modeling is an important step towards understanding the efficient development of unconventional plays and how they behave in a production scenario. The quality and accuracy of reservoir models could substantially benefit from an integrated approach which enhances the traditional subsurface fracture data with outcrop analogs. The current study reveals the complexity of fracture networks and distributions allows the four fracture sets to be differentiated and analysis of the fracture drivers. The size and spacing of the fractures and joints are affected by both lithology and structure. The throughgoing fracture swarms, lithofacies-bound fractures, and strata-bound fractures are common for all four fracture sets. The strata-bound and lithofacies-bound fractures and joints occur within more brittle chalky zones. The negative flower structures common to the Denver Basin have been proven to affect fracture intensities by increasing the density of fracture swarms near the fault zones.

Acknowledgments

I would sincerely like to thank Colorado School of Mines Department of Geophysics and Reservoir Characterization Project Faculty, Staff, and Sponsors. Special thanks go to Anadarko Petroleum Corporation for enabling the research.

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GSH/SEG Spring Symposium

Sharper Imaging Hits the Mark

By Grant Byerley, GSH-SEG Spring Symposium Technical Program Chair,
Xianhuai Zhu, GSH-SEG Spring Symposium Chair

The theme of the 2018 Spring Symposium was "Sharper Imaging" and the focus was to highlight case studies where recent advances in acquisition and processing technology have improved seismic imaging and ultimately our ability to be more predictive in pursuit to find oil and gas. Many seasoned oil finders have on occasion encountered that "a-ha" moment when new seismic data arrives and suddenly a clear image of the subsurface geology unlocks new potential and completely changes the game regarding the identification and risking of new drilling prospects. This moment sometimes referred to as "turning on the lights" or "putting on the glasses" in review meetings when comparing new images with the older legacy seismic data used in the past.

True to the theme, the 2018 Symposium honored Dave Hale, one of the pioneers in seismic imaging technology over the past three decades. Dave received the Virgil Kauffman Gold Medal from the Society of Exploration Geophysics for his work on dip-moveout processing of seismic data. He also received SEG's awards for Best Paper in GEOPHYSICS in 1992 (imaging salt with seismic turning waves) and Best Paper Presented at the Annual Meeting in 2002 (atomic meshing of seismic images). Dave was the Fall SEG/AAPG Distinguished Lecturer and also was made an Honorary member of the GSH in 2015.

The presentations of the speakers reflected Dave Hale's contributions to the industry, such as "Structure tensor" and "Turning waves". Some of the results showed at the

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symposium are actually from their on-going projects! The first day of talks highlighted how operators are applying the latest seismic acquisition technologies to deliver improved images of the subsurface while at the same time delivering it cheaper and faster. This session covered talks on high density land 3D, simultaneous source, compressive seismic imaging (CSI), high resolution P-cable seismic surveying, fiber optics distributed acoustic sensing (DAS) seismic and optimized acquisition for complex salt imaging and FWI.

The second day focused on recent advances in imaging and processing. Several talks build upon some of Dave Hale's original work developing structural tensors, image guided tomography and convolutional neural networks (CNN's). The talks highlighted how innovative applications of these techniques are being used more quantitatively to improve 3D imaging and interpretation. We wrapped up the technical program with a series of talks highlighting some of the recent advances in full waveform inversion (FWI) and least squares migration (LSM) which appear to be delivering another step change in image quality to the interpreter's workstations.

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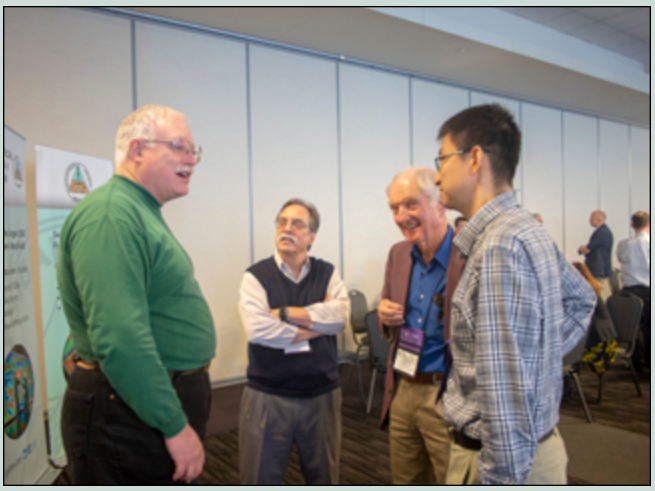
There were plenty of opportunities to network and exchange ideas as well. The Exhibition room had lots of activity, including the unveiling of the just published "Nuggets Book II". The Guru was present to autograph books for the lucky buyers during the Reception honoring Dave Hale. Dave got the Toast & Roast treatment the following day during the luncheon. The luncheon on the first day provided an exciting edition of the Challenge Bowl, led by the extraordinary Game-Show Host, Peter Duncan. Most excited were the winners of one of the University of Houston Teams who will play in the Finals at the SEG Annual Meeting in Anaheim, CA.

