February 2019

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 9 • Number 6

The Epicenter of Geophysical Excellence

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On The Cover...

Seismic Surveying in Alaska.

Picture courtesy of Geokinetics.

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

April 2019	**Feb 8**
May 2019	**Mar 8**
June 2019	**Apr 12**

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A Word from the Board

Welcome 2019!

By Craig J. Beasley, President Elect

Maybe I should not tempt fate with my upbeat title "Welcome 2019", but I am throwing caution to the wind and speculating that it can't get much worse than the last 3-4 years. Like everyone else, I suppose, I am wondering what will be in store for us in the coming year. Some things are certain – death and taxes for example, just not certain who and how much. I expect to take the reins of the GSH from Dennis in the not-too-distant future, and there are few other things that seem certain. The near-term future of our science, profession, and businesses seem not so certain.

From my experience with industry downturns, of which I feel I have too much, by all rights, we should be on a solid, stable path of recovery at this point in the business cycle. Just a few months ago, that seemed to be the case. Oil prices seemed to be on a long-term increasing trend, due to restricted industry investment coupled with steadily increasing demand. However, now we find uncertain and volatile markets again. Here is a sample of headlines appearing on my phone at this moment as I write:

> *"Crude oil prices rally as Saudi Arabia eyes more drastic measures" – Investors Business Daily, 2 hours ago, and*
>
> *"Goldman Sachs slashes 2019 oil price forecast amid oversupply concerns" – CNBC.com, 5 hours ago.*

So what are we to make of this? Actually, both can and probably will be true.

In a way, downturns are all the same. Market forces of supply and demand eventually take effect, often overshooting, and we eventually return to a stable, perhaps expanding, business environment. But they are always different. This time, the differences are obvious, but it is difficult to predict the outcome and timing of the effects of these new features. The biggest new element, and perhaps the one most responsible for our current situation, is the growing role of shales, particularly in the US. A lot of new production came in during the previous period of higher prices – ah, remember that? Conventional wisdom held that there was a cost factor for shales that would be a factor as prices fell, making much of that production uneconomical. That was true to some extent, but as always, the pundits underestimated the ability of the oil business to respond to such challenges. And of course, we did, dramatically reducing the cost of producing shales.

Craig J. Beasley

Other forces can be sited – the great crew change, the rise of electric vehicles, environmental and political situations etc. have all played some sort of role in the state of the current market, but none carry the weight of the shale revolution. There are at least 3 lessons we can take from this situation, assuming my analysis has some credibility:

1. Don't expect or rely on the traditional geophysics business to come roaring back as it has in the past. For example, there will certainly continue to be an offshore/deep water market for our trade, but such investments will surely be diminished in the near term, in favor of less capitally intensive investments and those with shorter payback, such as some shale plays offer.

2. If you believe the first one, orient yourselves and your business interests to address the needs in the shales. From my limited perspective, there is a lot of information we can add to the shale production process, but we need to supply it in a timely manner. It reminds me of the early days of 3D seismic. There was so much information we could provide with a 3D seismic survey, but we had to reduce the 2-year(+) timeframe for providing it. We face similar challenges in the shales, and I am certain we can make similar strides in our turnaround times. If we don't, we will be out of that game.

Word From the Board continued on page 5.

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

A Word From the Board continued from page 4.

3. The 3rd lesson is to invest in shales (this is safe because I didn't say when). It may be a little late for that, but more to the point, go back and read 1.) and 2.) again.

I would be remiss if I did not stress the significant help you can find in these turbulent times from your professional societies. We are fortunate, those of us who live in Houston, to have one of the premier geophysical organizations (local, national or international!) located right here in Houston. Membership is a bargain, as most of the services provided are free or are charged at cost. Response has been very good, considering the downturn we are in, but it could be better. We have lost many members and are working hard to encourage everyone to stay with us and take advantage of training, networking, technical meetings and all the things that make up the GSH. It will be well worth it. □

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

From the Other Side

By Lee Lawyer

Many of you may recall our last GSH Symposium, our 'honored' guest was Dave Hale. We had a great meeting. I have forgotten what the subject was, but I clearly recall the interaction of the group with Dave. We gave him a mild roast at the luncheon. One of the slides pointed out his startling resemblance to the actor, Sam Elliot (or vice versa). But the high point was the talk by Dave. In short, we had a good time.

Sam, oops, I mean Dave, has a project to which he is deeply (or should I say highly) dedicated. He plans to walk the total length of the Continental Divide Trail (CDT), which runs 3,100 miles (5,000 km) from Mexico to Canada. Obviously, he will make the trek in stages. He promised to keep us informed of his progress. The following is an update:

Lee,

Reading the Leading Edge this morning, I again miss your perspective From the Other Side!

With snow covering the high country, my CDT walking in 2018 is almost certainly completed. I walked 250 CDT miles this year, for a total now of 1050, and 1600 remaining. (Per my calculation, he will be short 750 miles! LCL)

Attached are some representative photos. The first two were taken about 16 miles from Ghost Ranch in northern NM, as I finished a liter of water before soon refilling. I treated and carried over a gallon from this good source.

The photo with Laura was taken at the NM / CO border, where she met me as I completed the NM portion of the CDT, about 3 miles from Cumbres Pass.

Since then I have been home in Boulder, with Laura, and with computers larger than the iPhone I carry on trail. With the rising tide of machine learning, more than once I have recalled a conversation with you in La Habra in 1986. It went something like this. "You have a Cray. Why do you need interactive workstations for interpretation? Can't you write programs that do all that for us?"

Dave

It appears that Dave is wearing tennis shoes. Consider sprained ankles, cactus needles, off-trail needs and miles from help. I challenged him on this deficiency and he gave me this statement: *"Those are trail running shoes! My feet and ankles have adapted and grown stronger because I wear them everywhere. Trail runners are lightweight and dry quickly. Roughly 80% of long-distance hikers today wear them."* Sounds good, but I will take light-weight hiking boots when I start walking the CDT.

I looked up the CDT on Wiki and found a notice about the Trail in New Mexico. It listed the hazards one could encounter on the Trail: Avalanches, Black Bears, Grizzly Bears, Dehydration, Falling, Hypothermia, Landslides, Lightning, Mountain Lions, and Severe Weather. I guess the reason they didn't mention rattle snakes was the altitude of the trail (Above which reptiles get too cold to strike?). □

Dave and Laura

Dave on the trail

Dave at the water trough

Technical Luncheons

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch North

Sometimes it Pays to be Cheap – Compressive Time-lapse Seismic Data Acquisition

Felix J. Herrmann

Speaker(s): Felix J. Herrmann,
Georgia Institute of Technology, Atlanta, Georgia
2019 1Q/2Q Distinguished Lecturer

Westside

Tuesday, Feb. 19, 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)

Downtown

Wednesday, Feb. 20, 2018
11:00 a.m. – 1:00 p.m.

Location: Petroleum Club of Houston
1201 Louisiana St., Floor 35
Houston, TX 77002
(Valet parking onsite)

Northside

Thursday, Feb. 21, 2018
11:00 a.m. – 1:00 p.m.

NEW LOCATION

Location: Repsol
2455 Technology Forest Blvd.
The Woodlands, TX 77381

** Please allow some extra time to sign in with security, and required escort to auditorium on 2nd floor.

Abstract:

During these times of sustained low oil prices, it is essential to look for new innovative ways to collect (time-lapse) seismic data at reduced costs and preferably also at reduced environmental impact. By now, there is an increasing body of corroborating evidence - whether these are simulated case studies or actual acquisitions on land and marine - that seismic acquisition based on the principles of compressive sensing delivers on this premise by removing the need to acquire replicated dense surveys. Up to ten-fold increases in acquisition efficiency have been reported by industry while there are indications that this breakthrough is only the beginning of a paradigm shift where full-azimuth time-lapse processing will become a reality. To familiarize the audience with this new technology, I will first describe the basics of compressive sensing, how it relates to missing-trace interpolation and simultaneous source acquisition, followed by how this technology is driving innovations in full-azimuth (time-lapse) acquisition, yielding high-fidelity data with a high degree of repeatability and at a fraction of the costs.

Biography:

Felix J. Herrmann graduated from Delft University of Technology in 1992 and received in 1997 a Ph.D. in engineering physics (DELPHI Consortium) from that same institution. After research positions at Stanford University and the Massachusetts Institute of Technology (Earth Resources Laboratory), he joined the faculty of the University of British Columbia in 2002 where he is now affiliate professor. Since 2017, he is cross-appointed at the Schools of Earth & Atmospheric Sciences, Computational Science & Engineering, and Electrical & Computer Engineering of the Georgia Institute of Technology. His research program spans several areas of computational exploration seismology including economic and low-environmental impact (time-lapse) acquisition with compressive sensing, data processing, and wave-equation-based imaging and inversion. He was among the first to recognize the importance of curvelet transforms, compressive sensing,

Technical Luncheons continued on page 8.

Technical Luncheons continued from page 7.

and large-scale (convex) optimization addressing problems involving simultaneously acquired/blended (time-lapse) data with surface-related multiples. He developed curvelet-based denoising and matched filtering methods that are now widely used by industry. He also made several contributions to full-waveform inversion and (least-squares) reverse-time migration by introducing concepts from stochastic and constrained optimization designed to produce high-fidelity results at lower costs. More recently, he has been involved in developing rank minimization techniques for seismic data acquisition, in the development of a domain-specific language for finite differences called Devito, and in the application of deep convolutional neural nets to seismic data processing and inversion. To drive innovations within industry, he started in 2004 SINBAD, a research consortium responsible for several major breakthroughs resulting in tangible efficiency improvements in industrial data acquisition and full-waveform inversion. At Georgia Tech, he vows to continue these activities by setting up a new research consortium with a focus on machine learning. He serves as deputy editor for Geophysical Prospecting and is a Georgia Research Alliance eminent scholar. □

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Please consider supporting the GSH through your Company Matching or Gifting Program. Volunteer hours are often rewarded with an Outreach Grant / Gift to the organization. Check with your employer now.

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Technical Breakfasts

Least-Squares Full Wavefield Migration

Register for Tech Breakfast North

Register for Tech Breakfast West

Speaker(s): Dr. Nizar Chemingui: Department Manager, Seismic Imaging Technology, PGS

Dr. Nizar Chemingui

North

Tuesday, Feb. 5, 2019
7:00 – 8:30 a.m.

