

April 2019



*The Epicenter of
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GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 9 • Number 8



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*Image courtesy of
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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

June 2019.....Apr 12
Sept 2019..... July 12
Oct 2019..... Aug 15

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A Word from the Board

What's Happening in the Board Room?

By Sara Davis, Secretary



As we continue our journey through these changing times in the oil patch, the GSH board is looking for creative ways to raise the financial standing of the organization. Income to GSH has traditionally come

from membership dues, event participation and sponsorships. With fresh ideas, we hope to identify ways to increase income and decrease expenses. Please encourage your colleagues to become members of the GSH, and if you can, help secure sponsorship dollars at any level.

The GSH has continued to offer events that allow us to maintain a vibrant geoscience community through educational, networking and social activities. Those involved in the ongoing production of our monthly luncheons and SIG meetings will be making recommendations to the board on how to continue to improve these programs. In assessing our options, we are currently evaluating the impact of implementing a fee structure for non-GSH members who attend our free events. Our hope in the coming months is to inspire non-members to join and continue to enjoy the events free of charge as a benefit of their GSH membership.

We recently created the new "Unconventional SIG" which will address a broad range of topics that are pertinent to the unconventional sector of the oil and gas business.

The Spring Symposium is fast approaching! A great deal of effort has gone into this year's event, which will be held on Tuesday and Wednesday, April 16th and 17th. This year's

topic is "The Resurgence of Seismic Inversion" and has a line-up of exceptional speakers.

The event will honor Dan Hampson and Brian Russell who founded HampsonRussell. A "Toast & Roast" is part of the program in which attendees will learn more about our honorees outside of their respective business personas, and is sure to provide some lively entertainment.

Also taking place during the Spring Symposium is our annual Student Challenge Bowl. The Challenge Bowl is a fast-paced contest where teams of geophysics students from area universities square-off in a competition of wit and geophysical wisdom to determine who will participate at the Global SEG Challenge Bowl. Please visit our new web page in the Outreach pull-down menu for more information about this. Also, additional information about the Spring Symposium, including contact information for sponsorship and Vendor Exhibit opportunities can be found on the GSH website at www.gshtx.org/symposium2019.

First VP, Maitri Erwin who oversees the Spring Symposium, would like to recognize Jim Schuelke and Simon Voisey, Technical Chairs for the time and effort they have both dedicated organizing the technical program and ensuring that this year's event will be a tremendous success.

The nominations process for next year's board of directors is complete. Please make your voice heard and vote this month as new board members will be introduced at the Annual Meeting and Honors & Awards dinner on Thursday, May 9th. Mark your calendars and plan to attend this annual event during which we will recognize GSH members who have made significant

A Word From the Board continued on page 5.

contributions to the advancement of our mission, along with members who have reached significant milestones. We will also announce additions to our Honorary and Lifetime membership roster.

Our Outreach Committee, led by Lisa Buckner, has been hard at work nurturing the geoscientists of the future. Lisa and her team continue to support a full slate of events including career days, workshops and science fairs throughout the Houston metro area. Volunteer opportunities abound for supporting this committee! If interested, contact Lisa at outreach@gshtx.com.

The Geoscience Center continues to be a valuable resource for archiving important geoscience artifacts and publications. We are launching a "Legacy-Giving" campaign to encourage the allocation of estate gifts from our members. Please consider a gift to the Geoscience Center to continue the

growth of the center – whether in the form of a donation now, or as part of your legacy.

Currently underway is a project in partnership with the SEG to upload pertinent information to a Wiki page. Volunteers are gathering at the Geoscience Center on Saturdays to chip away at this initiative. If interested in supporting the Geoscience Center in any way, please contact Bill Gafford at geogaf@hal-pc.org.

The board appreciates the efforts of each and every member of our GSH community and encourages everyone to pitch in to support our organization. If we can create momentum by each of us doing one small thing, we can make the GSH stronger than it has ever been. Please support our society by inviting industry colleagues to join GSH, asking your employer to be a sponsor, and by participation in and promotion of the various events that will be held in the coming months. □



ANNOUNCING THE 2019
**GEOPHYSICAL SOCIETY OF HOUSTON
HONORS & AWARDS BANQUET**

Thursday, May 9th, 2019
Cocktails - 6:00 pm, Dinner - 7:15 pm

Norris Conference Center
Magnolia Room
816 Town & Country Blvd.
Suite 210
Houston, Texas 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.





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

Employers Matching and Gifting Programs

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.

The Geophysical Society of Houston is a 501(c)3.



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:

nmaidland@resolvegeo.com - 713-972-6209



From the Other Side

By Lee Lawyer



I have had feedback from a reader of this column. He said my material needed more energy, more controversy, something to pep it up. Since this person was (and is) a friend, I did not yell at him. I simply asked him to provide a topic or topics that would qualify.

He repeated his statement regarding the need to energize the column. Okay, okay.... this one is controversial, but I need help with topics. There are those that suggest I shouldn't write when I don't have a subject. This has never stopped me in the past, so I say why start now!

Should I take a position on Global Warming, that is man-made global warming? The earth has been warming for 20,000 years, which makes it difficult to come up with hard data to prove that mankind is responsible. But it would really surprise me if we weren't partially responsible. Check out smog in California a few years ago. They have greatly reduced the smog with stringent restrictions on automobile emissions and the use of automobiles by commuters. They required and encouraged car pools. It worked in the Los Angeles area. Can we scale that up to global dimensions? I don't recall a discussion of smog induced temperature increase, i.e., the 'greenhouse effect'. I do recall it was sort of hard to breathe during bad smog days. Maybe someone has temperature data in the LA basin during smoggy days and non-smoggy days. That would clearly prove the man-made greenhouse effect.

There are people who are adamant that there is no man-made increase in global warming. It is all a hoax. They rightly fear we will wreck our economy trying to reduce CO₂ emissions. On the other side, there are those that want to eliminate the petroleum products for transportation and heating, and have a tax on carbon emissions, and give a rebate back to the masses?? If you believe that, I have a bridge in Arizona for sale.

These are two extremes. Now, I challenge my readers to fight it out. I am ready for controversy. But this is

really old news. I need current events to energize 'From the Other Side'. I could update the picture of me in the column. That would be exciting. Do you remember the time when the SEG eliminated my picture? I substituted a Neanderthal skull one month. Lawyer vs. the SEG Editor didn't last long, but it was fun while it lasted.

As far as I can tell, the 'History of the GSH' has not been updated since 2006. Art Ross brought us that far. A lot of history has happened since then. We have had 13 Presidents and other officers. It is time for an update. It was also decided that I would make that update. (I wasn't at the meeting.) But first I have to know the history before I can update it! The following is a thumbnail history of the GSH with my comments. (Please don't stop reading.)

The SEG changed their bylaws in 1947 allowing the formation of SEG Sections. I can't recall the exact requirements to start a Section, but it required a petition signed by 20 Active SEG members. The Organizing Meeting of the "Houston Section of the SEG" met and elected officers and prepared a formal petition to be a charter Section of the SEG. That charter was issued on February 14, 1948. The name was changed to Geophysical Society of Houston 10 years later.

We have the names of the early officers. A few may be familiar to the older generation of Houston geophysicists. Paul Ferren, E. W. Johnson, and D. P. Carlton, who donated stock currently worth over \$500k. The only one I personally knew was Roy Lay. You can get the detailed list of officers from our Web site. Meetings were held at the Rice Hotel, which still stands but has been turned into condos, I believe. I like one tradition. Each year the newly elected President is given the gold shovel. I guess the idea was that a shovel would be required because of all the B.S. that naturally occurs during GSH meetings. It was a joke at the time but has been strictly observed ever since.

So now for the update. The President in 2006-007 was Kathy Hardy, the first woman President of the GSH. We struggled along, living with the Houston Geological Society. I was Editor for 2003-4 and

From the Other Side continued on page 8.

2004-5. Our by laws specified that the Editor was a one-year term only, no second term. I didn't recall that when I volunteered for a second term. Since the ballots were already out, the GSH Excom did a 'fast foot shuffle' and changed the bylaws and I became the first two-year Editor.

Realizing the need for continuity on the Board, the Elect positions were put in place the year the same year Mike Graul was made President (2009-10). His tenure was marked by the decision to initiate the GSH Journal. A couple of years later, the GSH and HGS split and went their separate ways. Jim Schuelke was President and did a great job setting us up to live by ourselves. The GeoScience Center was opened during Scott Singleton's term as President (2012-13) although a large portion of the artifacts were already in our hands but stored in various places.

With the election of seven more Presidents, our thumbnail sketch of the GSH comes to an end. Now wasn't this exciting (but not controversial!!)? □



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- * **Catalogued Artifacts**
- * **Student Activities**
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- * **Teacher Workshops**

See more on the website:
www.gshtx.org

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Opening Plenary Session Speakers Announced

"Business Breakthroughs with Digital
Transformation Crossing Disciplines"
Monday, 17 June, 1:00–2:15 PM

Opening Plenary Session speakers include:

Mark Chiles, Senior Vice President & Chief Digital Officer, Hart Energy
Chetan Desai, Vice President Digital Technology, Schlumberger
Detlef Hohl, Chief Scientist Computation and Data Science, Shell
Susan Howes, Vice President Engineering, Subsurface Consultants and Associates, LLC
Nagaraj Srinivasan, Senior Vice President, Landmark and Halliburton Digital Solutions

The opening session will explore the different elements of transformation, the technologies, data management and integration, and the cultural change integral to realizing and sustaining true digital transformation. In addition, you will gain a clear understanding of the content from subsequent conference sessions, ensuring that you will receive maximum value for your participation.

Make plans now to attend this interactive and participative conference, register today!

energyindata.org

Technical Breakfasts

Integrating Geology and Geophysics into Engineering Workflows to Enhance Unconventional Production

Register
for Tech Breakfast
North

Register
for Tech Breakfast
West

Speaker(s): Tony Settari, CGG Canada
Dale Walters, Technical Manager, CGG



Tony Settari

North

Tuesday, Apr. 2, 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

Abstract:

In traditional conventional oil and gas reservoirs, the roles of the geoscientist and engineers have been very defined and distinct between the two fields, with the role of the geoscientist to locate and drill potential reservoir and the engineer's role to generate production. In the past, once the discovery was made and production began, there was generally little interaction between the geoscientist and the engineering. With the advent of lateral wells and hydraulic fracturing of unconventional reservoirs for oil and gas recovery, there is a strong argument that there is now a role for geoscientists (geologist, petrophysicist and geophysicist) during the completion and production phase, which has traditionally been the domain of the engineers. However, the limited interaction between the geoscientist and engineering groups in many operating companies in the past has meant many geoscientists don't speak the language of engineers and vice versa.