This symposium was geared towards all geologists and geophysicists whether they were new to the industry or in advanced stages of their career. It presented a great opportunity to network within one of the largest local community of geophysicists in the world - Houston, Texas. The aim was to educate all in the basic and advanced techniques used in seismic acquisition and processing that are changing the game when it comes to seismic imaging. It presented a great opportunity for industry professionals to stay as sharp and up-to-date as possible on the latest developments in seismic technology.

The GSH appreciates the 192 participants who enlivened discussions and will take the ideas to the geophysical community. We also value the support of all of the volunteers who planned and executed this multi-faceted event. The GSH also appreciates the support of our Sponsors, Exhibitors and Advertisers without whom we would not be able to have enjoyed such a successful event.



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This is a geophysical item...

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This month's answer on page 33.

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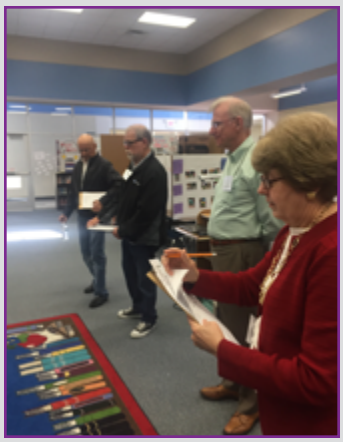
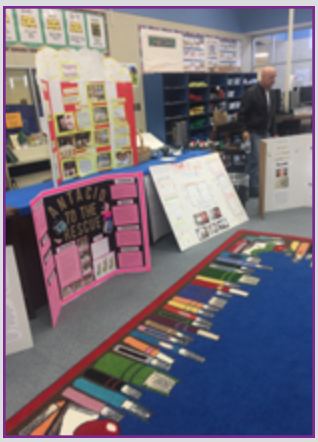
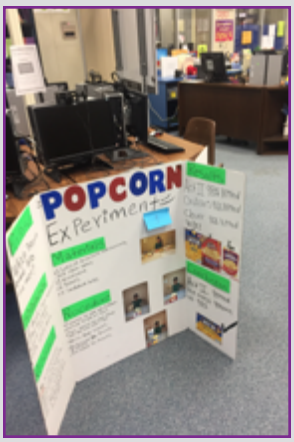
GSH Outreach

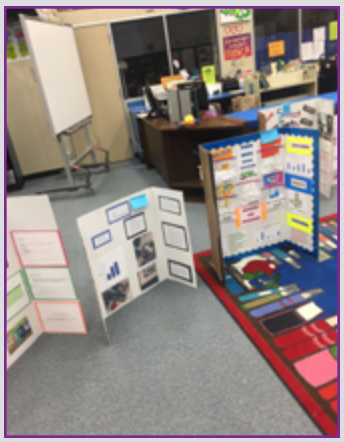
Committee Activities *By Lisa Buckner*

February was another busy month for the GSH Outreach volunteers. We were invited to participate for the fourth time at **Family Science Night in Bellville, TX.** The Bellville Engineering Science Technology (BEST) Booster Club sponsored the Family Science Night at the Bellville Junior High School gym on Monday, February 12, and there were several interactive and informational booths at the event. I gave away 104 GSH logo coiled toy springs. Evidently, some wells in Austin County are being hydraulically fractured because several students and parents asked me about "frac'ing". Bellville is located between Sealy and Brenham, which is close enough that many parents work in Houston, including a contract employee at Hess.









Mission Glen Elementary School invited GSH Outreach volunteers to judge their school science fair projects on Thursday, February 15. Ken Green said "We had a good time judging about 70 science fair projects from 4th and 5th graders." Thank you GSH volunteers Ken Green, Bill Marshall, Elena Ermolaeva and GSH friends, Linda Marshall and Margie Keck for taking the time to listen to the students present their projects to real scientists.

On Saturday, February 17, GSH hosted a booth at the **Girls Exploring Math and Science (GEMS) event for Girl Scouts at the Houston Museum of Natural Science**. Approximately 2,100 Girl Scouts, troop leaders and other individuals attended. This was the second year for GSH to participate in this event, and it is so popular that we had to apply to be exhibitors. SPE and Oxy also exhibited. Mac Hooton brought some rock samples to share with the girls. He brought samples of lead ore, copper and the Woodbine formation. The girl scouts really enjoyed picking up and looking at the samples. He also plugged a geophone into his mobile phone and used an app to display wave motion when they struck the table. The jumbo colorful coiled toy spring drew a lot of attention to our booth as well as the oil samples and interpreted seismic section. Visitors were given an "Earth is calling ... will you answer?" brochure. We gave away 241 GSH logo coiled toy springs after watching a demo of P and S wave motion. The exhibit booth volunteers were asked to judge student science projects during their break from manning the booth. The winning project was a stuffed animal bear that had been made into a robot with head and arms that moved using a game control. Thank you, Mac Hooton and Huw James, for volunteering alongside me to inspire the girls to pursue STEM and geoscience in particular.