Sponsored by Anadarko Petroleum and Quantico Energy Solutions

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

West

Wednesday, Feb. 13, 2019
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

Depth migration of primary reflections often yields an image with insufficient illumination due to limitations in acquisition or processing. Previously, we demonstrated that multiple reflections can illuminate a wider area of the subsurface and enhance the overall image quality, especially for shallow targets. However, migrating the full seismic wavefield (including primaries and multiples) often results in strong artifacts due to crosstalk between different orders of reflections.

In the presentation, we discuss a least-squares inversion solution for Full Wavefield Migration (FWM) that is capable of imaging all reflection modes in the data. The method solves for the earth reflectivity by means of data residual reduction in an iterative fashion. The inversion approach is key to enhancing the resolution of the image and compensating for the illumination variations due to incomplete acquisitions. The least-squares solution also attenuates the artifacts caused by the crosstalk between different orders of reflections.

Successful applications to several field surveys demonstrate the effectiveness of the solution for migrating the full seismic wavefield and improving the quality of reflectivity models beyond the imaging of only primary reflections.

Biography:

Dr. Chemingui is the Department Manager for Seismic Imaging Technology at PGS. He holds a Ph.D. in Geophysics from Stanford University, a Master's degree from Rice University, and a Bachelor degree in Geophysics from the Colorado School of Mines. He joined the seismic industry in 1999. He worked for ExxonMobil in the subsurface imaging division and for GXT (now ION) as a Senior Research Geophysicist. In 2006 he joined PGS and has held various positions in the R&D department. He has authored and co-authored numerous publications and patents on seismic imaging. He received academic and professional awards for his work, including the Cecil H. and Ida Green award in geophysics from CSM and a best paper award in The Leading Edge. He is a member of SEG, EAGE, AGU, and GSH. □

Data Processing & Acquisition SIG

An in Depth Look into Amplitude Versus Angle Analysis

Register for Data Processing

Edan Gofer

Speaker(s): JEdan Gofer, Research Geophysicist, Schlumberger

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

Tuesday, Feb. 12, 2019
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

Sponsored by Schlumberger

Abstract:

Reservoir characterization uses inversions of seismic data (Amplitude Versus Angle (AVA) or Amplitude Versus Offset (AVO) inversions) to impact drilling, stimulation and completion decisions. Therefore, it is important to understand the fundamentals underlying such inversion methods, including the choice of parametrization of the media (isotropic or anisotropic) and the choice of equations (linear or nonlinear versions).

In both conventional and unconventional plays, reservoirs may display strong reflectivity due to strong elastic contrast between the layers. Along strong contrast interfaces, nonlinear equations are required to model the reflectivity accurately. AVO analysis of strong contrast interfaces with linearized equations is valid only in the near offsets. If one of the layers is anisotropic, the AVO response will be affected not only from P-impedance and V_P/V_S ratio contrast but also from the anisotropic contrast. All these effects must be taken into consideration when preparing inversion workflows.

Biography:

Edan Gofer is a research geophysicist in Schlumberger. Edan joined Schlumberger in 2013 and has been working on technologies associated with seismic amplitude analysis and reservoir characterization. Edan received his BSc in Geophysics in 2009 and his MSc in Geophysics 2012 from the Tel Aviv university, Israel. Currently Edan is continuing his studies and is a PhD candidate at the same university. □

Rock Physics SIG

Automated Scanning of Fine-Scale Geological, Petrophysical and Geomechanical Rock Properties and its Application in Reservoir Characterization

Register for Rock Physics

Ramil Ahmadov

Speaker(s): Ramil Ahmadov,
New England Research

Sponsored by NER, CGG and Ikon Science

Wednesday, Feb. 6, 2018
5:15 p.m. Refreshments
5:30 p.m. Presentation Begins
6:30 p.m. Adjourn

Location: CGG
10300 Town Park Dr.
Houston, TX 77072

Abstract:

The integration of plug and log scale characterization is key to generating representative geological, petrophysical and geomechanical models at all stages from exploration and development to production. The importance of whole core and plug measurements is especially vital in finely laminated rocks where well-log scale measurements miss mechanical heterogeneities that are required for realistic mechanical models. The presence of mechanical heterogeneity and anisotropy under the well log resolution is commonplace in unconventional plays and can deeply impact geomechanical assessments ranging from wellbore integrity to horizontal stress estimates. Yet, in order to fully realize the value of lab-based geological, petrophysical and geomechanical characterization, it appears critical that laboratory workflows be optimized in terms of both outputs and turnaround times. In this talk, we present an in-house fully automated core scanner for fast and non-destructive physical property measurements (not just scanning) of elastic, transport and compositional properties of rocks at a very fine scale (down to mm) as well as a set of workflows to incorporate aforementioned properties in conventional and unconventional reservoir characterization with examples from Permian Basin, Vaca Muerta Formation in Argentina and deepwater GOM.

Biography:

Ramil Ahmadov is a Principal Geoscientist at New England Research. Prior to joining NER, Ramil has held various roles at BP and Ikon Science. He has over 10 years of experience in conducting pure and applied research in the area of rock physics, quantitative interpretation and petrophysics. Ramil has considerable experience integrating laboratory, well log, seismic and production data within integrated multidisciplinary teams at all stages from exploration and development to production. Ramil holds MS Geology and PhD Geophysics degrees both from Stanford University. □

Unconventional SIG

The Unconventional Revolution in Exploration Geophysics

Register for Unconventional

Nancy House

Speaker(s): Nancy House, President
Society of Exploration Geophysicists 2017-2018

Thursday, Feb. 7, 2019
11:30 a.m. - 1:00 p.m.

Sponsored by TGS

Location: TGS
10451 Clay Rd.
Houston, TX 77041

Abstract:

3D seismic imaging revolutionized hydrocarbon exploration providing a robust picture of the subsurface. Higher prices enabled expensive technologies and investments development of previously uneconomic deposits. The balance between development and the market value of the gas or oil is critical. Recent advances in 3D seismic allow interpreters to map areas of higher productivity, and identify bypassed reserves. MicroSeismic mapping has made completion more efficient and safer. Geophysical data is now an accepted early development tool of successful oil and gas companies.

By extending AVO to the pre-stack domain, it's possible to simultaneously invert for Vp, Vs and density. Armed with these three fundamental rock properties that dictate elastic and inelastic rock response, researchers were able to combine those properties to tie directly to how well a rock will respond to hydraulic fracturing, or which rocks contain a higher TOC, or other rock properties that control how a rock responds to seismic waves or hydraulic fracturing. Currently hundreds of different seismic attributes that are generated from 3D seismic data are used to identify the highest productive areas and how to develop them.

Biography:

Nancy House, a member of SEG for 40 years, has worked as a geophysicist for multinational corporations (Exxon, Phillips Petroleum, Mobil, Encana and Chevron) and small independent oil companies primarily as an interpreter for onshore and offshore US, South America and Africa (West and East), and other areas. She is currently owner of Integrated Geophysical Interpretation Inc. in Littleton, Colorado.

Remaining engaged in SEG and continually learning emerging technologies throughout her career allowed for participation in varied, challenging and interesting projects worldwide. This provided not only experience in petroleum geophysics but particularly in the delicate balance between science and economics in the exploration and production of hydrocarbons. She is second-generation petroleum geoscientist growing up in Wyoming, Colorado of the US, South America and Singapore. She has a BA in Geology/Geophysics from the University of Wyoming, an MSc in Geophysics from Colorado School of Mines, and did additional postgraduate work at Colorado School of Mines in Reservoir Characterization, Economics and Geophysics (2000-2002).

As President of SEG 2017-2018, she focused on leading the SEG in strategic planning and implementation of strategies in a safe and sustainable manner while exposing the social contribution of geophysics globally. With the continued dedication of staff and volunteers, SEG will continue to provide knowledge, guidance and support to generations of Exploration Geophysicists around the world. □

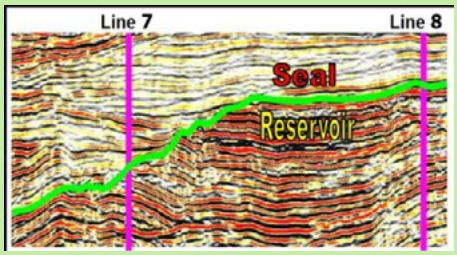
A Live Webinar

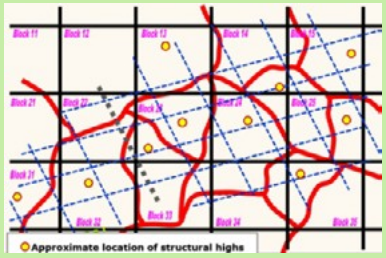
Sponsored Jointly by the SEG and GSH

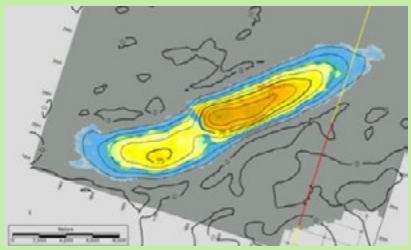
SOCIETY OF EXPLORATION GEOPHYSICISTS

Seismic Applied throughout the Exploration Life Cycle

Webinars on Seismic Interpretation







Four Half-days (10 AM – 2 PM)

Feb 5-8, 2019

Presented by

Fred W Schroeder

During these four sessions, you will interpret seismic data for an actual offshore field throughout the exploration life cycle. The New Venture stage will culminate with a mock lease sale. Then you will define a prospect. Next you will mature your prospect and propose a wildcat well location. You will tie the discovery well to the seismic data. Finally you will consider how the field might be developed. Short lectures will prepare you to do hands-on exercises. The instructor will walk you through the analysis. Come prepared to work.