West

Wednesday, Apr. 3, 2019

7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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



Dale Walters

In this presentation, we discuss a series of case studies completed by the CGG Geoscience group with an integrated geoscience and engineering team working on various unconventional reservoirs throughout the mainland United States. The case studies discussed in this presentation provide examples of how the geoscientists have provided input into engineering outcomes by adjusting the "language" they use. Examples are shown on how geological and geophysical outputs have been successfully used to provide data to better drill and complete wells and capture variations in rock properties, which is fed into fully coupled reservoir/geomechanical simulations, following which how these variations impact the potential injection and production from a well. The presentation will also discuss how these integrated geoscience/engineering interpretations can then be extended throughout production history matching and optimization of future drilling and completion designs.

Breakfast continued on page 10.

Biography:

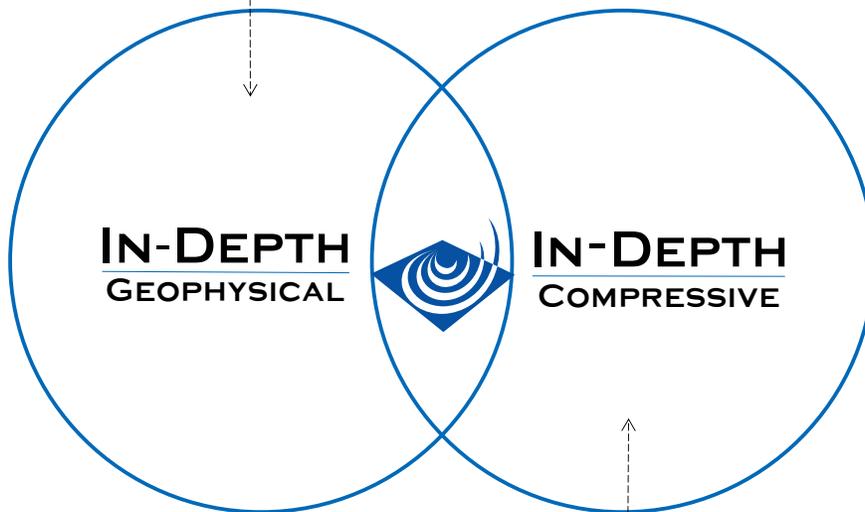
Antonin (Tony) Settari

Dr. A. (Tony) Settari is with CGG Canada (formerly with TAURUS Reservoir Solutions Ltd. which became a part of CGG in 2015). He is also a Professor Emeritus at the University of Calgary, where he has taught since 1975 and has held the Endowed Chair in Petroleum Engineering. His areas of interest include reservoir simulation, fracturing and geomechanics. He is a co-author of the classical textbook on Petroleum Reservoir Simulation (Aziz and Settari), and has written two other texts and over 150 technical publications. He is a Distinguished Member of SPE, and received several international prizes including the SPE Anthony B. Lucas Gold Medal, the Eni Prize "Frontiers in hydrocarbons" and the SPE C. Ferguson certificate.

Dale Walters

Dale Walters has 20 years of engineering experience, participating in large reservoir and geomechanical engineering studies throughout the world within a multi-disciplinary team environment. He has conducted multiple geomechanical and caprock integrity projects both in Canada and abroad. Coupled reservoir and geomechanical experience includes steam stimulation projects of heavy oil reservoirs, compaction of sandstone and chalk reservoirs, compaction induced seismicity, modeling fracturing in Unconventionals and jointed media, produced water reinjection, waterflood fracturing, stress dependence of fractured reservoirs, sand production and wellbore stability. He is a Technical Manager at CGG focusing on reservoir geomechanical consulting. He is a registered Professional Engineer with APEGGA, and holds BSc. and M.Sc. degrees in Civil and Geotechnical engineering from the University of Calgary. □

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Rock Physics SIG

A Perspective on Geomaterials Anisotropy and Heterogeneity, With Some Challenges in Image-based Predictions

Register
for
Rock Physics

Speaker(s): Laurent Louis,
Adage Corporation

Wednesday, Apr. 3, 2019

5:15 p.m. Refreshments

5:30 p.m. Presentation Begins

6:30 p.m. Adjourn

**Sponsored by NER, CGG
and Ikon Science**

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



Laurent Louis

Abstract:

As high resolution 3D images are getting increasingly incorporated into core analysis workflows, strategies for improving the connection between parameters in effective medium models and accessible metrics in image volumes are becoming more and more pertinent. Though the digital rock physics technology is traditionally associated with numerical simulations, the availability of 3D image data sets of ever improving quality also undoubtedly warrants sustained efforts in basic characterization and parameter extraction with the goal of feeding updated effective medium models. Two obvious advantages of effective medium models over numerical simulations are the immediateness of the prediction through functional relationships, and the added benefit of a conceptual phenomenological understanding. There are a number of known challenges to the prediction of elastic and mechanical properties, which for a large part stem from the multiscale heterogeneity that exists in the physical properties of a material's constituents, and the associated strain field. Nonetheless, by defining the model/image connection as our objective, a number of studies can be proposed which should lead to a coherent series of improvements.

This presentation starts with a review of a new stress-dependent strength model that was recently

proposed for porous sandstones. After applying the model to a large published data set, we then reason on the significance of its parameters as well as on the possibility to quantify them directly through information extraction from X-ray CT images. Throughout this work, stress sensitivity emerges as perhaps the most critical aspect in the prediction of elastic and mechanical properties. The presence of two stress sensitivity elements in the model provides a seed to a comparison with the work that has been done on static and dynamic elastic properties, and guides our search for microstructural constraints in high resolution X-ray CT images.

Biographies:

Laurent Louis was until recently a principal scientist at New England Research in VT, USA. He has previously held R&D roles at BP and Shell in Houston, and holds a PhD in geophysics from the University of Cergy-Pontoise (France). He specializes in rock mechanics, X-ray CT imaging and structural petrophysics. In 2018, he founded Adage Corporation, a technical services and R&D company focusing on the integration between rock physics data and X-ray CT images. Adage aims especially at progressing a capability for image-based prediction of geomechanical properties through effective medium modeling. □

Unconventional SIG

Artificial Intelligence For High Resolution Reservoir Characterization

Register
for
Unconventional

Speaker(s): Barry Zhang,
Co-Founder and Chief Executive Officer
of Quantico Energy Solutions

Thursday, Apr. 4, 2019

11:30 a.m. - 1:00 p.m.

Sponsored by TGS

Location: TGS
10451 Clay Rd.
Houston, TX 77041



Barry Zhang

Abstract:

The traditional neural networks that have been used for years can be of limited utility due to lack of sufficient training data in order to correctly model physical systems. Similarly, multi-variant linear statistical approaches have been used and applied to seismic facies recognition. Both techniques lack sufficient resolution for modern drilling windows and hydraulic fracturing analysis. However, earth models are extremely important as it has been shown that in most cases operators experience inconsistent IP's and variable estimated ultimate recovery (EUR) which can be significantly improved with a high-resolution earth model for well placement and completion.

Commercially proven methods have been developed to overcome these challenges by integrating artificial intelligence techniques with geophysical constraints. These methods can be applied to seismic inversions. Conventional inversion methods can be band limited and several calibration constraints placed on seismic requires more human interactions for interpretation that directly affect the result. An AI inversion method increases bandwidth which is directly proportional with the resolution. Reservoirs that cannot be discerned when their thickness is below seismic resolution can now be visualized in high fidelity with the AI approach.

AI methods that properly integrate geophysical constraints greatly reduce risk and uncertainty

critical to making strategic, tactical decisions, and calculating value of information. Cross validation using blind test wells provide confidence about the quality of the results.

Biography:

Barry Zhang is Co-Founder and Chief Executive Officer of Quantico Energy Solutions, an artificial intelligence company focused on drilling and geoscience solutions for the oil and gas industry. Shell, Equinor and Nabors Industries are major investors in Quantico. Barry has invested in and served on the boards of directors for several oilfield services technology companies as part of his roles with Shell Ventures, Kenda Capital and HitecVision. Prior to that, he focused on the tech and telecom sectors with stints in investment banking in both New York and Silicon Valley. Barry is a leading expert in artificial intelligence for the oil & gas industry. He has been sought out for his AI expertise by major news publications such as the Wall Street Journal, Bloomberg and Frost & Sullivan.

Barry graduated from Yale University with a Bachelor of Arts in Economics. In pursuing his undergraduate degree, he also studied European monetary policy at the University of Oxford. He received his MBA from Northwestern University's Kellogg School of Management. □

Data Processing & Acquisition SIG

Integrated Broadband Preprocessing (IBP)

Register
for Data
Processing

Speaker(s): Mehdi Aharchaou; Exxonmobil

Co-author(s): Erik Neumann; Exxonmobil

Tuesday, Apr. 9, 2019

4:30 p.m. Sign-in, Snacks, Social Time

5:00 p.m. Start of presentation

Sponsored by Schlumberger

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



**Mehdi
Aharchaou**

Abstract:

“Broadband Marine Seismic” emerged in the last decade as a key technology area driven by the goal of higher resolution and S/N. In today’s broadband processing sequence, source designation, receiver and source-side deghosting, mean-sea-level redatuming, and phase Q correction are often applied sequentially, with amplitude Q compensation delayed till migration or post migration. We ask “how much of this workflow can we still improve?”

In the first part of this talk, I present a newly-developed method, Integrated Broadband Preprocessing (IBP), which aims to jointly achieve all the above-mentioned preprocessing steps, by estimating spike-sparse tau-p models fitting prestack data before migration. IBP works on single-sensor and multi-sensor measurements, and is compatible with all streamer profiles. I give examples of how this integrated approach, powered by near-optimal time-slowness sparsity, results in cleaner broadband data with less artifacts. In the second part, I zoom in on IBP’s background Q compensation, and contrast it with the commonly-used 1D inverse Q filtering. In particular, I share a time-referencing formula which is simpler and more accurate than the standard NMO-based time referencing (Xia’s method). I then show an uplift from the application of pre-SRME amplitude Q compensation on multiple attenuation.

Biography:

Mehdi Aharchaou is a research geophysicist at ExxonMobil. During his 5 years with the company, he has worked on various cutting-edge signal processing and inversion technologies, on topics such as deghosting, noise suppression, Q compensation, source designation, trace interpolation, sparse Radon and multiple attenuation; and he has presented on some of these topics at the SEG. Prior to joining the oil and gas industry, he graduated from Georgia Tech, Rice University and INP-ENSEEIH (Toulouse, France) with three Masters Degrees in Geophysics and Electrical Engineering, and he worked on multiple real-world problems in oceanography, borehole geophysics, in addition to earthquake and exploration seismology. His interests lie in the processing, imaging and inversion of geophysical data. Recently, his interests evolved towards the integration of machine learning and artificial intelligence to automate the geophysical exploration workflow. □

GSH Annual Golf Tournament 2019

The Woodlands Country Club Palmer Course has been chosen to host this year's Geophysical Society of Houston's Annual Tournament. This 27-hole facility is carved out of Texas Pine trees and features undulating and mounded terrain, complete with challenging bunkers and intricate water hazards. This course has become a favorite venue for all levels of golfers.