GSH Outreach continued on page 27.

GSH Outreach continued from page 26.

On Wednesday, February 21, GSH Outreach volunteers Elena Ermolaeva and Mac Hooton participated as guest presenters at the **Ridgemont Elementary FBISD Career Day**. They spoke with students at separate tables in the school gym. Since Mac brought his rock and mineral samples, he told the students about geology. Elena told them about how geophysicists use sound waves and gave away 150 GSH logo coiled toy springs. Elena says "at mass events at schools it's really hard to catch EVERYONE's attention, but if at least one kid's eyes lit up after finding out what geophysics is, it was totally worth it. I think it's my personal impression. Thank you!"

GSH Outreach volunteers participated in two events on Saturday, February 24: **EYH and SEFH** (see article by Gokay Bozkurt). Larkin Spires and I facilitated two of the many classroom hands-on activity workshops at the **AAUW Expanding Your Horizons (EYH) in Science and Mathematics conference** for 400 middle school girls from all around Houston. About 28 middle school girls and 6 of the high school student volunteers (boys and girls) attended our workshops sessions. Working in teams of four, the girls filled paperboard shoe boxes with layers of sand and gravel and hid a small balloon, pre-filled with a black dyed water "oil reservoir". They traded their box with another team. They then conducted a seismic survey to find the "oil reservoir" by tapping the box lid with their hands (source), listening with their ears (receivers) and processing with their brains. They used a bamboo skewer to "drill for oil". Girls were given a GSH logo coiled toy spring and an "Earth is calling ... will you answer?" brochure to take home. NASA Flight Director, Ginger Kerrick, gave a very inspiring keynote address about setting career goals and standing up for yourself against bullies and discrimination.

On Saturday, March 3, Mac Hooton and I hosted an exhibit for educators and the **2nd Annual Greater Houston Area STEM Conference** at the University of Houston Clear Lake campus. Mac brought his rock and mineral samples to share with the K-12 educators. We handed out a flyer listing all the activities in which we participate including school career days. As a result, we have already received an invitation to a school career day on May 21 from Bay Colony Elementary School in League City. On the back side of the flyer was a list of websites for additional resources. We also distributed 16 of the poster-sized USGS Tapestry of Time and Terrain Maps, which are part of the USGS Maps in Schools Project. Along with the map, they received the accompanying USGS pamphlet, an activity for their students and map presentation suggestions. Thank you to CGG for sponsoring the purchase of 100 maps in 2015.

Upcoming outreach events where you can volunteer (contact Lisa Buckner at lbuckner@hess.com):

May 21, 2018 (1:00 PM – 3:00 PM) – Bay Colony Elementary Career Day, League City

Do you know of a school that has a career day seeking speakers, career fair or science night at which GSH might be able to host an exhibit booth? If so, please contact Lisa Buckner at lbuckner@hess.com and we can work together to bring awareness to the students of the many high paying and fun careers in the geosciences.

GSH Outreach continued on page 28.

Technical Article continued from page 27

GSH Outreach

59th Annual Science and Engineering Fair of Houston

By Gokay Bozkurt and Bill Gafford

Picture 1: GSH representative Bill Gafford with three of the award recipients.

The Geophysical Society of Houston (GSH) participates in many community outreach projects throughout the year. We actively engage with K-12 students in a variety of venues around Houston to foster an interest in math and science among these brilliant minds, while fueling their curiosity towards geological and geophysical concepts.

One of these venues is the Science and Engineering Fair of Houston (SEFH). It is the largest fair of its type in Texas, and one of the largest in the world. SEFH serves as the regional fair for all public, private, charter and home school Junior and High School students in Harris County and 22 surrounding counties throughout Southeast Texas. GSH proudly supports this event as a Special Awarding Agency alongside 48 other professional societies and organizations in Houston.

On February 24th, SEFH convened for the 59th time and was hosted by the University of Houston at their Main Campus Athletic/Alumni Center. Middle and High School exhibitors showcased close to 1,000 research projects concerning 16 technical categories.

Seven GSH volunteer judges graded and reviewed projects deemed relevant to our professional interests. The judging committee selected a 1st and 2nd place winner for both the Junior (grades 7-8) and Senior (grades 9-12) divisions. The GSH also nominated the Senior division winners for consideration as Summer Research Assistants at the Houston Museum of Natural Science.

Outreach continued on page 29.

Outreach continued from page 28.