Session 1
- Overview
- Play Elements
- Gippsland Basin Geology
- Map Top of Reservoir
- Acquire Acreage

Session 2
- The Alpha Lead
- Prospect Mapping
- Wildcat Well Location
- Making a Well-Seismic Tie

Session 3
- 3D Seismic Interpretation
  - Mapping Faults
  - Mapping Horizons
- Predicting Reservoir Facies

Session 4
- Reservoir Quality
- Estimating Recovery
- Planning for Development
- Platform Design

Fred Schroeder holds a BS in Engineering Physics from Lehigh University and a Ph.D. in Marine Geology from Columbia University. For most of his career he worked as a seismic stratigrapher developing and applying new interpretation methods. For two years of semi-retirement, he was an contract trainer within industry and at Texas A&M. Serving as a volunteer, Fred has given seminars and short courses to over 2500 students. Working with IRIS, he has placed many of his training materials on the web to help educate graduate students.

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Concurrent Seismic Acquisition With Two Identical Crews Using the Simultaneous Shooting Technique

Rahul Dixit, Nick Moldoveanu, Stephen Alwon, Jason Thekkekara, Francisco Figueira, Rachel Yates; WesternGeco*

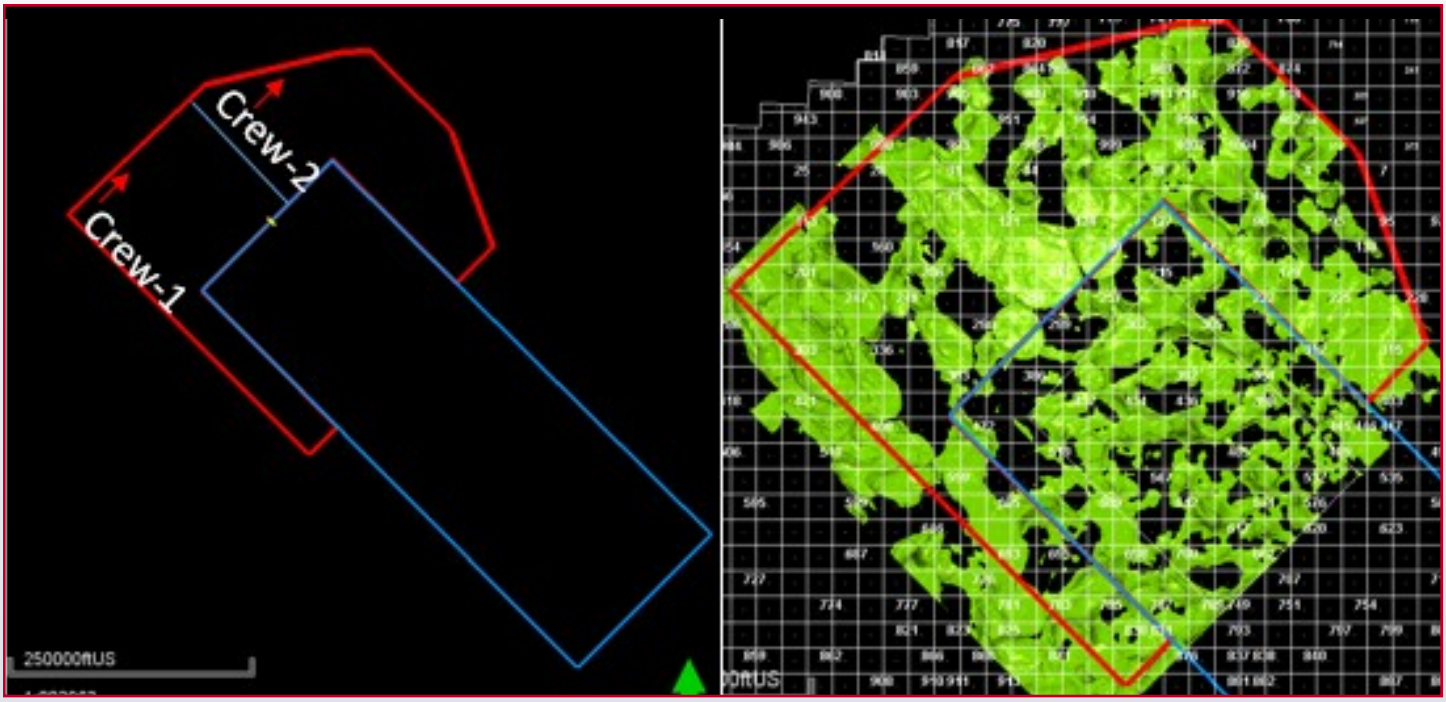

Figure 1: Outlines and locations of the two surveys: 2013 is the blue outline and 2014 is the red outline; the green color (right panel) marks the extent of the salt in the area; two identical crews, separated by a minimum distance (left panel), were used to acquire data for the 2014 survey.

Summary

Improving seismic acquisition efficiency and reducing turnaround are important tasks for seismic contractors, particularly in the current business environment. In this abstract, we present a case study where we used two identical crews shooting different part of the same survey, and each crew used the simultaneous shooting method to enable long-offset marine acquisition. This acquisition approach allowed us to acquire efficiently long-offset data in the required time frame.

Introduction

In 2013 and 2014, two seismic surveys were conducted in the east-central area of the Gulf of Mexico. This area is a geologically complex basin resulting from the interaction and deformation of salt and overlying sediment layers over geologic time. The main targets in this area are the Jurassic Norphlet, located typically at depth of 7300 to 8500 meters, the sediments around the salt diapirs, and the shallow Pliocene sediments that contain stratigraphic traps. Understanding the stratigraphic details and imaging the salt diapirs and deep sediments requires broadband, long offset seismic data. The shapes and the locations of the two surveys are shown in *Figure 1*.

The first survey, outlined in blue, was acquired in 2013 using an eight-streamer configuration, 12 km in length, and with a 120-m separation. The cable depth profile was a linear slant, from 10 m to 40 m to enable better preservation of lower frequencies and receiver deghosting. A dual source array was used and the shot interval was 37.5 m, flip-flop. Towing 12-km streamers proved to be challenging due to the strong currents and numerous obstructions

Technical Article continued on page 15.

For Information Regarding Technical Article Submissions, Contact GSHJ Coordinator Scott Singleton (Scott.Singleton@comcast.net)

Technical Article continued from page 14.

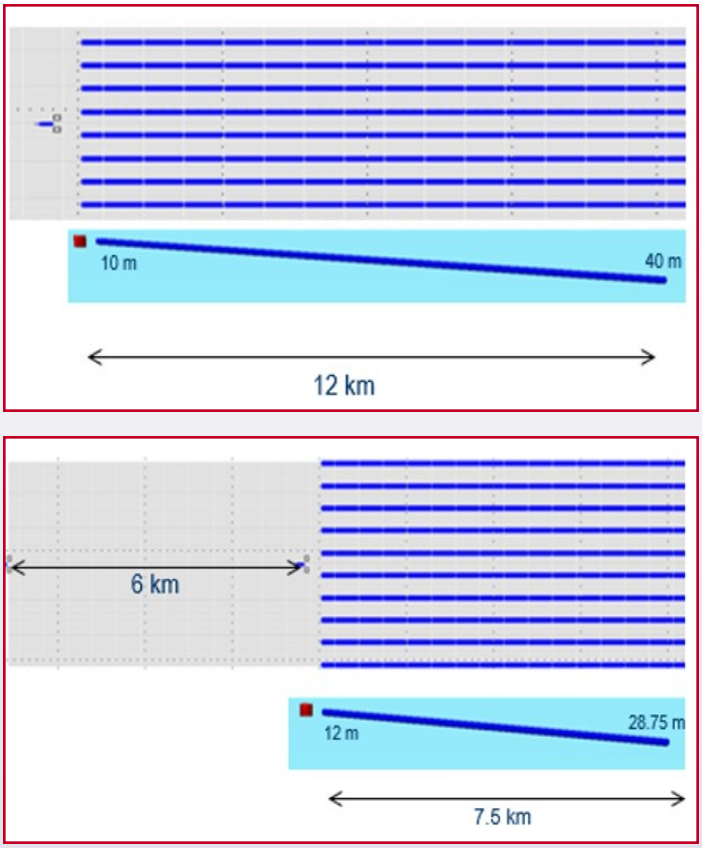

Figure 2: The acquisition configuration for the 2013 surveys with long streamers and shorter streamers with a source vessel in front.

in the area, and it was decided to shoot the last part of the 2013 survey (western side) with 10 shorter streamers, 7.5 km long, at a 120-m separation, and an extra source vessel positioned 6 km in front of the streamers. The water depth greater than 1000 m allowed us to reduce the shot interval to 25 m and to fire the four source arrays sequentially with overlapping records and continuous recording. Both configurations for the 2013 surveys are shown in *Figure 2*. Acquisition and processing the 2014 survey is the subject of this work.

Concurrent seismic acquisition with two identical crews using the simultaneous shooting technique

The 2014 survey, outlined in red in *Figure 1*, was acquired with similar acquisition parameters as the last part of the 2013 survey: 10 streamers, 7500 m in length, 120-m separation, source vessel in front of the streamers at 6 km, and a dual source array on each vessel. To improve the source sampling it was decided to use simultaneous shooting with two dithered sources *(Figure 3)* (Moore, 2008). The nominal shot interval was 25 m and an important feature of this design is that the sources fired at the same time are separated by 6 km.

As the total survey area was 6898 km^2 and a short delivery time for acquisition and processing was required, two identical crews, using the same acquisition parameters were used to acquire data in the same time *(Figure 1)*. The survey planning assured that the two crews always maintained a minimum separation distance of 30 km. Distance separation and dithering of all sources made this shooting strategy very successful in terms of minimizing the effect of seismic interference and halving the total acquisition time.

Processing simultaneous shooting data

Different methods have been developed in the last five years to separate sources that are fired simultaneously, and these can be classified into two broad categories: active separation and passive separation.

Active separation: Under this category, there are two types of methods:

- Based on modelling and sparse inversion (Moore et al. 2012).
- Based on noise attenuation applied in different domains: common receiver gather, common trace gather, common offset gather, or shot gather.