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Apache

EXPLORING WHAT'S POSSIBLE

Horizon Focused Birefringence Analysis of 3C PS Seismic Data: Permian Basin - Case Study, NE Midland

Tony Johns*, WesternGeco

Summary

Increased exploration activity over the Permian Basin in West Texas has led to using more non-conventional means of acquisition such as incorporating horizontal sensors for multicomponent P-wave and C-wave (PS) imaging. Unique seismic properties from PS (or pure SS), such as Shear Wave Splitting (SWS) induced by azimuthal anisotropy, facilitate fracture characterization, leading to an improved understanding of the reservoir.

This paper applies the method presented by Boiero and Bagaini (2016, 2017) by utilizing their new approach to invert for interval values of SWS intensity (SI), as defined by Chevrot (2000), to obtain a model of anisotropic parameters

varying with depth. SI is a robust measurement with respect to structural variations and facilitates estimating key anisotropic properties within a geological formation by analyzing the differences of SI measured at the top and bottom of a geological sequence. The method circumvents iterative layer stripping, which is an advantage for shallow layers where anisotropic parameters are difficult to estimate due to poor coverage, and consequently makes SWS analysis simpler to apply.

Results from two independent SWS birefringence studies of the 3-component (3C) PS data from a NE Midland, Texas, survey will be presented together with a discussion of ongoing work that was prompted in response to the attributes uncovered.

Acquisition

The 326-square mile NE Midland 3D-3C survey was acquired near Midland, Texas, in Q2 of 2016.

Seismic acquisition consisted of:

- 3 sets of Vibrators
- Sweep freq 2-90Hz
- 3C 10Hz geophones
- Receiver/source group interval 165-ft
- Receiver/source line interval 825-ft.

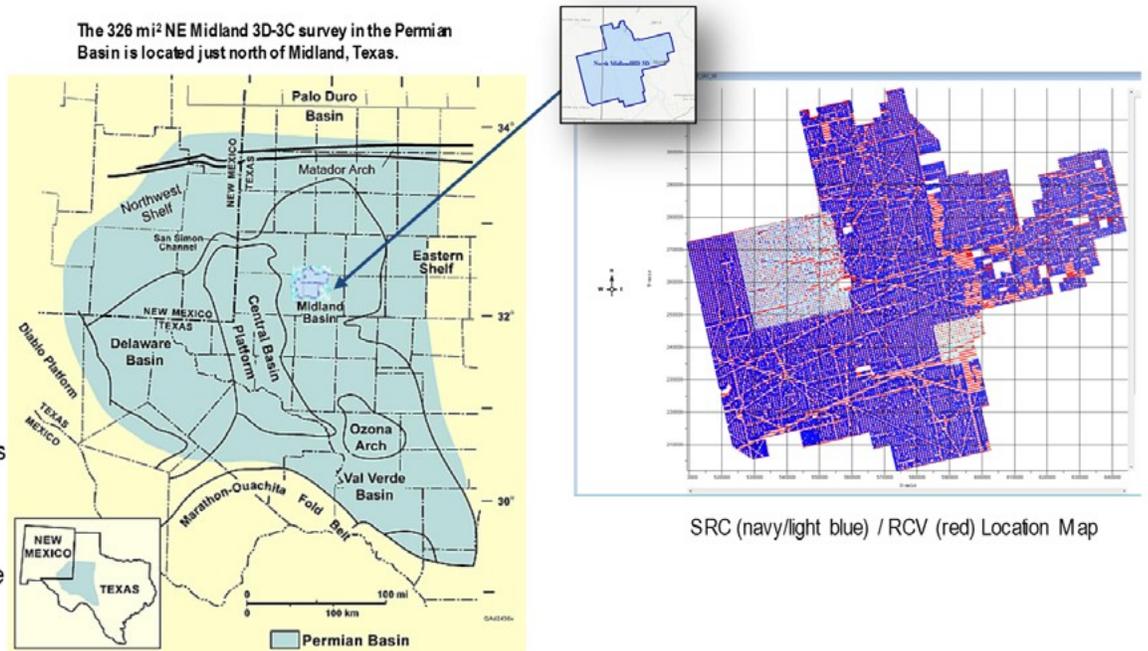


Figure 1: The 326 mi² NE Midland 3D-3C survey area in the Permian Basin is located just north of Midland, Texas.

Technical Article continued on page 17.

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

Introduction

The NE Midland multiclient 3C-3D survey was acquired in late 2016 over the Permian Basin in NW Texas, (Figure 1). Both the PP and PS seismic data were processed simultaneously. The PS processing included noise attenuation, signal processing and anisotropic pre-stack time migration as well as unique converted wave procedures such as 3C detector orientation and rotation, PS receiver statics, PS to PP event registration and SWS analysis / compensation.

Survey acquisition

The 326-square mile NE Midland 3D-3C survey was acquired near Midland, Texas, in Q2 of 2016. Seismic acquisition consisted of 3 sets of vertical Vibrators, sweep frequency 2-90Hz, recording into 3C 10Hz Geophones with a receiver and source group interval of 165-ft and both receiver/source line intervals of 825-ft.

Data Processing

The PS processing flow was organized in the following key stages:

1. Multicomponent Orientation and Vector Fidelity
 - a. Geophone Orientation
 - b. Horizontal Geophone Rotation (X/Y→R/T)
2. Noise Attenuation:
 - a. P-wave contamination Adaptive Subtraction
 - b. Mono-Frequency Noise Attenuation
 - c. Anomalous Amplitude Attenuation
3. PS Receiver Statics Calculation and application
4. PP-PS Event Correlation for V_p/V_s estimation

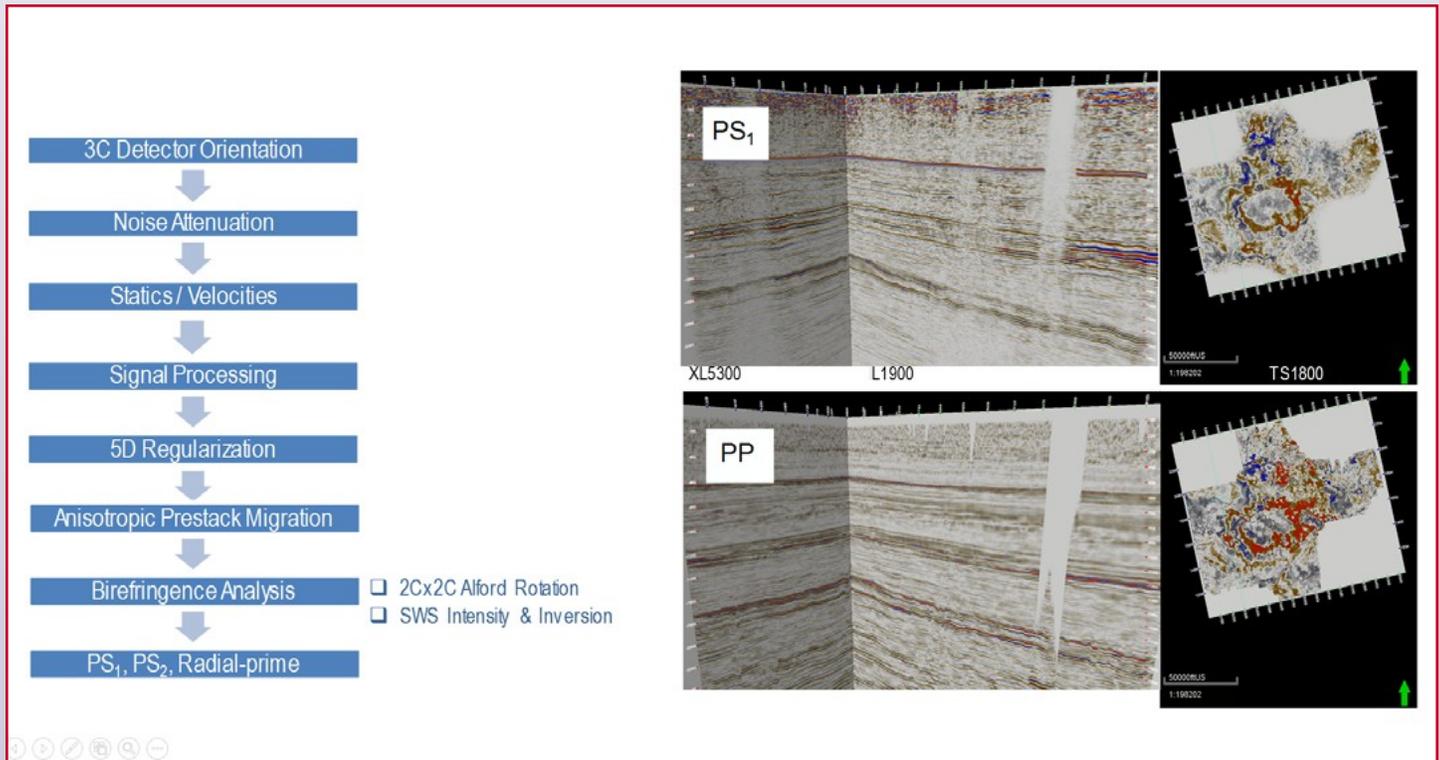


Figure 2: 3D Petrel rendering of a representative inline, crossline and time slice from the PS₁ (top), and PP migration cubes.

5. Q^{-1} and Surface Consistent Spiking Deconvolution
6. PS_{nmo} velocity analysis
7. Surface consistent residual statics
8. Full 5D Interpolation and Regularization
9. Azimuthal anisotropic pre-stack time migration
10. Birefringence analysis:
 - a. 2Cx2C Alford Rotation, and alternatively
 - b. SWS Intensity and Inversion
11. Rotation to PS1 (fast), compensated PS2 (slow) and compensated Radial-prime (R').

The above flow was then followed post imaging by an extensive suite of applications involving

residual moveout, Weighted Least Squares Radon demultiple, azimuthal alignment, spectral enhancement and a refined PS-to-PP correlation to de-stretch the PS volumes to PP-time. Example of 3D inline/crossline and time-slice from the processed PS1 and PP migrated cubes is shown in *Figure 2*.

The focus however, of this paper, is a discussion of the birefringence analysis work performed in Step 10 above.