The GSH judging committee is proud to announce
Special Award recipients and the titles of their research work:

Senior Division, 1st Place **Stephen Drabbant,**
"Improved Reception Techniques to Overcome the Sun's Negative Effect on Radio Propagation"

Senior Division, 2nd Place **Conrad Schmitt,**
"Transmission of Signals Through Soil: A Down to Earth Solution"

Junior Division, 1st Place **Anisha Parson,**
"Go With the Flow (GFLOW)-Real-time Street Flood Prediction and Warning System"

Junior Division, 2nd Place **Abishek Rathnakumar,**
"Long Range Wireless Electricity Transmission"

The Awards Ceremony for the 2018 Science and Engineering Fair of Houston was held on Saturday, March 3, 2018, at the Cullen Performance Hall at the University of Houston. The Guest Speaker was Steve Wolf, who is a professional Stunt Scientist. He gave a very interesting demonstration on how science is used in movies to create action stunts safely. Special awards were then announced and presented to students whose projects were selected by various companies and professional organizations, including the GSH. Bill Gafford attended the ceremonies and handed out awards certificates and gift cards to our winners [Picture-1]

We would like to take this opportunity to extend our appreciation to all the dedicated members of the Judging Committee for the successful representation of our society at the SEFH.

This year's GSH Special Awards Judges were: Gokay Bozkurt (Judging Coordinator), Paul Blubaugh, Matthew Couchman, Xiang Lin, Syed Mehdi, Emmanuel Ubaha, and Edith Sotelo [See Picture-2]

Thank you very much!

Picture 2: GSH Special Awards Judging Committee.
From Left to Right: E.Ubaha, X. Lin, E.Sotelo, G.Bozkurt (Lead), S,Mehdi, P.Blubaugh, M.Couchman

Guru Threatened by Angry Mob, Scolded by Editorial Board

Houston. In an unprecedented display of violence, local GSH *Journal* readers protested the sluggish revelation of Inversion Great Truths long promised, but undelivered by the snarly Guru. The GSH Editorial Board sided with the unruly crowd and added a stern warning that he'd better start being on time with his technical trivia or be replaced by ***"Seismic Eating",*** an article growing in popularity in spite of its semi-infrequent appearance in the ***Journal***. While primarily aimed at the strange appetites of the geophysical community, it covers other engrossing topics such as exercises for aging interpreters, maintaining a happy attitude when your boss is a bullying buffoon and a bore, and the ever-popular series on Millennial Dressing for Success in a Cubical Society.

Duly noting the subtle hints, The Guru has indicated full compliance to follow.

Inversion: Not as Easy as it Sounds

$\rho_0 = 2.24$	$V_0 = 9000$	$Z_0 = 20160$	$R_0 = 0.066$
$\rho_1 = 2.30$	$V_1 = 10000$	$Z_1 = 23000$	$R_1 = -0.032$
$\rho_2 = 2.271$	$V_2 = 9500$	$Z_2 = 21570$	$R_2 = -0.107$
$\rho_3 = 2.175$	$V_3 = 8000$	$Z_3 = 17400$	$R_3 = -0.066$
$\rho_4 = 2.119$	$V_4 = 7200$	$Z_4 = 15250$	$R_4 = 0.103$
$\rho_5 = 2.208$	$V_5 = 8500$	$Z_5 = 17770$	

We'll work with these values in a mixed bag of units, $(g/cm^2)(ft/s)$, in developing a strategy for inversion. The concept being exposed to the harsh light of reality is this:

Forward Modeling **d = Gm.** **d** is the observed data (reflectivity in this cartoon case)
G is operator (**x + ÷ ∗**) that produces **d** from **m**
m is the earth model (impedance)

So, relating to the earth graphics, **d = R**, the set of 5 reflection coefficients at the layer boundaries; **m = Z**, the set of impedances in the 6 layers. **G** is described on the next page.

Tutorial Nuggets continued on page 31.

Tutorial Nuggets

Tutorial Nuggets continued from page 30.

G is most commonly expressed as a function relating the input model **m** (impedance) to the observed seismic trace, **d.** In real life the simplest trace is reflectivity with a wavelet, **W(t)**, attached via convolution, **d = R(t)∗W(t).** We'll get back to that, but for now, in our cartoon world, just consider the wavelet to be a spike so that the trace **d = R**.

$$R_{N+1} = \frac{Z_{N+1} - Z_N}{Z_{N+1} + Z_N}$$

This is the classic expression for R_{N+1} at the **boundary** between the layers Z_N and Z_{N+1}. Note that there will be **5** such equations to obtain the **5** reflection coefficients between the **6** layers. At the right is the equally classic expression for ***inversion***, producing the **impedances, Z,** in these layers: $\mathbf{m = G^{-1} \cdot d}$.

$$Z_{N+1} = Z_N \left[\frac{1 + R_{N+1}}{1 - R_{N+1}}\right]$$

As shown, the inversion is done iteratively. Implementing this equation is fraught with danger, difficulty, and annoying arithmetical truths.