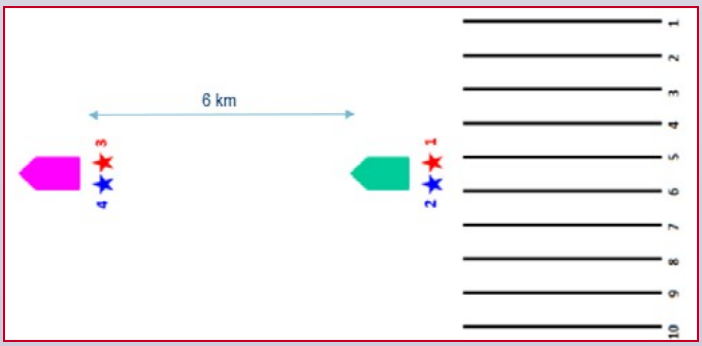

Figure 3: Simultaneous source shooting with two dithered sources shooting in flip-flop mode: 1 + 3 and 2 + 4; nominal shot interval was 25 m.

Technical Article continued on page 16.

Technical Article continued from page 15.

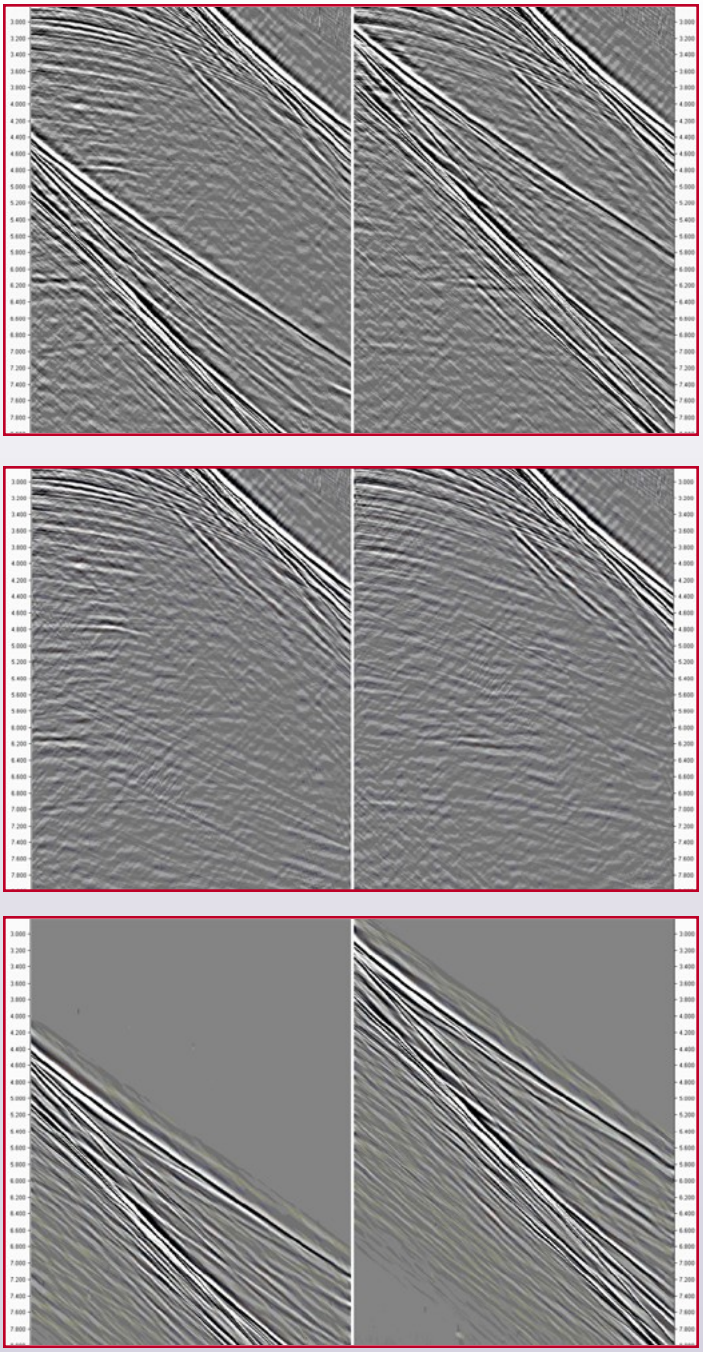

Figure 4a: Examples of shot gathers before separation (top), after (middle) and difference (bottom)

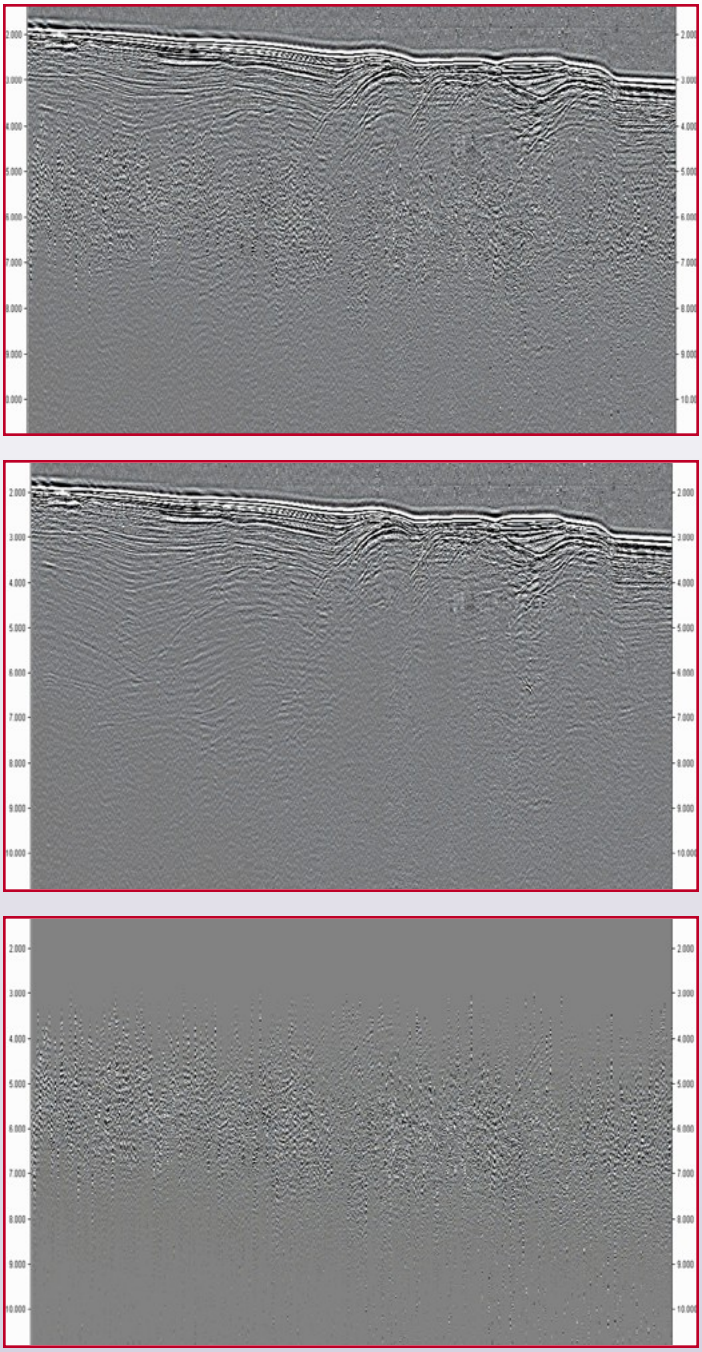

Figure 4b: Example of receiver gather before separation (top), after (middle) and difference (bottom)

For both methods, the input is the composite shot of interfering sources and the output are the separated shot records.

Passive separation: The theoretical basis of this method is that modern imaging algorithms can separate the interfering seismic energy at the imaging step and no active separation is required; the assumption being that all processing steps before imaging (noise attenuation, demultiple, and velocity model building) can be accurately performed on non-separated shots. In this survey, noise attenuation type active source separation was used in order to minimize turnaround time.

Technical Article continued on page 17.

Technical Article continued from page 16.

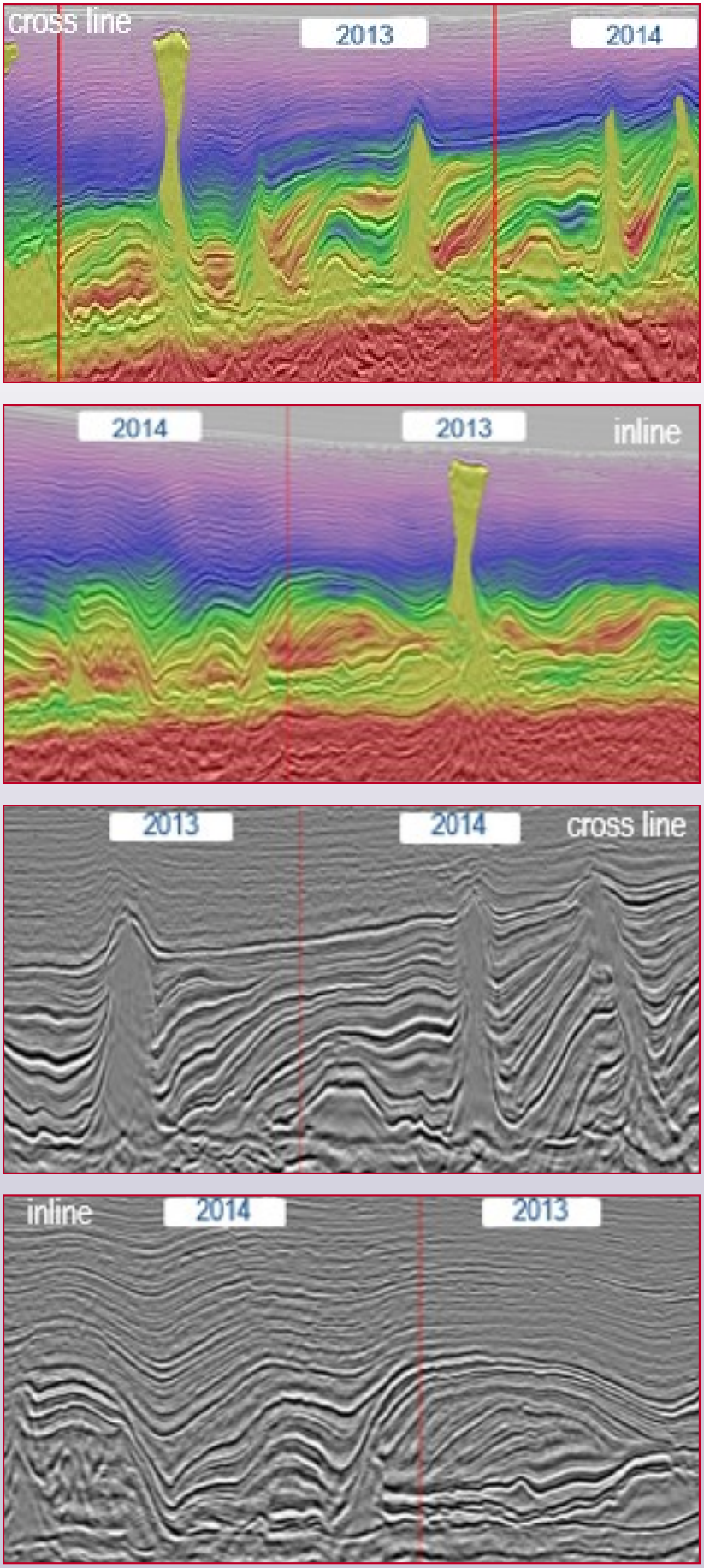

Figure 5: Comparison of velocity models and final migrated images for crossline and inline passing through the boundary of the 2013 survey and the 2014 simulataneous shoting survey; the red line marks the boundary between the two surveys.