Shear Wave Splitting (SWS) analysis

A convenient domain for detecting SWS and for analysis of the fast and slow directions or “principal axes” is after a rotation to radial and transverse directions. Radial refers to the direction aligned with the source-receiver azimuth and transverse is the direction perpendicular to radial. The radial and transverse data can be analyzed pre-stack or after partial stacking into azimuthal sectors. The analysis can also be

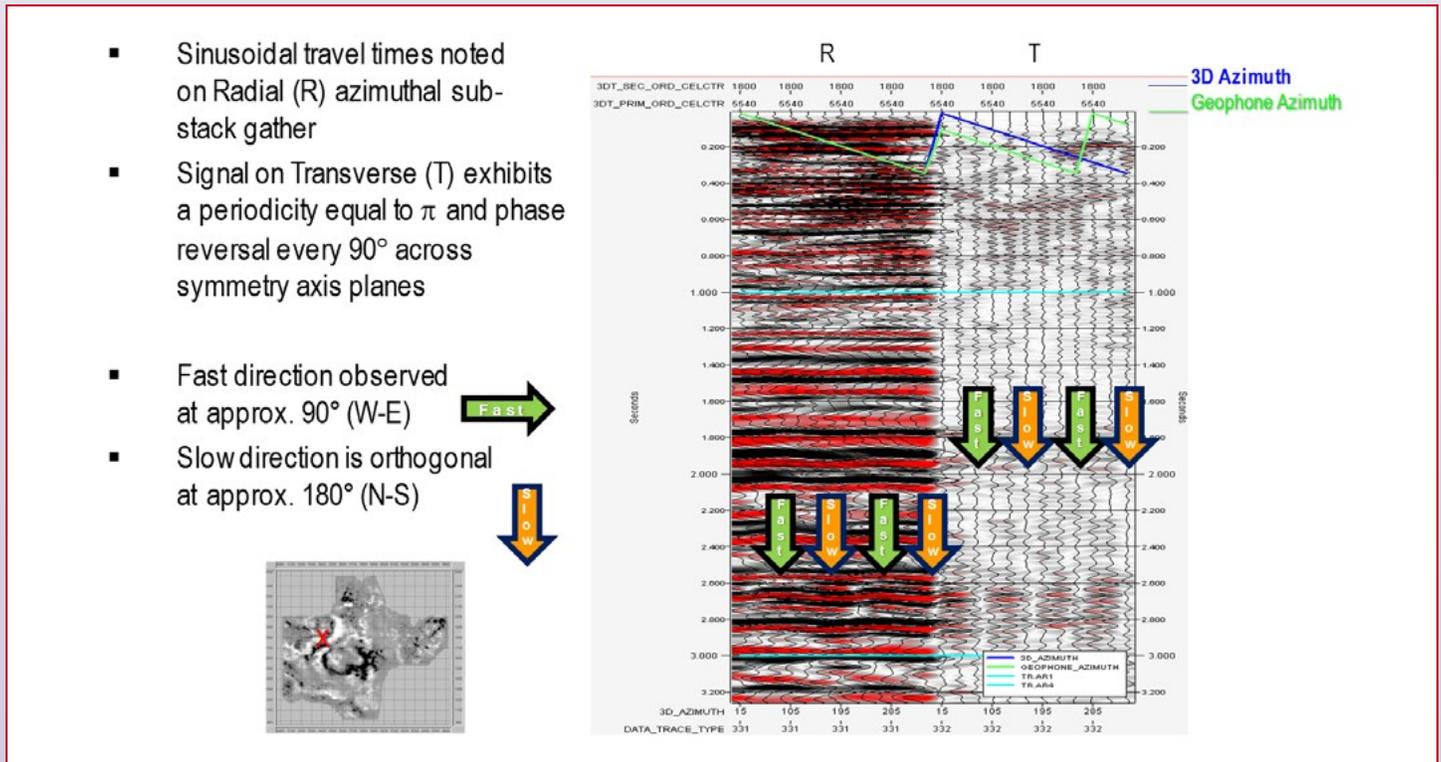


Figure 3: Azimuthal sub stack image gather for a Radial (left) and Transverse (right) R/T pair. Twelve azimuth traces per component increasing from 15° to 345°, incrementing every 30°. The fast shear direction aligns close to W-E, identified by a green arrow, with slow being orange. Polarity reversals on the T are noted every 90°.

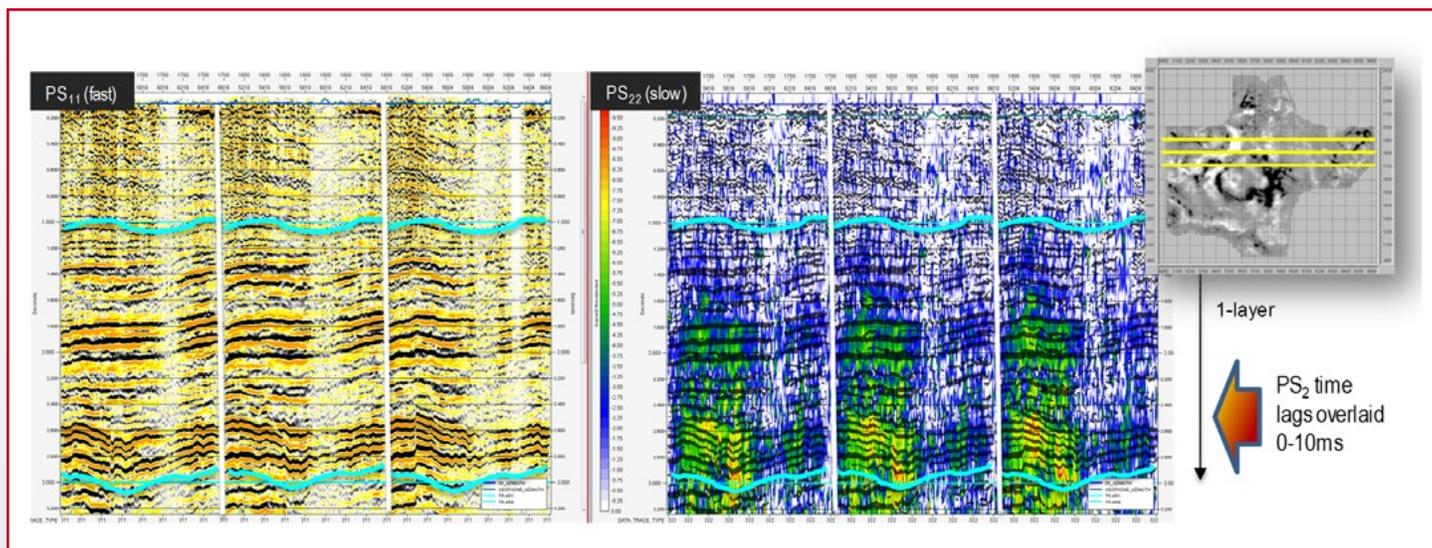


Figure 4: Three concatenated inlines of PS2 (slow) sections with the cumulative S2 time delay between 1-3secs as a color overlay. Time delays range 0-10 ms with hot colors indicating the highest. Location of inlines shown as yellow line in time-slice (top inset).

applied after prestack migration, provided that azimuthal information is retained, for example by using a sectored or offset vector tile (OVT)-based migration.

In the absence of any azimuthal anisotropy and assuming a layered medium, there will be no coherent signal present on the transverse component. Therefore, one preliminary indication that shear-wave splitting is present will be observable signal on the transverse component. It should be noted that signal can also arise on the transverse component for other reasons such as structure, so it's important to correlate the presence of events on the transverse to equivalent coincident reflectivity on the radial component. A distinctive feature of SWS is represented by signals on the transverse component that have, when analyzed as a function of azimuth, a period equal to π with polarity reversals every 90° , which is generally not the case with other causes of transverse signal. Past case studies identified unmistakable evidence of SWS and demonstrated almost *text-book* behavior of the azimuthal R/T responses (Johns, *et al.*, 2006 and 2007), (Lewallen *et al.*, 2011). Observing this kind of periodic signal on the transverse data is considered a first order indication of probable azimuthal anisotropy and the NE

Midland PS dataset proved to be no exception (*Figure 3*). Note, the existence of TTI and strong lateral heterogeneity would significantly alter the π periodicity, so care should be exercised if analyzing complex geology.

SWS analysis can be viewed as a two-step process: first, estimate the orientation of principal or S_1 direction and second, estimate the time-delay between S_1 and S_2 . The objective is to estimate the S_1 direction Φ , and time delay Δt for each common conversion point location in the survey at the current analysis interval. Because the earth may contain layers with different stress or fracture regimes leading to different S_1 directions, the recorded shear-waves may have been split multiple times, with both S_1 and S_2 from the deepest layer being split again into new S_1 and S_2 directions from the layer above and so on. These wave phenomena produce considerable complexity of waveform in which the directions for layers are masked by layers above for all but the shallowest layer. Thus, it's important to unravel the effect of the overburden to isolate the SWS characteristics at the target level. To account for the existence of several layers with different S_1 directions, most conventional methods deploy a layer stripping approach (Gaiser 1999, Bale *et al.* 2009). In each layer stripping step the

estimated time delay is computed then applied to the data after rotation to S_1 - S_2 coordinates, by first shifting the PS_2 (slow) data to match PS_1 (fast) and then rotating back to radial/transverse (R/T) with this result being referred to as radial prime and transverse prime (R'/T').

To study and analyze the SWS properties from birefringence for this 3C-3D NE Midland survey, both conventional and new independent approaches were examined. The conventional approach consisted of an Alford Rotation method, adapted to PS-waves for course layer stripping (Gaiser, 1997, 1999). Using the 1D theory of Alford (1986), the sub stacked azimuthal 2C data are rotated to 4C (or 2C x 2C) data groups that consist of R and T components from two orthogonal azimuth sectors. The data are corrected in a top-down layer-stripping manner (Winterstein and Meadows, 1991a, 1991b) by computing the principal S-wave directions and time delays in user- defined windows. This means that splitting parameters are estimated layer-by-layer from the top down. Unfortunately, errors in layer stripping occurring in shallow layers often propagate to deeper layers (Haacke,

2013) and can lead to misleading results due to an inadvertent overcompensation of the SWS time delays. Therefore, to mitigate the potential precision discrepancies from layer-stripping, the shear wave SI method was tested and compared to the Alford Rotation results. The SI method is a robust measurement with respect to structural variations and is commutative, which means that it can be summed along a ray and linearly related to interval anisotropic perturbations. Areas of consistency between the two methods would provide validation of the derived anisotropy attributes.

Analysis of the NE Midland PS was conducted on the R/T data after 5D regularization and azimuthal VTI pre-stack time migration. Discrete azimuthal sub-stacks every 30° were then created as input to both SWS analysis methods.