Problems: **(1)** It requires knowledge of the Z_N before we can get Z_{N+1}. Where does Z_0 come from? (One can argue you're either standing on it (land) or swimming in it (marine), but errors here will propagate throughout the entire set of **Z. (2)** Instability. **(3)** Scaling – the real trace has amplitudes in what **ICON** calls International Geophysical Amplitude Units (**IGAU**) – which no one understands or cares about. For now we'll let scaling be part of the wavelet estimation.
(4) Z is a non-linear function of **R** (try the division of [1+R]/[1-R]). This will cause problems when we try numerical inversion techniques including simple **Matrix** inversion (next time). **(5)** In addition to ignoring the **W(t)**, there is always the ubiquitous **noise**, which can blow the whole thing out of the tub. And lastly, **(6)** There are no **constraints** on this solution which means, among other things, that knowing only **R,** the solutions for **Z** are non-unique. The inversion problem has **6 Unknowns** and only **5 observations** or independent **equations**. Not Good.

Is there any help or hope? Yes indeed, as we will see in May. Stay by your computer.

The quickie Puzzle for **May**: Using the 8 digits 1, 2, ..., 7, 8, make two 4-digit numbers from all 8, such that their sum is a minimum for all other none-trivially different 4-digit numbers.

The more or less obvious answer: Deal out the **1** to **8** in **sequence**, first to one 4-digit number and then to the other. Example: Numbers A and B: A = 1358; B = 2468. A + B = 3825. Note that A = 2358, B = 1467 yields the same sum: 3825. There are 8 such combinations with same sum.

Shifty

The June Nugget Puzzle

Shifty Stringer is a well known Houston gambler believed to use a dishonest coin or two to pad his pension. Most of the losers are geophysicists with a misguided sense of trust and probability. Your problem is to propose a game that will give you and Shifty a **50-50** chance of winning regardless of how the die has been loaded, that is how lop-sided the probability of heads vs tails. You are not restricted to a single roll. This little probability gem was first suggested by John Von Neumann, a master mathematician and top expert in game theory.

The much anticipated answer to Lee Lawyer's **Truel** dilemma appears on the next page.

Tutorial Nuggets continued on page 32.

Tutorial Nuggets

Tutorial Nuggets continued from page 31.

Puzzles Possibilities Probabilities

For the past two months we have been embroiled in yet another Lee Lawyer pickle. Recall that he had involved himself in an **GSH** power struggle which was to be decided by a **Truel**. In the deadly game of **Truel**, the three contestants, **A**, **B**, and **C** participate in the following way. The three are ranked by accuracy with trueling pistols. The lowest, **A**, having probability of hitting his target, **Pa(H) = 1/3**, firing **first** at either of the other two**, B** or **C**. B has a probability of hitting his man, **Pb(H) = 2/3**, while **C** is **deadly accurate** with probability of **Pc(H) = 1** – he always hits what he aiming at. After **A** does his thing, **B** takes his turn, firing at either **A** or, if he's still standing, **C**. Then, assuming he's still breathing, it is **C's** turn with the same options. The game continues in the same order until only man remains above room temperature.

Unfortunately for **L**ee, he is **A, the worst shot**. Hoping to maintain his status on this side of the grass, he is asking for our help**. What is Lee's best strategy?**

We gave a brief answer in April (***The Nuggets*** were heartlessly reduced to one page), leaving Lee dazed and befuddled as to his best course of action. The Guru recommended Lee shoot at neither **B** or **C**, but simply shoot into the ground. Here's why.

After Lee hits the ground (barely), **B** must shoot at **C -** otherwise sure death ensues.

Case 1. **B** misses **C** with **P**(BmC) = **1/3**. **B** is a Goner as **C** then hits **B** with **P**(ChB) = **1**. **N**ow it's Lee's chance with **P**(AhC) = **1/3**. This case gives **Lee** (A) a probability of life = (1/3)((1/3) = **1/9 = Pa(AhC | BmC)·Pc(BmC).**

Case 2. **B** hits **C** with **P(BhC) = 2/3**. It's Lee turn. Here we must consider what happens if both **Lee** and **B** miss on a round to cover all contingencies: **Pa(AmB)·Pb(BmA) = 2/9**.

P(Lee Wins) = **(2/3)** (1/3) [(2/9) + $(2/9)^2$ + $(2/9)^3$ + $(2/9)^4$ …] = (2/3) [(3/7)] = **6/21**. (Here we used the sum of an infinite series to get the term in brackets, [ ] = 3/7.)

The Total Probability **Lee lives to write another FTOS*****: **6/21 + 1/9 = .367 = 39.7%.** This probability is the best among the Truelists, with B at 38.1% and C(best shot) at 22.2%**.**

*****While **Lee** was indeed the most probable victor in the **Truel,** as luck (probability's wayward child) would have it, in the actual deadly contest, **B's** shot ricocheted off **C's** head striking the hapless author rendering him **clueless (**as you may have noticed in the most recent **FTOS).**

Dazed and Clueless Man in Truelist attire, found wandering Aimlessly in GSH Forest. Claims to be famed FTOS Author

U of H Wavelets

SEG Wavelets Host Guest Lecture from Chevron

by Jackson Zerr

Photo contest winner Julian Chenin in Norway

On February 23, 2018, the Society for Exploration Geophysicist Houston chapter, SEG Wavelets, hosted a lecture entitled "Petrophysics & Seismic Applications." The guest lecturer, Ivana Bunting, has many years of industry experience working as a Senior Geophysicist and a Senior Petrophysicist. Ivana is a University of Houston alumnus who currently works as a Staff Petrophysicist for Chevron.