Examples of shot and common trace (receiver) gathers, before and after source separation, are shown in *Figure 4*. These illustrate that source separation based on noise attenuation was very effective.

The conventional processing sequence was used for signal processing and imaging after simultaneous source separation. High resolution Kirchhoff migration and reverse time migrations were used to produce final migration images.

In *Figure 5 and 6*, we show an example of final velocity models and final migrated data from 2014 long-offset, broadband, simultaneously acquired data, and the 2013 broadband, long offset survey acquired conventionally. These two surveys do not overlap, but by examining lines that pass through the boundary of both surveys (inline, crossline directions and depth slice) it can be seen that images and model are seamless.

Discussion and Conclusions

Using a dual-vessel configuration with a streamer vessel towing 7-km streamers and a source vessel 6 km in front, combined with simultaneous shooting, allowed us to efficiently acquire long-offset data in an area with strong currents and obstructions. Separating the interfering source energy based on noise attenuation was conducted in the shot domain and also in the common trace domain.

During the 2014 survey, another seismic crew, from a different contractor, acquired seismic data, and interfering energy was

Technical Article continued on page 18.

Technical Article continued from page 17.

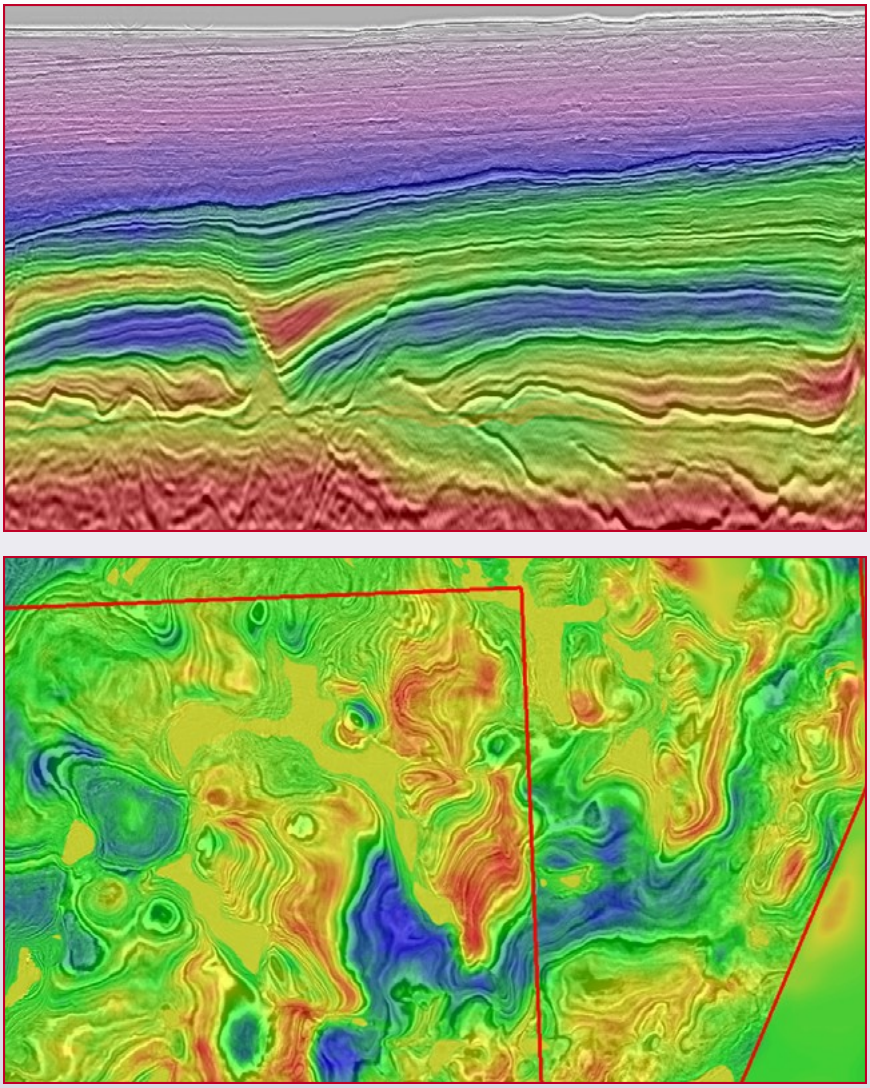

Figure 6: Velocity overlay on cross line (top) and depth slice (bottom) passing through the boundary of the 2013 survey and the 2014 simultaneous shoting survey; the red line marks the boundary between the two surveys.

visible on our records. In addition to the noise attenuation flow designed for simultaneous sources, for the records affected by seismic interferences from the other crew, a multi domain 3D spatial filter designed in the tau-p domain (Yu 2011) was used that was very effective in removing the seismic interference.

Concurrent seismic acquisition using two identical crews based on a minimum separation distance and using dither times was successful. Using dither times helps to remove residual seismic interference in common receiver (trace) gathers. This proved that this is an effective solutionto reduce acquisition time without affecting data quality.

By examining lines that pass through the boundary of both surveys (inline, crossline directions and depth slice) it can be seen that images and model are seamless. Quality of the final velocity model and migration images are comparable to the adjacent 2013 survey, which was acquired with conventional acquisition design.

Acknowledgements

We acknowledge WesternGeco Multi-Client for permission to publish this abstract and the colleagues who contributed to this work. □

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Yu, M., 2011, Seismic interference noise elimination–A multi-domain 3D filtering approach: 81st Annual International Meeting, SEG, Expanded Abstracts, 3591-3595, https://doi.org/10.1190/1.3627946.

Permalink: https://doi.org/10.1190/segam2017-17430856.1

GSH Outreach

Committee Activities *By Lisa Buckner,* outreach@gshtx.org

GSH will host a Community Booth at the **Girls Exploring Math and Science (GEMS)** event for Girl Scouts on **Saturday, February 16** at the **Houston Museum of Natural Science**. Four volunteers are needed from **7:30 AM – 1:30 PM** to setup, teardown and staff the booth. Benefits include admission to the museum until it closes at 5 pm, snacks during the event and the chance to make new friends, network with colleagues and have a lot of fun educating Girl Scouts and the general public!

The **AAUW Expanding Your Horizons in Science & Mathematics** (EYH) conference for middle school girls in grades 6-8 is on **Saturday, February 23 at Spring Forest Middle School**. EYH is designed to nurture young women's interest in mathematics, science, and technology related careers to expand their career vision in these areas through a series of hands-on workshops led by dedicated women professionals. I'm serving on the EYH committee and gave a training talk to the workshop presenters on January 29 held at the Federal Reserve Bank. One or two volunteers are needed to assist the girls with the hands-on petroleum reservoir exploration activity and me with the presentation, AAUW membership is not required. We'll be hosting two student hands-on workshops either in the morning or in the afternoon. Lunch will be provided by the American Association of University Women (AAUW) West Harris County Branch. Approximately 450 girls eagerly participate in this event every year. If you know of a girl who would like to participate, moms and dads are welcome too, registration ends February 13.

The **Science and Engineering Fair of Houston (SEFH)** needs you to volunteer. At least six GSH volunteer Special Awards Judges will be needed on **Saturday, February 23 from 11:30 AM – 4:15 PM** (lunch is included) at the George R. Brown Convention Center Hall E to select winners for GSH Awards. We work in teams and no previous judging experience is necessary. Contact the GSH Lead Judge Gokay Bozkurt to volunteer at gbozkurt2002@yahoo.com. The SEFH is also in need of **500** Place Award Judges (see flyer).

Information regarding both types of judging can be found at http://www.sefhouston.org. The general public is invited to view all of the science fair projects during the Public Day Open House from 4:30 PM – 6:30 PM on Saturday, February 23. The awards ceremony will be held on Saturday, March 2 at the UH Cullen Performance Hall. Science fairs are not only important for our students to learn more about Science, Technology, Engineering and Math (STEM) but also for Houston's future.

Six or more volunteers are needed on **April 6** to host the GSH booth at **Scout Fair**. Thousands of scouts attend this event and we give away 600 - 900 GSH logo coiled toy springs. This admission free event will be held at NRG Area from 10 AM – 3 PM. If you are available, please contact me to volunteer for lots of fun! □

If you are interested in volunteering for any future outreach events, please contact Lisa Buckner at outreach@gshtx.org.

AVO Synthetics: The Forward Model

Thanks so much for your mindless question, anonymous students.
Try to grasp this concept. The discussion of AVO to which you will now be exposed, will show the way Forward, a position from which we will march back to find what we started with!
Do you understand he significance of this?
I thought not. But never mind, just pay attention and you will be enlightened fully.

What the hell is he talking about?

Confused Constituent

I can't be sure, but I think he finally realizes he screwed up this subject so badly, that the only way out is to do it over.

A helpful student ventures a guess.

Guru gracefully explains

Forward to the Past

Or "Those who cannot remember the past are condemned to repeat it."