SWS (Alford Rotation) results

After initiating the 2C x 2C Alford Rotation layer stripping approach it was soon apparent that the time delays in the shallow overburden were of the order of one sample value and not

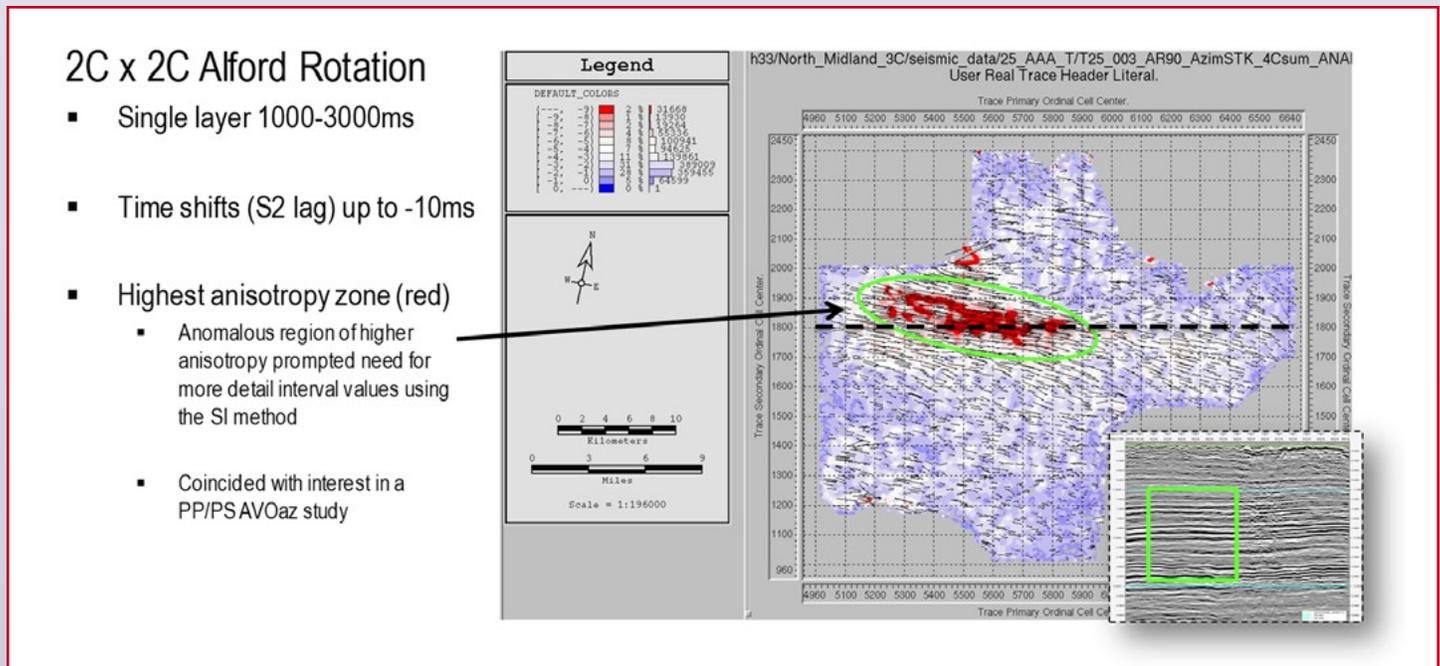


Figure 5: Line ordinal color attribute map of S_2 (slow) time delays with S_1 (fast) direction vectors derived from single layer (1.0-3.0 s) Alford Rotation. Cumulative time shifts of up to 10 ms are measured (red) in a zone of highest anisotropy (green oval). PS_1 inline section through interest area is shown in bottom-right inset.

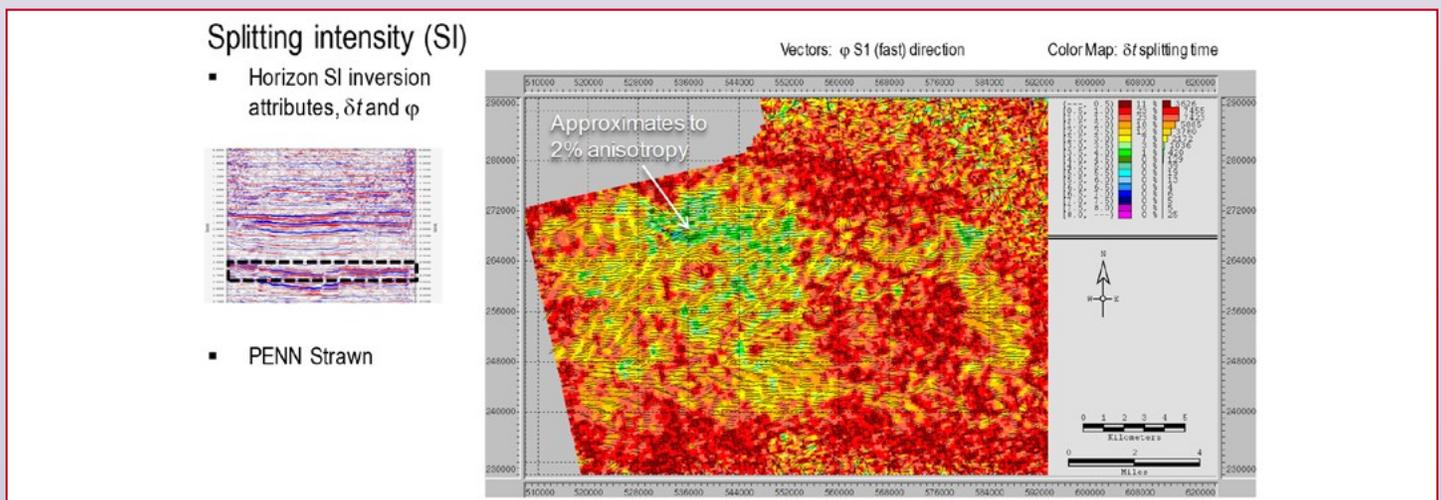
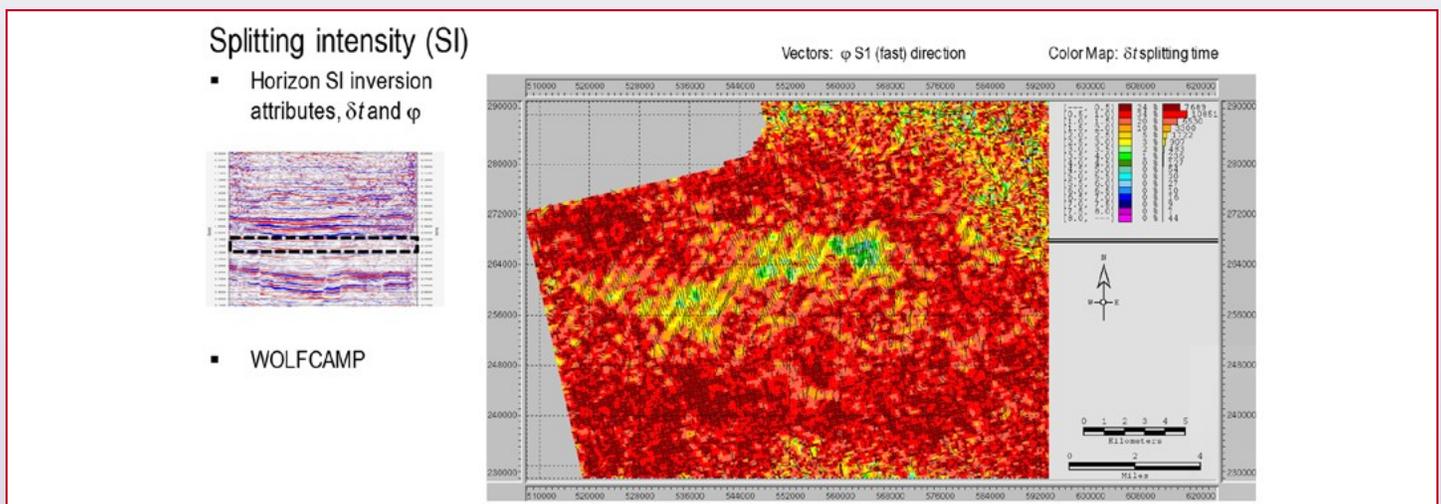
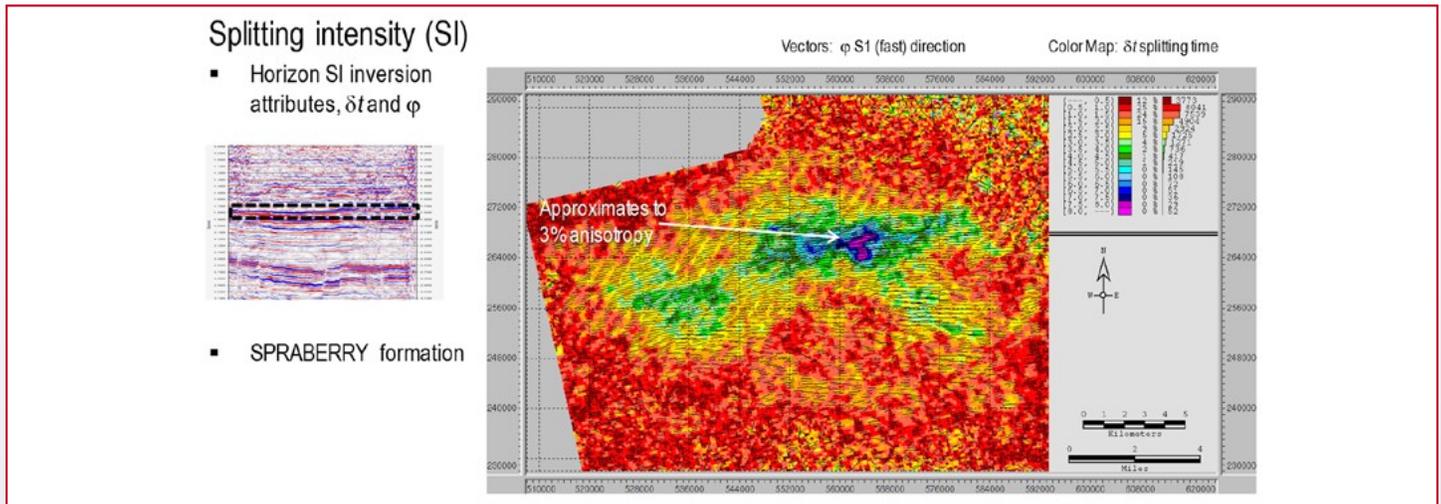


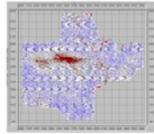
Figure 6: Bin x/y color attribute map of SI time shifts with S1 (fast) direction vectors measured from layer2 at 1400 ms (top) with similar displays for layer3 and layer5 at 1800 ms (middle) and 2600 ms (bottom), respectively. Time shifts range from 0ms (red) to 8ms (violet). Fast orientation is measured to be a consistent 90° W-E direction. The highest interval anisotropy approaches 3% for Spraberry layer3 and reduces for the deeper Strawn layer5 where the strongest anisotropy is noted to shift to the NW.