Over thirty faculty and staff attended her talk "Petrophysics & Seismic Applications" which gave an overview of the general need for integrations, what data is needed for interpretation, data editing methods, and some general seismic applications. Bunting outlined key interpretation factors by describing fundamental theories and their role in more sophisticated methods including seismic inversion, anisotropy, and well ties.

Ivana also gave advice to students who are nearing the end of their academic career by drawing on her own experiences moving from the University of Houston to the industry. She described her transition between academia and industry citing the challenges she faced and goals she set.

Faculty and Students along with Ivana Bunting after her talk.

The SEG wavelets are very thankful for Ivana Bunting for sharing her knowledge and experience through her lecture. Students who attended the talk were able to learn key petrophysical methods and get advice from an experienced Chevron employee.

Mystery Item

The Mystery Item on page 25 is a parallel plotter and drafting tool.

Geoscience Center News

By Bill Gafford

1790 W. Sam Houston Pkwy. N. (Right on Shadow Wood)

Picture 1

Picture 2

The next **Living Legends Doodlebugger social event will be on Thursday morning, May 10.**

Although these events started as a gathering mainly for retirees, anyone is welcome and spouses are invited too. We would especially enjoy having some younger people join in the conversations and come see some of the interesting geoscience artifacts in our museum collection.

We enjoyed having a visit in February with Dorsey Morrow, SEG Executive Director, and Bill Barkhouse, Associate Executive Director. They enjoyed seeing our expanded Bob Sheriff Library and some of the interesting geoscience instruments on display.

Included in our collection of geoscience artifacts are some excellent examples of the high quality of workmanship in the early days of geophysical exploration. This is evident not only with the instruments themselves, but with the cases or enclosures for the instruments. The early torsion balances were transported in boxes made of mahogany and zinc. One is shown in Picture 1. This combination was used because of the durability of the materials and also because

Picture 3

Geoscience Center News continued on page 35.

Geoscience Center News continued from page 34.

Picture 4

they had less effect on the sensitive instruments. Early magnetometers were also transported in custom made cases. These cases also included the tools for adjusting and maintaining the instrument as can be seen in Picture 2. Other early geophysical instruments were constructed of a combination or metal and wood and can be roughly dated by their appearance, such as the radio transceiver in Picture 3. As time progressed, aluminum became the primary material used, as seen with the camera in Picture 4. More recently, cases for items such as geophones have been made of molded plastic.

Our collection of "The Geophysical Directory" is used from time to time to provide information about instruments in our collection. The advertisements and pictures of items have helped us identify and date some of the recording instruments where we have not had any documentation on them. We are interested in filling some gaps in our collection if anyone has some of the older directories and would like to donate them. We are also trying to put together information about some of the older service or contractor companies and are interested in any company history publications. Also, volunteers are always needed to help with our ongoing projects.

Visitors are welcome at the Geoscience Center on Wednesday mornings from 9:00 until noon or by appointment. Please contact me at geogaf@hal-pc.org or at 281-370-3264 for more information.

18th ANNUAL SALTWATER TOURNAMENT

Friday, October 5, 2018
TopWater Grill Marina
815 Avenue O, San Leon, TX

We are looking forward to a big event this fall and we encourage full family participation.

Galveston Bay Complex Division

Trophies will be awarded for the heaviest individual Redfish (Non-Tagged), Speckled Trout, and Flounder. Trophies will also be awarded for the heaviest individual Stringer - 1 Redfish, 3 Speckled Trout, and 1 Flounder.

Galveston Offshore Division

Trophies will be awarded for the heaviest individual Ling, King Mackerel, and Mahi-mahi

Registration fee includes: Launch Fee, GSH Fishing Cap, and Fish Fry Meal after weigh-in, Refreshments, Trophies, and DOOR PRIZES.

REGISTRATION OPTIONS INCLUDE SPACES ON A BOAT WITH A GUIDE!
spaces are limited...