Recapping Synthetic construction. **[NB:** While this topic has been frequently capped in these pages, we feel quite strongly that occasional recapping fulfills the Guru's inspirational mantra that the true teacher **"Can't cap too much."].** The initial step in making any **synthetic** is to calculate or estimate **reflectivity** from available information. What information? The basic data is the impedance (ρ·**Vp** and ρ·**Vs**), which comes from either **well logs** or off-the-wall **imagination,** if you're in the ***what if*** game in which you want, for example, to do **fluid substitution.**

Let's start with **well log data** that generally produces a synthetic with a fighting chance of matching real **seismic data** at the well location. At the right, is an example from June 2018 Nuggets. $\mathbf{Z_N}$ is the impedance (ρ_N·$\mathbf{Vp_N}$). (The **V** shown is **Vp**).

$\rho_0 = 2.24$	$V_0 = 9000$	$Z_0 = 20160$	$R_0 = 0.066$
$\rho_1 = 2.30$	$V_1 = 10000$	$Z_1 = 23000$	$R_1 = -0.032$
$\rho_2 = 2.271$	$V_2 = 9500$	$Z_2 = 21570$	$R_2 = -0.107$
$\rho_3 = 2.175$	$V_3 = 8000$	$Z_3 = 17400$	$R_3 = -0.066$
$\rho_4 = 2.119$	$V_4 = 7200$	$Z_4 = 15250$	$R_4 = 0.103$
$\rho_5 = 2.208$	$V_5 = 8500$	$Z_5 = 18770$	

The Vp is derived from a compressional (P-wave) sonic curve (DTC) which measures interval time in units of microseconds (**μs/ft**). It is converted to **Vint** by **(sonic)$^{-1}$(10^6)** every **0.5 ft .**

Tutorial Nuggets continued on page 21.

Tutorial Nuggets continued from page 20.

The example indicates relatively thick layers of uniform properties. OK for illustrative purposes, but unrealistic compared to real well log curves. We'll worry about this momentarily, but let's deal with some notational idiosyncrasies. With an eye to the future use of the forward modeling equations for inversion, we note that the **impedance** (here called **Z**) is given by its **natural log** in the matrix equations.

$$\mathbf{D} \quad \mathbf{L} = \left(\frac{1}{2}\right) lnZ \qquad \mathbf{R}$$

$$\begin{pmatrix} -1 & 1 & 0 & 0 & 0 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{pmatrix} \bullet \begin{pmatrix} 4.956 \\ 5.022 \\ 4.99 \\ 4.882 \\ 4.816 \\ 4.92 \end{pmatrix} = \begin{pmatrix} 0.066 \\ -0.032 \\ -0.107 \\ -0.066 \\ 0.103 \end{pmatrix}$$

D represents the differencing operator between $\left(\frac{1}{2}\right)$ **lnZ$_{i+1}$** and $\left(\frac{1}{2}\right)$ **lnZ$_i$.**

L is the vector of $\left(\frac{1}{2}\right)$ **ln Z** values.

R is the **Reflectivity** at the layer boundaries

Note that because **R** is taken at the boundaries, N layers delivers (N-1) **R** values. Inversion of **R** to **L** will be tough with **fewer equations** than unknowns.

We discussed solutions to the inversion problem (using constraint equations, etc) in earlier *Nuggets*, but what we have studiously avoided is the discussing the very real issue of band limitation of the frequency spectrum of **Z**, which goes from **0 to sic 'em** (Nyquist). First, the differencing operator, **D**, effectively multiplies the spectrum by **πf** removing all traces of **Z's** dominant frequency, **f = 0**. While we can deal somewhat with this abomination, a real life addition to the forward model, **the wavelet,** which is convolved with the reflectivity to produce a reasonable approximation of the real seismic trace, **S(t) =W(t) ∗ R(t),** puts a real crimp in the inversion process – especially one that can reasonably be expected to recover the real **Z** with accuracy, if not precision. While theoretically deconvolution should cure all that, you'll go broke betting on it. We learn to live with the band limitation of the seismic data and estimate, via inversion, meaningful and useful value for impedance, that will lead to even more useful values of **rock or lithologic properties** (porosity, water saturation, sand, shale, carbonate fractions, and the like.

As we drift toward the goal of **AVO inversion of PP angle gathers**, we recognize that the addition of **shear information** opens the possibilities and reduces the ambiguities significantly. Beyond that, we look to the joint inversion of **PS (or SvP)** converted wave AVO to further purify our estimates of essential rock and reservoir truth.

To accomplish these tasks, we must be able to **model with accuracy**, the seismic data. This brings us back to how to account for the transition from high resolution log data, sampled at **0.5 ft** to time data where the real seismic lives. It is commonly agreed and widely argued that impedance should be computed from the ρ and **velocity logs**, **Vp** and **Vs** (derived from sonics, **DTC** and **DTS**). The spectral issue is this: should the impedance be computed from the **raw** (but edited) logs, the **"blocked"** logs or with some **smoothing** applied (approximating the effect of the band limitation of the wavelet). The answer must lie in the **match** of the resulting **AVO model** and its **real seismic counterpart** at the well location. In March, The Test.

Tutorial Nuggets continued on page 22.

Tutorial Nuggets continued from page 21.

Solution to the Christmas Gift Puzzle

December 25th happens to be the least common birthday, but let's suppose it is your birthday, and further suppose that this year you will be N years old, where N is the last 2 digits of the year you were born.
How old will you be on Christmas day?

A couple of trial and error guesses will quickly converge to your age last month as 59, having been born in 1959. This is actually true for any day, not just Christmas, but that seemed more in the holiday spirit. For a more general approach (and one that will impress your less gifted friends), try this arithmetic:

2018 - (1900 + n) = n; 2n = 118; n = 59 = Age; Born 1959
Or (as was pointed out by a gifted child proof reader): 9 yerars old, born in 2009

1st Puzzle of 2019

Help Katie Balance the Budget

Down at the GSH International Headquarters, the buzz is about the new **Austerity and Frugality** Program, initiated on January 1, with much fanfare and hoopla (including an astonishing $21374.65 bar tab). Heading up the new initiative is **Katie Baker**, **Treasurer** and **Chief Bean Counter** of the **GSH Morals and Money Department**. Her first cost cutting exercise was to reduce **outrageous power costs at the HQ**. Her move in that direction was to cut all electrical power to the HQ. Higher Powers on the office staff prevailed, and power was restored to the computers. Katie held firm, however, on powered light systems, AC, and other non-essentials.

While others frittered away their time with family, Christmas and New Year's festivities, Katie analyzed her new light and heat source for the GSH, **Dollar Store Candles**. Her observations on the two finalists for GSH Frugal Light are as follows:

Candle 1 is **1 inch longer** than Candle **2**. Candle **1** was lit at **3 PM**, and Candle **2** began burning at **5 PM**. At **9 PM**, they are the **same lengths**. Candle **1** burns out at **11 PM**, while Candle **2** self extinguishes at **10:30 PM**.

Clearly they burn at different rates, probably due to different diameters and wax quality (one of the candles consisting of basically human ear wax, the other, Sperm Whale wax and traditional Beeswax).

What are the **original lengths of the candles?** Send your answers to the **GSH** with supporting evidence and a sizable donation for **Katie's Kause**.

Ryan Marshall ‣ (713) 962-9414 ryan.marshall@dawson3d.com

GSH Office ‣ (281) 741-1624 karen@gshtx.com

Register NOW on-line @ the **www.gshtx.org** events calendar

Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 26.

GSH OUTREACH is looking for volunteers for:

***Science Fair Judges**

***Career Days**

***Earth Science Celebration**

***Young Women Energized**

Contact Lisa Buckner at: outreach@gshtx.org

To support OUTREACH:

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Theory and case studies highlighting advances in seismic inversion that impact drilling decisions

SPEAKERS & TOPICS

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David Johnston (Differential Seismic) - 4D inversion
Jon Downton (CGG) - Machine learning inversion
Klaas Koster (Oxy) - Conventional & unconventional reservoir characterization
Maria Perez (Anadarko) - Operator case history
Brian Russell (CGG) - History of inversion
Colin Sayers (Schlumberger) - Integration with engineering
Rob Stewart (University of Houston) - PP PS inversion
... and more!

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- Social gathering on Tuesday evening
- Banquet toasting and roasting the honorees during lunch Wednesday
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- Exhibit booths available

2019 Honorees
Dan Hampson and Brian Russell

For sponsorship and booth details, call the GSH at 281-741-1624 or visit **gshtx.org/symposium2019**

The Mystery Item
on page 24
a geophone auger used for planting geophones.

Recognizing Outstanding GSH Volunteers...

Kathy Sanvido

by Tommie Rape

The GSH would not be able to function were it not for the two paid staff that maintain the GSH office and support all of the GSH activities. The staff, Kathy Sanvido and Karen Blakeman, are very dedicated to the GSH and often go beyond the call of duty to help ensure that our organization functions well in every aspect. They both volunteer time and effort well beyond their paid time, and we want to recognize their volunteer efforts today. In this article we will recognize Kathy; check last month to find out about Karen.

Kathy Sanvido was born and raised in Houston, Texas, the youngest of five children. Kathy obtained a B.B.A. in marketing from the University of Houston (UofH) while working full time at one, and sometimes, two jobs. One of those jobs was Purchasing Agent for Smith Industries, Inc. While attending UofH, she also worked part time at MACRO Enterprises, Inc. Even before completing her degree, Kathy advanced at MACRO to become the Marketing Director; there she was responsible for growth of the company resulting from marketing and outside sales of this custom software development firm. She changed her employment to MapInfo Corporation, where she was a Marketing Representative responsible for managing a seven-state territory. During this job she established a new company record for sales in that territory. Kathy left MapInfo to assume an even bigger job, that of raising three boys (currently 23, 24, and 26 years of age). While raising her sons, her aptitude for hard work translated into her becoming a volunteer leader at the boys' school and a Cub Scout leader for the boys. Kathy was also a Board member of her Home Owners' Association. Kathy's volunteer work at the school led to her being hired as the School Database Manager for the Salem Lutheran School, where she initiated and completed the modernization of the school's administration data to electronic form.