Comparison of methods

- A benchmark is made to the single layer Alford Rotation that effectively measured the cumulative effect of the SWS

- SI inversion for layers 3, 4, 5

$\Sigma \delta t_3 + \delta t_4 + \delta t_5$ splitting time



- Alford Rotation

Cumulative $\delta t_{3,5}$ time lag from single layer_{3,5}

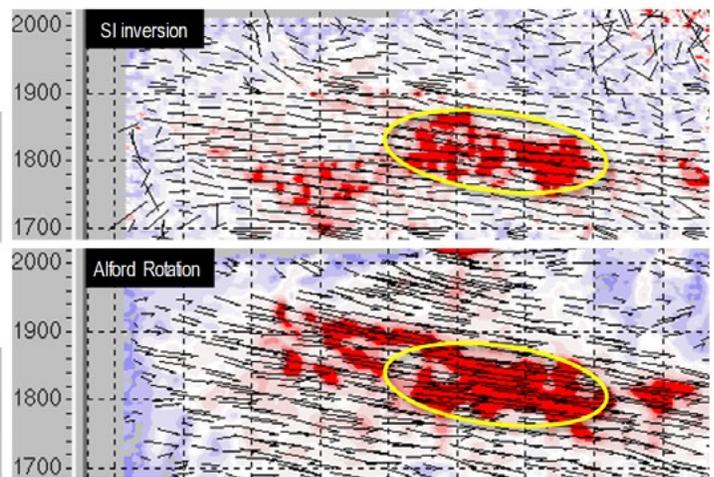
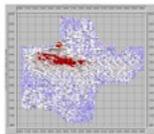


Figure 7: Integration of the SI interval SWS attributes from layers 3-5 (top) compared to the single-layer attributes derived from the Alford Rotation (bottom). Colors represent S2 time delays, vectors the fast shear polarization direction. Inline ordinals annotated left.

inducing significant anisotropy. It was evident that an overcompensation of the shallow layer(s) was highly probable and without a priori justification it was deemed prudent to limit the analysis to a thick single layer and resolve instead the cumulative effect through the target interval of 1.0-3.0 s PS two-way time (Figure 4).

The single layer SWS attributes averaged over a large time-gate (Figure 5), were then applied to the pre-stack R/T data to generate the PS1/PS2 modes for subsequent migration and completion of the final PS seismic data volumes.

After identifying an anomalous region of significantly higher anisotropy it was decided to exploit the SI analysis and inversion method to determine the anisotropy interval values within discrete geological layers. There was also interest at this point to undertake a joint PP/PS AVOaz study as it was suggested that the information gleaned from this SI analysis could help to constrain the inversion.

SWS (SI) results

The inversion revealed relatively isotropic behavior in the first two layers (1000 ms and 1400 ms) comprising the overburden followed by a significant onset of anisotropy at layer3 (1800 ms) corresponding to the Spraberry formation with time shifts of up to 8ms and a W-E principal polarization direction. The anomalous region equates to only 3% anisotropy, which is quite low, but underscores the sensitivity of shear waves, and the SI, to subtle changes in the rock matrix. The measured anisotropy is reduced to 2% at the deepest horizon, layer5 (Strawn), with evidence of an apparent spatial relocation of anisotropic behavior to the NW. The randomness of SWS attributes in the first layer(s) indicates a relatively isotropic overburden (Figure 6).

A benchmark is then made to the single layer Alford Rotation that effectively measured the cumulative effect of the SWS. By integrating the combined SI interval time shifts over layers 3-5 and averaging the dominant fast

shear polarization direction, the similarity to the cumulative Alford Rotation result is clearly evident, notwithstanding some notable differences (Figure 7).

An expression for the percentage anisotropy, or the delta interval shear velocity can be derived

from the Splitting Intensity interval time lags (delta-t), as shown top center of Figure 8. The delta interval Vs is the ratio of the fast minus the slow interval Vs divided by Vs fast. In Figure 8 we note that the highest delta interval Vs (in red) is 0.03, which is confirmation that the percentage anisotropy reaches 3% in the Spraberry interval

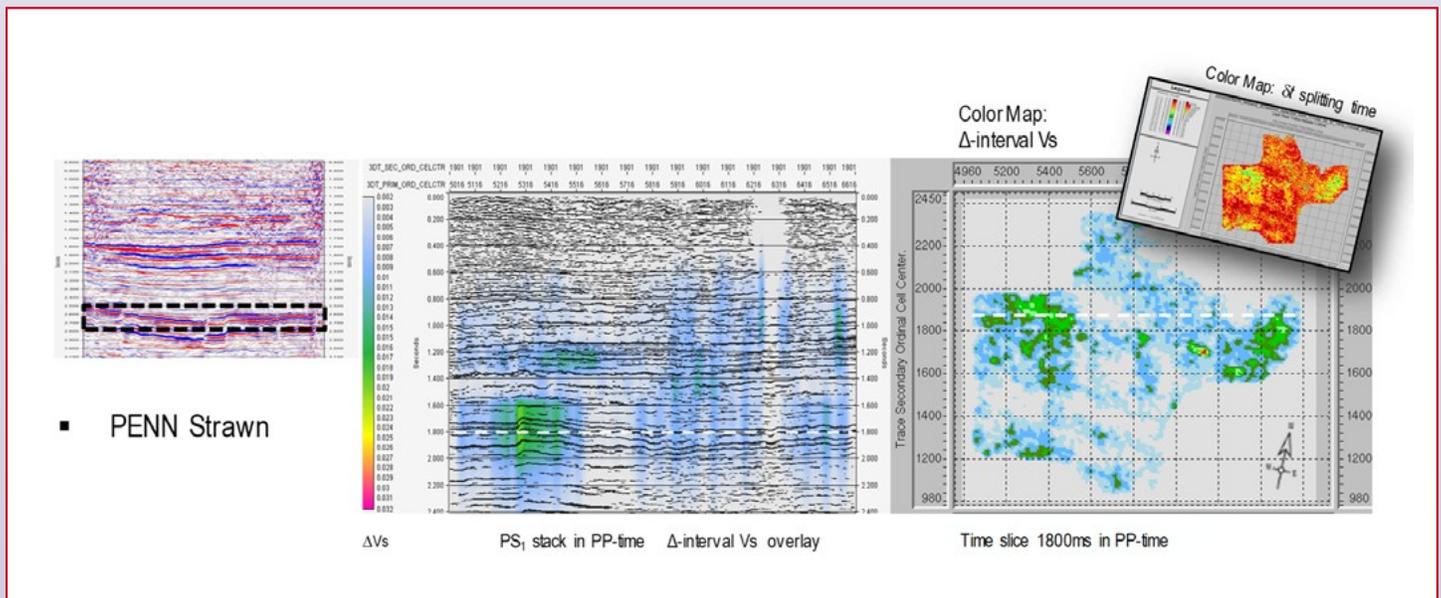
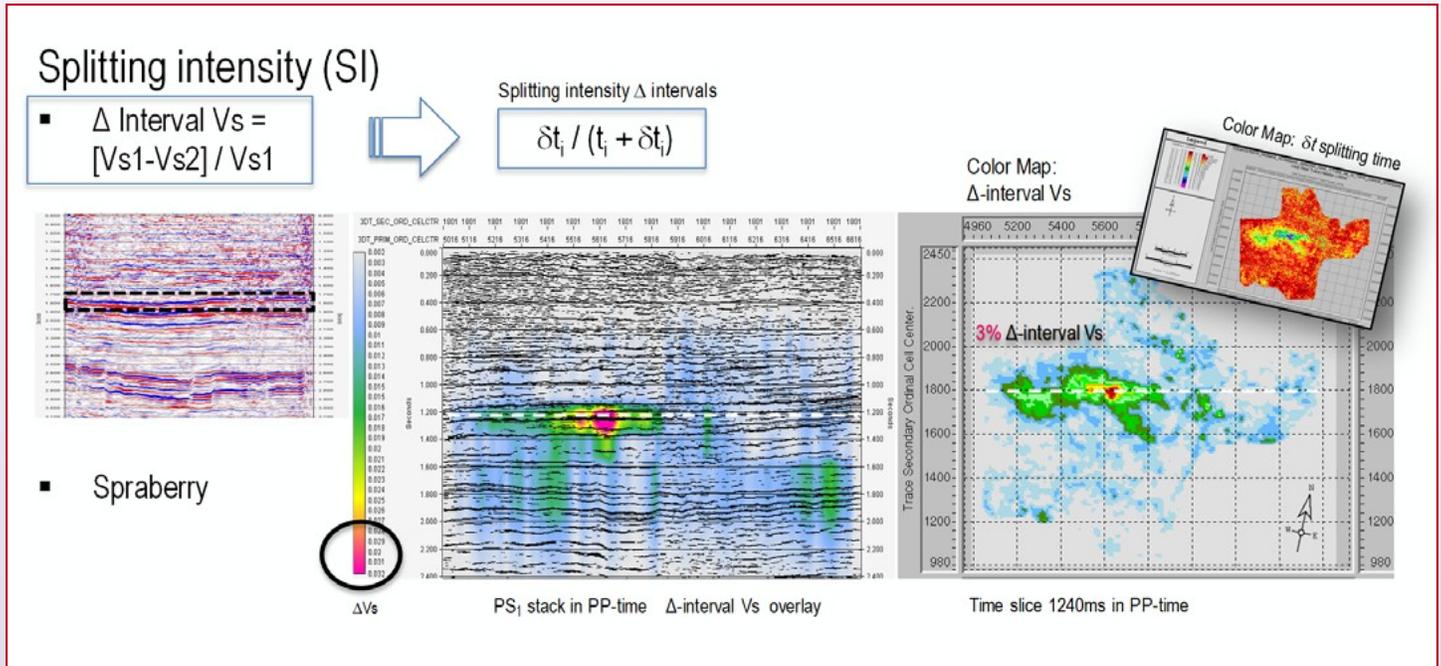


Figure 8: Vertical section and horizontal time slice of the PS1 stack volume (destretched to PP-time) at the Spraberry (top) and Strawn (bottom) formations with a color overlay of the delta interval Vs property field derived from the Splitting Intensity interval times. The location of each respective PS1 inline section and time slice is indicated by the white dotted lines.

and reduces to 2% (green color scale) deeper in the Penn Strawn formation to the NW.

Conclusions

In deploying the SWS SI inversion approach, a detailed set of horizon-based interval attributes were derived that described the subtle anisotropic behaviour of the Spraberry formation in the Permian Basin from the NE Midland 3C survey area. The SI method evades accumulative errors from conventional multi-layer stripping techniques. The sum of the individual SI responses correlated closely to the independently derived single-layer Alford Rotation result and provided further confidence in attribute integrity.