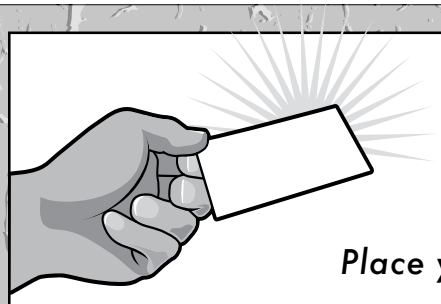
For more information, please contact:
Bobby Perez w: 281-240-1234 ext. 3233
c: 281-787-2106 rperez@seimaxtech.com
Nathan Lenz 713-808-5218
nathaniel.lenz@tgs.com

REGISTRATION OPTIONS prior to Oct 1st:
Individual $75
Individual with AM Guided Boat $200
Individual with PM Guided Boat $200
Dinner only $20

LATE REGISTRATION AVAILABLE

PLEASE REGISTER ONLINE AT:
http://www.gshtx.org

Upon Registration, each participant will be provided by e-mail with a copy of the specific tournament itinerary, rules and disclaimer.



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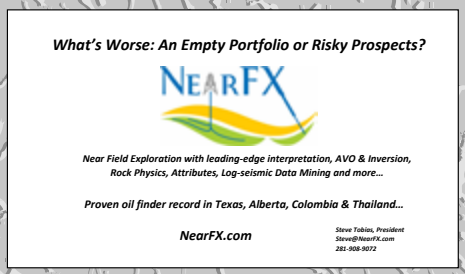

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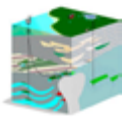
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Doodlebugger Diary

Shipwrecked in the South China Sea
Part 4: Our First Two Survey Vessel Replacements – The Huang May and Lingshiu *By Scott Singleton*

Doodlebugger Diary are the experiences of geophysicists during their working lives. Usually these are not recent events, but more recent ones are just as welcome. Think back to an earlier time when you were on a seismic crew, operating a magnetometer survey, gravity stations, or whatever. I included one that involved a data processing center. Seriously consider contributing a story or two. Scott Singleton recalls a few interesting stories. We are going to run them over several issues of the Journal. Scott is a past President of the GSH and still very active in professional affairs. I know you will enjoy his adventures as a truly certified doodlebugger. Lee Lawyer

If you have an item for the Doodlebugger Diary, send it to llawyer@prodigy.net *or to* editor@gshtx.org.

When we last left our stranded crew they were getting to know Sanya quite well. Of course, you can rest assured that behind the scenes there was lots of effort to try to find replacement survey boats. During our time there we actually mob'ed 3 different vessels to survey different parts of the remaining pipeline route. The first two, the Huang May and Lingshiu, will be described in this installment. The third and final vessel, the Kan Cha 3, a Chinese Navy intelligence vessel (true!), will be described in the next installment as it deserves its own space.

We found the Huang May tied up at the dock in Sanya *(Figure 1)*. It was impossible to miss, with its golden crown tilted back. During busier times the Huang May was a party boat. It would take Communist party dignitaries

Figure 1: The Huang May in all its glory.

Doodlebugger continued on page 40.

If you would like to add stories to the Doodlebugger Diary, send them to: Lee Lawyer at llawyer@prodigy.net ***or mail them to Box 441449, Houston, TX 77244-1449***

Doodlebugger continued from page 39.

Figure 2: The Fugro crew sets up the instruments in the main gambling room of the Huang May

Figure 3: The fishing fleet in Sanya Bay.

and well-heeled vacationers offshore to gamble. The main room was lined with the Chinese version of slot machines *(Figure 2)*. So off we went, setting up our instruments inside the main gambling room and hanging the sensors off the back deck. I'm sure we cut quite a sight traversing back and forth offshore proudly flying the golden crown.

We used the Huang May to survey the condensate pipeline from the Yacheng 13 field to as close as we could get to shore. We succeeded in this task with the exception of one minor point – the captain refused to go anywhere near the rock pinnacle that the Nanhai 503 grounded itself on (it was during this time we found out that 'everyone' knew where the pinnacle was, except of course the Nanhai 503). This left us with a hole in our survey route, which of course wouldn't do, even though we were obviously going to deviate around the pinnacle. We still had to survey the general area, and this is where the captain of the Huang May refused to go.

So we spread the word that we were offering cash to rent a boat that would let us survey around the pinnacle. And where else to look for a small boat to get close to a rock sticking up out of the middle of the ocean? The fishing fleet of course *(Figure 3)*. Enter the Lingshiu, a humble fishing boat *(Figure 4)*. What better craft to get within a whisker of the pinnacle? So after the finances were agreed upon we mob'ed our gear onto it *(Figure 5)* and set off into the wild blue yonder *(Figure 6)*. This part of our survey was actually one of the most exciting – the captain nervously watching the wave-splashed rocks while the party chief kept urging him to get closer, and the rest of us intently watching the instrument readouts *(Figure 7)*. In the end we did manage to get close and acquired really nice data documenting the rise of the pinnacle to the seafloor

Figure 4: The humble fishing vessel Lingshiu

Figure 5: Mob'ing our gear onto the Lingshiu

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Doodlebugger continued from page 40.

Figure 6: View looking from the cockpit of the Lingshiu forward onto the front deck. The captain is on the right. The party chief is on the far left. Looks like we had the Furuno bathometer set up in the middle so the captain could keep a watch on 'the rock'.