Kathy's association with the Geophysical Society of Houston (GSH) began when the GSH and Houston Geological Society (HGS) maintained their office together. There she was the Website Manager for both organizations. Soon after the GSH separated its office from the HGS, Kathy volunteered at night helping Karen Blakeman organize the new GSH office. Recognizing her indispensability, the GSH hired Kathy part time and quickly altered that to a full time position with the GSH in 2012. She immediately became the GSH Webmaster and quickly also assumed the responsibility of Membership Manager. As the Webmaster, Kathy maintains the daily activity on the GSH website and handles the interaction with our website provider. Kathy also creates and distributes the GSH weekly newsletter eblast, which is the primary GSH tool for keeping our members (and others) informed of the many GSH activities occurring each month. As if the website management was not enough, Kathy quickly assumed the responsibility of Membership Manager. This position helped fulfill Kathy's passion, which is interaction with people. If you

Volunteers continued on page 28.

Volunteers continued from page 27.

have talked with Kathy at the GSH office with issues about membership, registration for events, or any other problem, then you have found out how **personable** and helpful she can be. You have probably found out, like I have on occasion, that her suggested solutions for problems seem more likely to succeed than the ideas I had. Kathy added our membership numbers to her list of passions, and was the primary force in doubling the GSH membership in a little over a year. If you have wondered whether you should join the GSH or not, talk to Kathy and you will find out points that you probably had not thought of before. Kathy also established the GSH booth that is present at professional events; this presence has helped increase GSH membership.

When asked about her volunteer efforts for the GSH, Kathy was reluctant to take any credit for that. She said that she just did whatever it took to get the job done. But many of us have seen Kathy work far beyond the call of duty. One example of this effort occurred when our previous website provider was hacked, and the GSH lost website functionality for a couple of months. Kathy went far beyond the call of duty to ensure that our members' activities were affected as little as possible. And she did this while working nights and weekends in helping build our new website. Kathy attends events (i.e. works at events) far beyond her normal working hours. When the GSH office was flooded and closed for almost three weeks after Hurricane Harvey, Kathy said that she was not going to let our members have excess suffering from the disaster; she managed to carry out almost all of her normal job duties while working from home. During the industry downturn of the last few years, Kathy was also very concerned about the GSH members who were losing their jobs. Representing the GSH, she volunteered to contact the Society of Professional Engineers (SPE) and joined their committee that organized and ran a job fair for petroleum industry professionals. This event was so successful that the organizing committee won an SPE award for Most Outstanding Committee in 2017.

Kathy does not think about separating her work from her volunteer efforts. She does what it takes to get

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the job done. She comes to the office on her days off to get the job done. Kathy feels that she works until "she" is satisfied with the job, and that is usually to a higher quality than what others around her feel is necessary. When pressed, Kathy did acknowledge that she liked to help people (and the GSH). She never really thought about what she gained from volunteering for the GSH. She stated that she did gain a great deal of satisfaction from being part of the GSH, because it was the nicest group that she had ever been involved with in the oil industry.

Kathy was once told that "She had a servant's heart". Where there is a need, she jumps in. There has to be a connection between that "servant's heart" and that passion to help others. The GSH and its members are lucky to have benefitted from this passion of Kathy, a GSH member and employee. The next time you see Kathy at the GSH office or a GSH event, talk to her and find out how personable she is, and be sure to thank her for all that she does for the GSH. □


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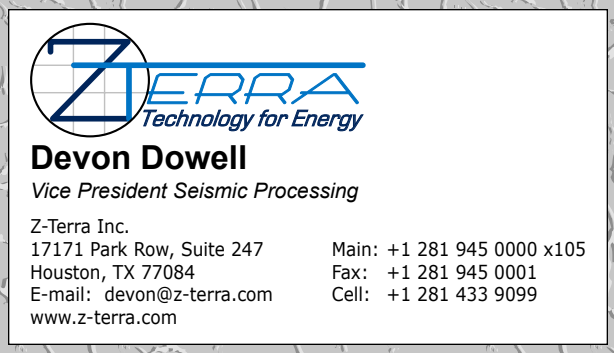
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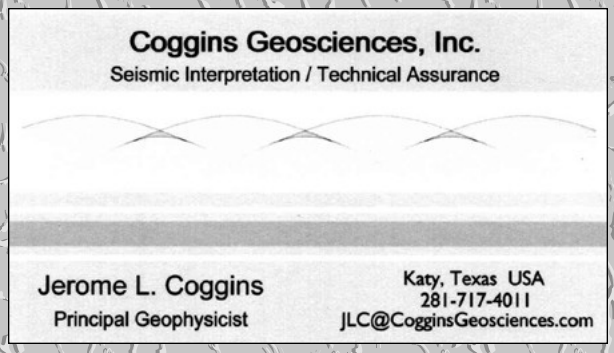
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U of H Wavelets

SEG Wavelets Hosts Distinguished Lecturer and Cohosts Annual Holiday Party By Matthew Sexton

Members of the SEG Wavelets gather together in the photo booth.

A photo featuring participants in the ugly sweater contest.

On November 14th, SEG Wavelets had the pleasure of hosting Dr. Satish Singh, an SEG 2018 3Q/4Q Distinguished Lecturer. Dr. Singh presented an insightful lecture titled *"Seismic Full Waveform Inversion for Fundamental Scientific and Industrial Problems"*. This lecture catered not only for students and faculty but also professionals as it covered the history of FWI and its applications in the O&G industry as well as in crustal studies and global seismology. Dr. Singh summarized FWI as a technique that can be used to provide high resolution, quantitative information about the elastic properties of the subsurface with the end goal of characterizing the subsurface geology. A couple of his talking points included breakthroughs with FWI such as its application to gas hydrate reflections as well as in characterizing the melt beneath ocean spreading centers. Dr. Singh also addressed the issue associated with acquiring seismic data in deep water by discussing the concept of downward continuation of seismic data which strengthens FWI by reducing diffractions while also enhancing wide-angle reflections. This approach has led to the quantification of gas anomalies in sedimentary basins and fluids at subduction fronts.

On December 3rd, SEG Wavelets in conjunction with AAPG Wildcatters and GeoSociety, hosted an annual holiday party at the Nouveau Antique Art Bar in Midtown, Houston. The holiday party is our favorite social gathering event and this year's event included food, drinks, and games such as an ugly sweater/photo contest, a photo booth, and a raffle for prizes. The venue served as a nice setting for a great turnout with many students, faculty, and even alumni stopping by to enjoy good food and company before school lets out for the holidays. □

Holiday party-goers smile for a photo.

Geoscience Center

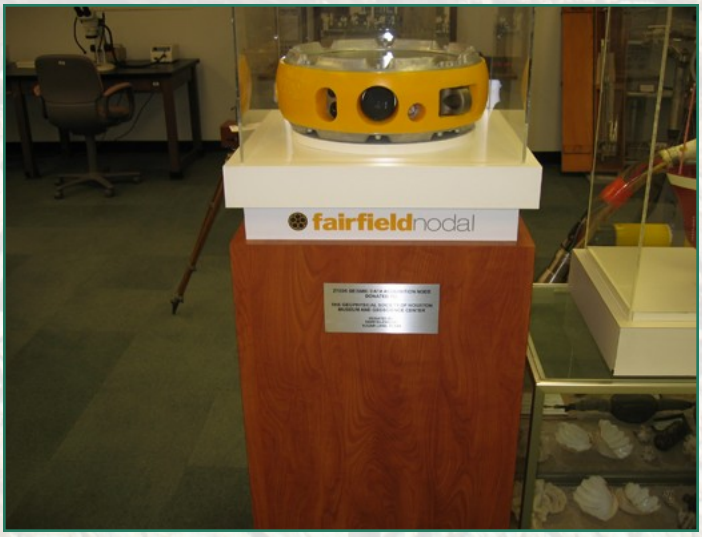
The History of Geophysics *By Bill Gafford*

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

Partial view of display

Our next quarterly **Living Legends Doodlebugger social event will be at the Geoscience Center** on Thursday morning, **February 14**. Everyone is welcome, no registration is necessary, there is plenty of parking and the event is free. Some of the Mystery Items that have appeared in the GSH Journal will be on display and some of our senior doodlebuggers will be on hand to explain some of

Model of marine seismic recording boat



Z node marine seismic acquisition module

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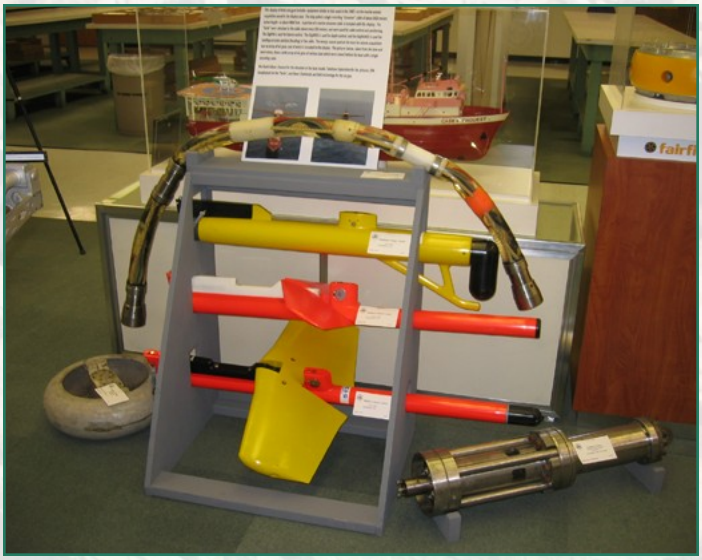

"Birds" for marine seismic cable control

Display case with various geophones

the artifacts and entertain with stories of the oil patch. Light snacks, coffee, water, and soft drinks will be available.

There are several locations in Houston and Austin where we have displays of some of our geophysical artifacts. One of the larger of these displays from our Museum Collection is located at the University of Texas, Jackson School of Geosciences, Bureau of Economic Geology, Houston Research Center, which is located on West Little York in northwest Houston. The facility houses a large collection of geologic cores and cuttings and has a large core layout room where core workshops are held and cores and cuttings are analyzed. Our display is located in this room and has been enjoyed by the visiting geoscientists. The pictures included in this article illustrate a portion of the items on display. Some of the more interesting items are marine related and include a portion of a marine acquisition cable and the associated "birds" which controlled the location, depth and lateral position of the cable. A typical air gun which was used as the energy source, is also included. There is also a model of a 1980's vintage recording boat and some shallow water geophones and hydrophones. The two display cases shown include a variety of land geophones, amplifiers, survey instruments, and computing devices. Also on display is a deepwater Z node, which illustrates current technology.