The subtlety of the interval anisotropy inferred by the SI inversion raises the question as to whether such intricacies are potentially extractable from the P-wave data alone. It is a question that the ongoing PP / PS AVOaz study will attempt to address, thereby potentially highlighting the advantages of multicomponent data.

Acknowledgements

I thank WesternGeco Multiclient for permission to publish this paper and acknowledge Kevin Douglas for assistance in the preprocessing of the PS data and Daniele Boiero for guidance with the SI inversion. □

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Permalink: <https://doi.org/10.1190/segam2018-2995469.1>



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David Johnston (Differential Seismic) - 4D inversion
Jon Downton (CGG) - Machine learning inversion
Klaas Koster (Oxy) - Conventional & unconventional reservoir characterization
Brian Russell (CGG) - History of inversion
Colin Sayers (Schlumberger) - Integration with engineering
Arcangelo Sena (ConocoPhillips) - Operator case study
Tad Smith (Consultant) - Rock physics for inversion
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This month's answer on page 32.

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GSH Outreach

Committee Activities By Lisa Buckner, outreach@gshtx.org



2019 FCMS Career Day - Mac Hooton



2019 FCMS Career Day - Peter Lazarone

The GSH was invited back for the **11th Annual First Colony Middle School Career Day in Sugar Land on Friday, January 18** to host a career exhibit booth. GSH Outreach volunteers Peter Lanzarone, Mac Hooton and I educated the 8th grade students about geophysical and geological careers in the oil & gas industry, educational requirements and starting salaries. Mac had his own table with a wide variety of rock and mineral samples including a core from a platinum and gold mine. We gave 192 GSH logo coiled toy springs to those who watched us demonstrate P-wave and S-wave motion and/or listened to our presentation. Interested students picked up the "Earth is calling ... will you answer?" brochure (<http://www.beageo.com>).



2019 The Educator Event at HMNS
Lisa Buckner Educator Workshop

On **Saturday, January 19**, GSH Outreach volunteers Mac Hooton, Andrew Davidoff and I manned the **GSH booth at The Educator Event @HMNS**. We spoke with hundreds of K-12 educators from all around the Houston region about the GSH Outreach Program and how we can help them bring awareness of geophysics to their students. The teachers picked up my GSH Outreach business card and flyer listing the types of events in which we can participate. A couple of educators contacted me to invite us to their school career days and science nights. We gave away 28 of the USPS



2019 The Educator Event at HMNS booth Andrew Davidoff Mac Hooton and Lisa Buckner

Outreach continued on page 29.



2019 Morales Science Night
Huw James and Katya Casey

Tapestry of Time and Terrain maps to educators. Houston Museum of Natural Science visitors played the Drilling for Oil game and we gave 35 GSH coiled toy springs. This year I taught one of the workshops for 13 middle & high school educators. They learned how to do the "Exploring for Petroleum" activity with their students by doing it themselves. They worked in teams filling shoe boxes with sand and gravel and buried a water balloon filled with black food coloring and water. They sealed the box lid with tape and exchanged it with another team. Then they tapped on the lid (source), listened with their ears (receivers) and processed with their brain to determine where the water balloon "oil reserve" was located. Finally, they drilled using a bamboo skewer. Everyone had fun trying and they learned why it is so important to completely fill the box with sand. Any air gap under the lid causes an acoustics issue. One educator had attended my workshop last year

and was back for a refresher because she planned to do it with her students the following week. Special thanks go to Mac for manning the booth while Andrew assisted me with conducting the workshop.

Thursday evening, **January 24**, Huw James, Katya Casey and I hosted the GSH booth at the **Felix Morales Elementary School Science Night in Pasadena**. The event was scheduled after their school science fair awards ceremony and was very well attended by the very curious students and their families. At our booth the students played the Drilling for Oil (black shoe polish) game with a pencil in the Gulf of Mexico (plastic box filled with cat litter). They had to avoid drilling near the coral reef (Nemo's home) and archeological site (pirate ship). About half of them drilled dry holes but they all had fun trying. We also explained sound wave motion using the colorful coiled toy spring and gave away 80 GSH logo coiled toy springs to students.

Huw James and Mac Hooton served as science fair judges at the **Aldine ISD High School Science Fair on Saturday, January 26**. It was the district level fair and the winners advanced up to the regional level, the Science and Engineering Fair of Houston held on February 23. This was the first year GSH volunteers participated.

On **Tuesday, January 29**, I gave a well received training presentation at the **Presenter Training and Dinner at the Federal Reserve Bank** for workshop presenters at the **27th Annual AAUW Expanding Your Horizons (EYH) in Science and Mathematics Conference**. There were 72 attendees at the dinner and 110 presenters at the conference. My EYH first time co-presenters for our "Exploring for Petroleum" workshop, Connie VanSchuyver and Marjosbet Uzcategui attended and said they obtained valuable tips about presenting to middle school girls from my training presentation as well as discussion with the other presenters at the event. The EYH conference for middle school girls was held on February 23rd (photos will be in next month's article). We did the same workshop activity that I taught at The Educator Event described previously.

Outreach continued on page 30.



2019 Owens Intermediate Career Day Lisa Buckner wave motion demo

Two events new to us were held on **Friday, February 1**. Peter Lanzarone and Alan Foley volunteered as career panelists at the **Spring Branch ISD STEM Conference** for high school students while I gave 4 classroom presentations to 5th grade students at the **Owens Intermediate School Career Day in Alief ISD**. I gave away

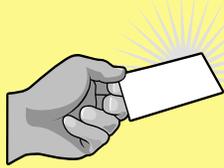
169 GSH coiled toy springs which the students used during the presentation to demonstrate P and S wave motion. I explained how these waves created by earthquakes were used by geophysicists to determine the outer core of the Earth is liquid and how we use them to find oil & gas.

Upcoming Outreach Events

April 6, 2019 (10:00 AM – 3:00 PM)
- Scout Fair @NRG Arena (over 10,000 Scouts)

April 13, 2019 (9:00 AM – 2:00 PM)
- Alief STEM Student Conference @HCC Alief Campus – West Houston Institute □

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



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The Mystery Item
on page 27
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Recognizing Outstanding GSH Volunteers...

Glenn Bear

by Tommie Rape

The many social and technical opportunities offered by the Geophysical Society of Houston (GSH) for the geophysical profession of Houston and beyond are due largely to many dedicated volunteers. The GSH wants to recognize some of these dedicated volunteers and will do so through this series of articles where we will present a monthly selected volunteer and provide our readers with some of the volunteer's professional and volunteer background. Hopefully this will increase our readers' appreciation of these volunteers and maybe encourage them to join the GSH volunteer ranks where they can partake of the many benefits that this work provides. – Tommie Rape

Glenn Bear was born outside a small town in Ohio and grew up on a farm. Glenn said that he never planned to go to college, but instead planned to spend his life working on the farm. However, upon advice from a high school guidance counselor, Glenn took a test and won a scholarship and decided to go to college. He obtained a BS in geology from Bowling Green State University. He liked geology, but also greatly enjoyed computers; so he combined the two interests and moved into geophysics. He subsequently completed an MS (1992) and a PhD (1997) in geophysics at Indiana University (IU). During his time at IU he met Lorie in a differential equations class. Glenn and Lorie, who is also a geophysicist, subsequently married and have raised two boys, who are currently in college. While in graduate school, Glenn had internships at BP, Chevron, Mobil, and Exxon. He ultimately decided to go to work full time with Exxon after obtaining his PhD. He has spent his career to date with Exxon (now ExxonMobil). He has moved back and forth between assignments in research and exploration. His assignments have covered a broad spectrum of disciplines including gravity, controlled-source electromagnetics, and seismic data acquisition and processing. In 2014, he took on the role of Skill Area Coordinator for ExxonMobil's seismic data processors deployed around the world. Earlier this year, Glenn moved back to the research company, where he is now the supervisor for a group developing and applying time-lapse seismic methods. Glenn and Lorie are currently planning a move to India where



he will develop and supervise a seismic data processing group for ExxonMobil.

Like many, Glenn's first volunteer efforts with the GSH came after he was recruited by a colleague; he was recruited to be an Assistant Editor in 2006. But more than most, Glenn's passion for helping the GSH grew and grew. Beginning in 2008, Glenn served two one-year terms after being elected Editor. During this assignment, he oversaw the publication of the monthly newsletter. Toward the end of his terms, Glenn helped plan the design and publishing of the inaugural issues of the GSH Journal. In 2011, Glenn became the 1st Vice President Elect, and then the 1st Vice President the following year. These positions meshed with his passion for technical material as he oversaw GSH's technical events. The quality and passion of Glenn's work for the GSH was well recognized, and he was elected President Elect in 2014 and then became

Volunteers continued on page 34.



President in 2015. His leadership skills and fervor for the GSH quickly proved beneficial as the industry downturn had a huge negative financial impact on the GSH that year. However, Glenn's dedication and volunteering for the GSH did not diminish following his term as President. Where the GSH needed help, Glenn jumped forward and VOLUNTEERED. When the Chair of the Finance Committee moved out of the country, Glenn assumed the position and continued his leadership during the continued difficult financial times. Glenn also stepped up to assume the role of Coordinator of the Northside Technical Breakfast and Technical Lunch events. A patriot's work is never done, so he also assumed the position of Co-Chair of the Office

Volunteers continued on page 35.