Figure 7: The survey crew intently watching as data came in while approaching 'the rock'. The party chief is in the foreground on the far right keeping watch on progress from the 'bridge', such as it were. The other instruments are more forward so we had to be on the very bow of the ship to see it all. Yes, that is me in the center back, believe it or not.

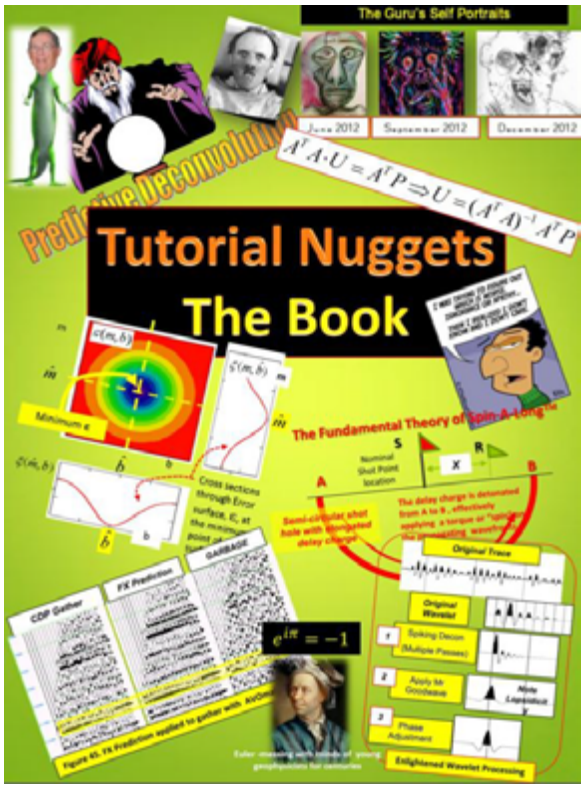
and then jutting straight up to the sea surface. Quite exciting. Sure wouldn't want to get a ship stuck on that rock. (Oops, too late. Already did).

By this time we were quite proud of ourselves. Stranded on a tropical island in a foreign land and still managed to get surveying done on makeshift survey boats. Any pretense of being privileged Westerners had long since evaporated. Anyone who had that attitude didn't last very long (and there were a few who weren't comfortable and left). We lived with the locals and helped spread a bit of cash around to those who very much appreciated it. And we had a fun (or at least memorable) time doing it.

But we were scarcely prepared for our next adventure, which was mob'ing onto our final survey vessel replacement, the Kan Cha 3. Dealing with the Chinese navy aboard one of their intelligence gathering ships was a bit different than we had encountered while hanging out with the locals. It was like night and day. These guys were deadly serious, and we were interlopers out to survey the Chinese coast for the US military. But we had something they wanted – cash. So our intrepid band of doodlebuggers moved onboard a Chinese intelligence ship for about a month, where an uneasy truce was agreed upon between the Chinese navy and Arco/CNPC.

Would it hold? Has any of you worked with Kiwis (from NZ, not the birds), who happened to make up about half of the doodlebugger crew? I wouldn't put anything past them. They certainly put me through all the traps and hoops, but I had to earn my place; none was given out freely. But by now we were a team. And we wanted to see what made up a Chinese intelligence ship. This was going to be interesting. Nothing was going to stop us, because by now we could hardly care less. Bring it on. And we would soon find out what those kiwis would do to have some fun.

Next month: Part 5 – Our Final Survey Vessel Replacement – The Kan Cha 3, a Chinese Navy Intelligence Vessel



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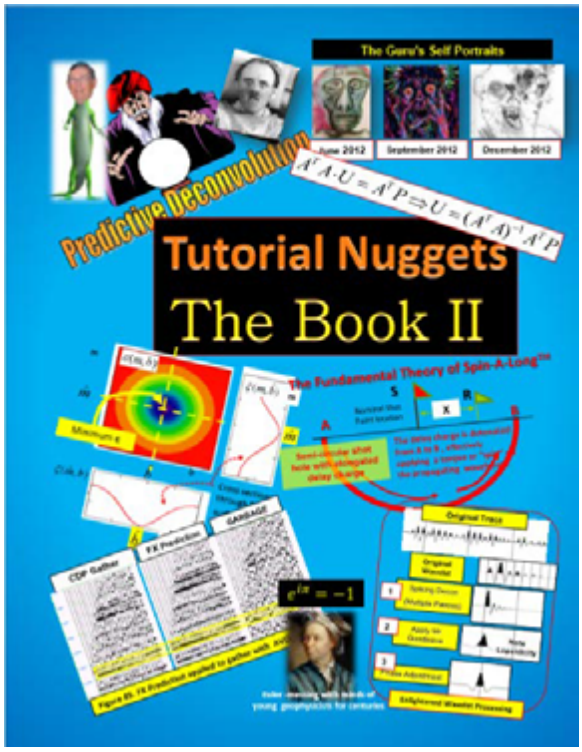

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