There is also a brief explanation of some of the items on display in a museum guide prepared by Les Denham. I will highlight other displays in future articles of the Geoscience Center news.

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. □

Display case with various seismic recording instruments

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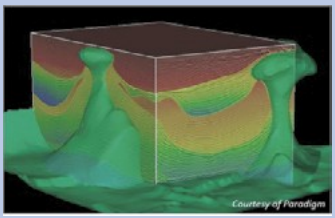

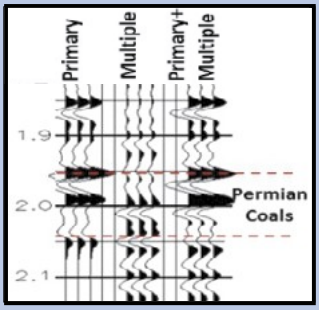

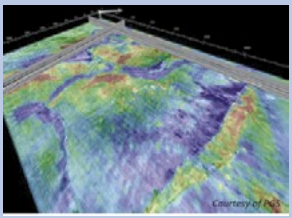

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• Basics and UPDATES on Anisotropy: Azimuthal P-P for better Imaging, Fractures & Stress Analysis Acquisition, Processing & Interpretation	Dr. Heloise Lynn
• Geophysical Signal Processing 101	Enders A. Robinson & Sven Treitel
• Seismic Amplitude 20/20: An Update and Forecast	Fred Hilterman & Mike Graul
• Extracting Geology from Seismic Data	Fred Schroeder
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Doodlebugger Diary

Peru – Land of the Inca Gods

Part 2 – The Survey *By Scott Singleton*

This month's Doodlebugger Diary is a continuation of the series Scott Singleton started in February 2018 with his 5-part series on being shipwrecked in the South China Seas in 1992 while surveying a pipeline route from Hainan Island to Hong Kong. He then wrote about his experiences in Eritrea in 1997 after the end of their civil war and in Vietnam in 1997 after that country opened up to Westerners once again. His new series is about his work in Peru in 1998.

The Doodlebugger Diary recounts 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, etc. I published a story about working in a data processing center. Please consider contributing a story about your past professional experiences. Contact me at Llawyer@prodigy.net *or our Editor at* editor@gshtx.org.

Figure 1: Map of Peru. From https://www.cia.gov/library/publications/resources/cia-maps-publications/Peru.html.

Arriving at the dock in Talara in the spring of 1998 *(Figure 1)*, I scanned the dock-front looking for the telltale signs of a seismic boat. There were scads of offshore workboats around *(Figure 2)* due to the fact that the Talara Basin in the 1990's was the only offshore oil production in Peru (see Part 1– Geology and History of Oil Exploration) and thus roughnecks and service crews were everywhere. Soon I saw

Doodlebugger continued on page 38.

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***

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Figure 2: Dock-front scene in Talara – offshore workboats tied up next to the local fishing fleet.

the usual Marisat dome, covered back deck, and reels of cable sections *(Figure 3)*, indicating I had found my prey.

The port of Talara was unique in its own way, as of course is every port around the world. The fishing dinghies were all of a uniform build (which was sort of strange, like they had all come from the same builder), were wind powered by a single mast (no motor), and all had a long pole to move the vessel in the port *(Figures 4, 5, and 6)*. The other thing that was very unusual is that the water was green, which in itself is not unusual but this color was a vivid green, likely because there was no plant debris or silt in the water so it was fairly clear except for the algae and microscopic organisms making it green. This distinctly contrasts with the Pacific which is a deep dark blue, a color which occurs just offshore.

The survey itself progressed without much of a problem from a logistics or project supervision standpoint. Long 2D lines are a godsend to enabling large amounts of line-miles to be shot, which is exactly what happened during the survey. This doesn't mean the survey progressed rapidly – with several thousand km of 2D lines the project went on for months, although, I unfortunately don't remember exactly how many months, but it was long enough for me to do two rotations with the acquisition crew.

The main points of interest concerned the clastic Eocene reservoirs, which were the objective of

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Figure 3: View from on top of the back deck of my 2D seismic boat.

the survey. These were stacked reservoirs since there were several similar sequences within the Eocene section, all of which had a gravel unit at their base (see Part 1 – Geology and History of Oil Exploration). I was told that in the past seismic data had not been able to penetrate these multiple gravel layers so imaging was confined to the shallowest sediments which was not sufficient for oil exploration. And on top of that, the reservoirs were either fluvial sand or sheet sand, and in the case of the former were very difficult to image and map unless the seismic had high fidelity and high frequency, which it had not been to this point in time.

So my primary responsibility onboard was to do preprocessing and take it through brute stack to see if the data we were acquiring would be sufficient to image the lower portions of the Eocene reservoirs. Every time we would come back to the port I would show my brute stacks to PetroTech's brass who were very keen to know what we were coming up with. During these meetings I met the owner of the company who was an American that had bought the rights to the offshore leases, and the exploration manager who was a geologist and an American who I happened to know from previous companies we both worked at (yes, it is a small world and professional networks can be of great assistance).

In a nutshell, the data in the northern part of the survey was not very good. This is the same area that most of the production was coming from in the form of a huge number of wellheads that dotted the entire area. The problem was these gravel layers. The southern part of the survey area contained much better data because this was on the flanks of the Talara Anticline and the producing layers steeply trailed off the side of the anticline (including the offending gravel beds). However, in this deeper sediment section there

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Figure 4: The Talara fishing fleet at rest. Note the uniform style and lack of motors.

Figure 5: One of the docks the Talara fishing fleet used. There was apparently a market happening at this time, probably to sell the catch of the day or week or whatever.

Doodlebugger continued on page 41.

Doodlebugger continued from page 40.

were not yet any economic hydrocarbon finds, so it was a moot point that the seismic was all really great looking.

Nonetheless, despite the fact my brute stacks along the top of the anticline didn't look very good to me, the PetroTech brass apparently thought it was significantly better than they had seen prior to this survey. Since my company, Energy Innovations, was working for them as birddogs on this survey, they invited me to their main offices in Lima to meet their geophysicists and processors to discuss processing workflows and how they might be improved to image the lower reservoir units. This I did and it was very interesting and informative for all involved, so much so that they wanted me to spend some time there working with their processors. This was an interesting offer but one I had to think about to figure out how it might mesh with what was happening in my personal life. But before I get into that part of my story I need to describe some extreme weather events that were happening, or rather had just happened, all along the coast of Peru. □

Next month: Part 3: The 1997-98 El Niño Event

Figure 6: Some of the fishing fleet coming into the port. Looks like a sailing regatta, but no, these sails are actually used to get from the port to the fishing grounds and back. The squat boat on the right looks like it could be a dredge barge for the port.

HGS Scholarship Night & Dinner Meeting

HGS Foundation Scholarship & Calvert Memorial Fund February 11, 2019
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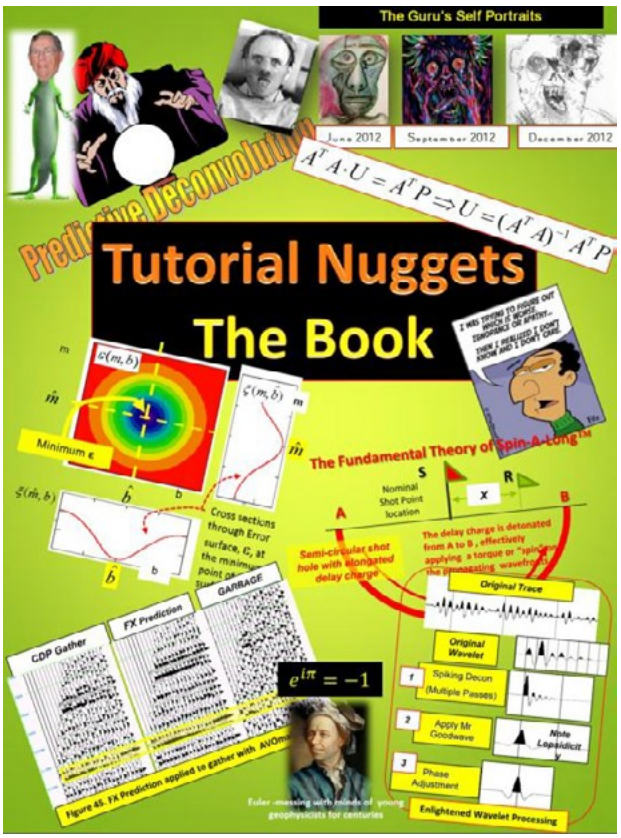

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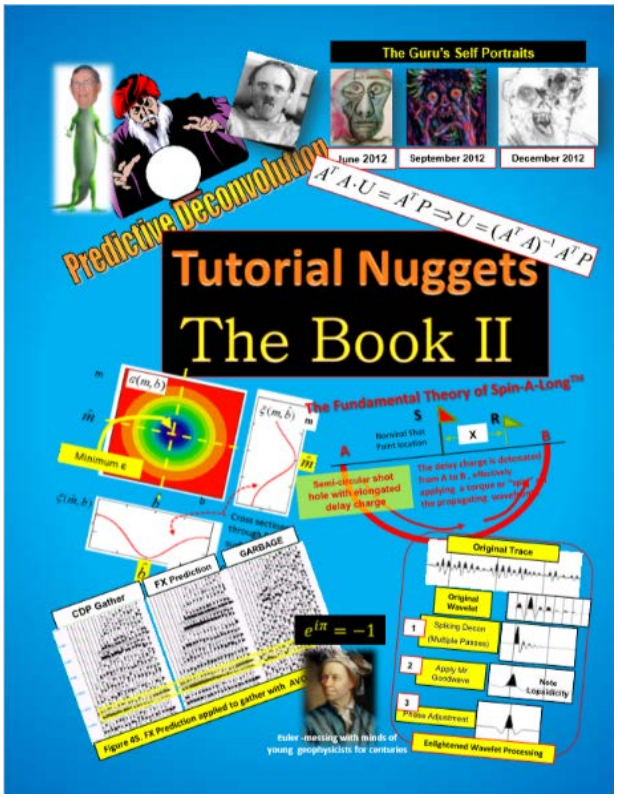

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