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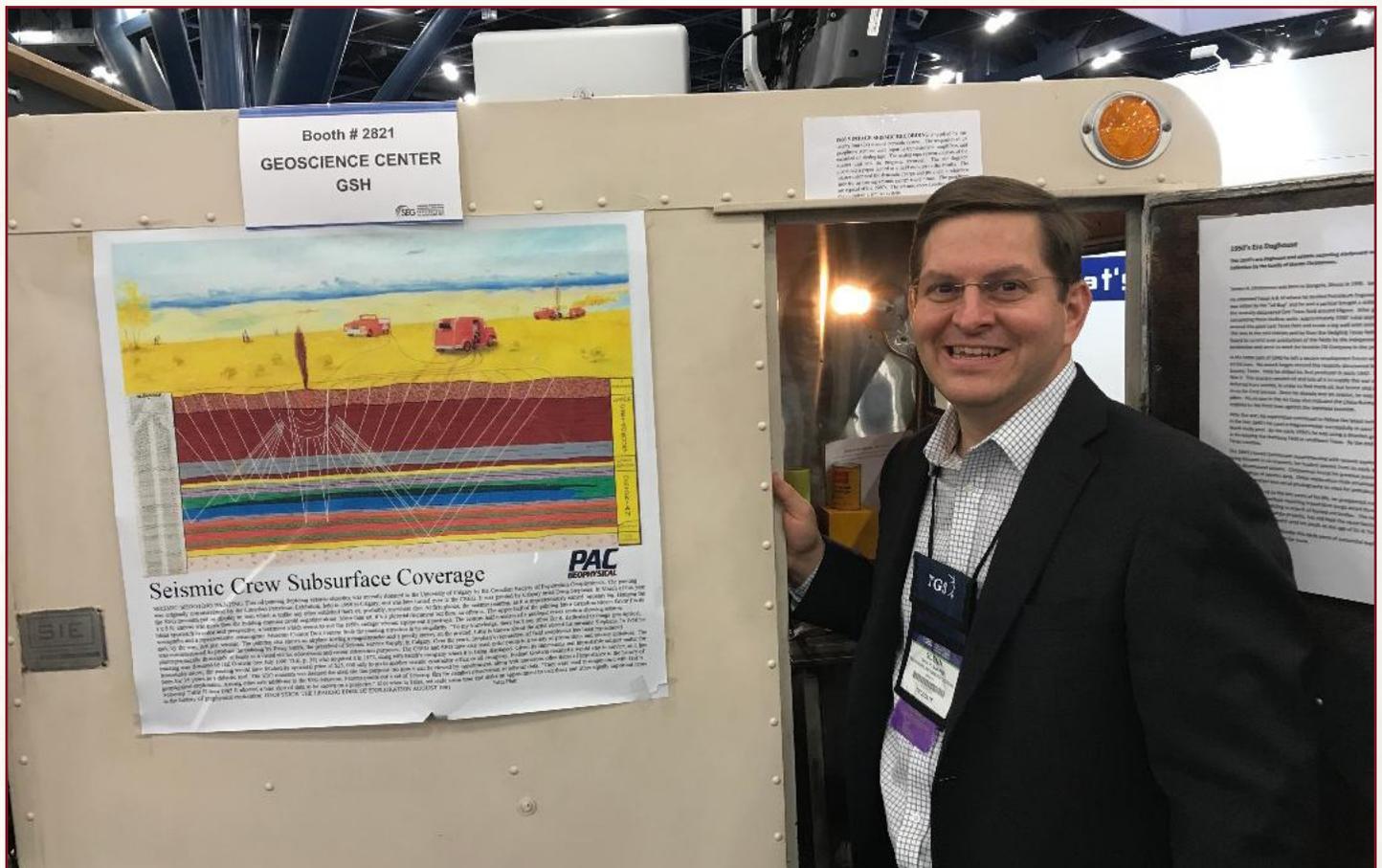
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Committee. Glenn's working with and supporting the GSH staff has helped the GSH leaders and members appreciate and recognize our staff as part of the GSH team. But Glenn's benefit to the GSH has gone beyond his official positions; his support and advice to GSH officers that came after him have proved to be a great asset.

Glenn's dedication to the GSH does not end with his hard work. Over the years, Glenn and Lorie have been major financial contributors to the GSH. They have been particularly generous with student scholarships and student sponsorship at GSH events. Glenn and Lorie purchased the booth that the GSH uses at conventions and other forums. They have contributed financially to the Geoscience Center and to the GSH in many other ways. They have also supported the GSH women's networking events, which both Glenn and Lorie fervently support. Glenn has also proven a valuable ambassador to ExxonMobil, his employer, which has also contributed financially to the GSH for many years. Glenn and the GSH are grateful for ExxonMobil's support, both financially and for graciously allowing Glenn's time with the GSH.

Naturally, Glenn's passion for helping others extends to other organizations besides the GSH. Glenn was on the Organizing Committee for the 2017 SEG Convention in Houston. He also serves on the SEG Foundation Board of Directors and is a volunteer instructor for the Student Education Program. Glenn has been a long time Scout Master for the Boy Scouts of America, and he continues his work with the Boy Scouts even though his sons have grown up and moved on. Glenn also serves on the Finance Committee for his church and shares his vocal talents by singing in the church choir. Glenn also works with the Habitat for Humanity in building homes for the needy. This is quite an impressive list of volunteer activities. He is also an active member of the CSEG, EAGE, and the Houston Geological Society (HGS).

When asked why Glenn is so active in volunteer work, his wife, Lorie, said that "Glenn is full of energy and wants to see things get done." That is quite an effective combination of attributes. Glenn attributes his volunteer work to a combination of benefits for both himself and for others. Glenn says that there is great value in the networking that the GSH provides. He attributes over half of his professional



Volunteers continued on page 36.

network to GSH connections. While he naturally has many professional connections through his work at ExxonMobil, he highly values connections outside of the company that have different perspectives and that are interested in a variety of geophysical skills. Relationship building is important to Glenn, and that is why he fervently supports opportunities that the GSH provides for doing so, e.g. symposiums, women's networking events, etc. Glenn credits his volunteering for the GSH for also benefitting him technically. From his work history with ExxonMobil, you can see that he is interested in a variety of geophysical disciplines. Through his efforts for the GSH, Glenn attends more technical events than he would otherwise and benefits greatly from the technical sharing. He proudly learns from all of his volunteer efforts, whether that be from geophysical technical events, or how to install a toilet from his work with Habitat for Humanity. Glenn also credits many of his leadership skills to working for the GSH. Glenn mentioned a quote (author unknown), "The key to leadership is getting people to do things that you want done because they want to do them." Learning to influence without authority has proved beneficial in many aspects of his life.

Glenn's other main volunteering incentive is in helping others. Glenn says that he feels an obligation in the grand scheme of things to give back since he has been so blessed; he wants to help other people who may not have been so lucky. This feeling helps drive his passion to help students who may want to get into our profession. In talking with Glenn, it becomes obvious that he likes helping others. When asked what was one of his more memorable experiences in working with the GSH, he related that it was when as President he called members to let them know that they had been nominated to run for a GSH office; he so enjoyed how honored the nominees were to be nominated. Glenn likes to build up people, and he likes the goals of the GSH to help people.

Glenn Bear has been a great inspiration to many people for his dedication to the GSH. When Glenn returns from his assignment in India, I am sure that he will return to working with the GSH. When you come across Glenn at one of the many industry events he attends, tell him "thank you" for all that he has done for others, and then, why not volunteer to help him and the GSH help others. Glenn will gladly direct you how to accomplish this. □

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SEG Wavelets Kicks Off the Spring Semester with a Happy Hour and Seminar *By Matthew Sexton*



Students and Members mingling during the Happy Hour at the Rooftop Bar and Grill.

On February 6th, the SEG Wavelets in conjunction with AAPG Wildcatters and GeoSociety, hosted a Happy Hour at the Rooftop Bar and Grill on the UH campus to kick off the spring semester. The social was a great opportunity for members and students to relax and get to know one another while also learning about each organization and upcoming events.

On February 7th, the SEG Wavelets hosted their first talk of the semester by welcoming Dean Mento from IHRDC. Dean Mento presented “Guidelines and Tips for Entering the Geophysical Job Market” where he outlined some key elements for students to consider when applying for jobs. Some of points Mento

emphasized was taking the free SEG competency assessment which helps geophysicists identify areas of improvement and also provides the tools and resources to do so. Mento also stressed on

the importance of being active in organizations and getting experience with fundamental interpretation software which can be added bonuses to separate yourself from other candidates. □



Dean Mento presenting to students about entering the geophysical job market.

Geoscience Center

The History of Geophysics By Bill Gafford

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

In previous months I have described two locations that are hosting fairly large displays of items from our Museum Collection. This month's article will include descriptions of other displays. At the University of Texas in Austin, at the Jackson School of Geosciences, we have a display of the Petty Collection, which includes geophones, amplifiers, and other instruments developed by Petty Geophysical in the 1930's. Also included are other geophysical items from the early days of exploration. Pictures of this display are included with this article.



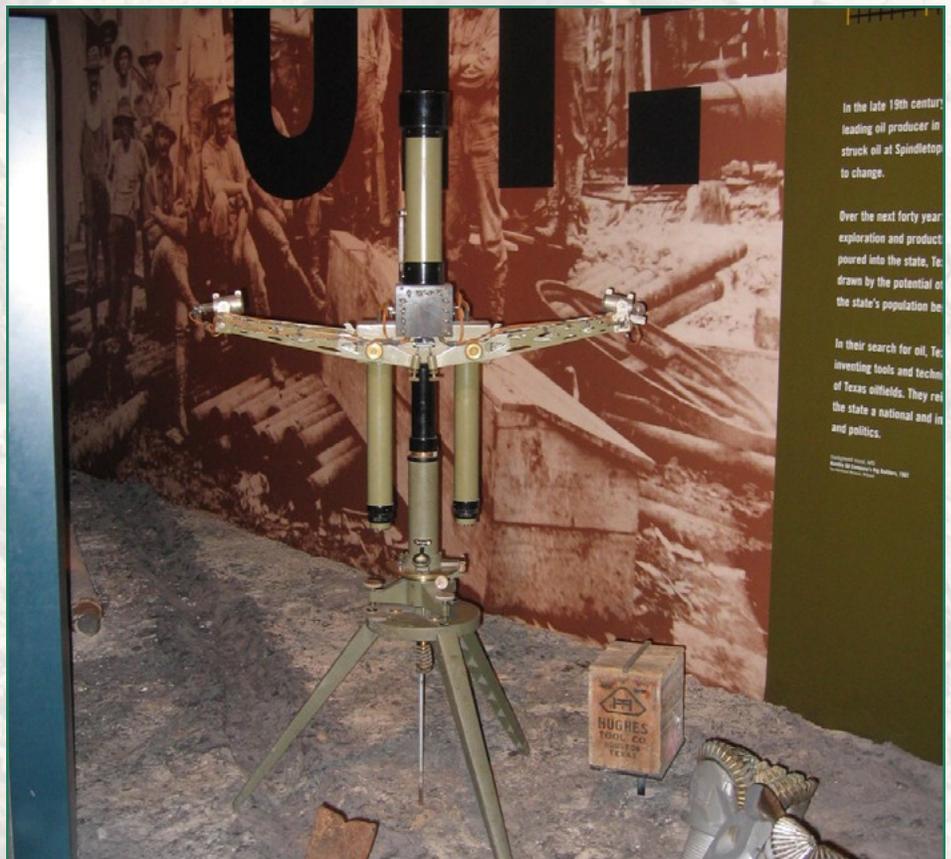
San Jacinto College North

At the Bullock Texas State History Museum we have a display of geophysical instruments from the 1920's including a torsion balance and early amplifiers, and cameras. Pictures of this display is included also.

We also have a display at the San Jacinto College North campus. The display also includes a seismic recording system from 1946, a torsion balance, a gravity meter, and a magnetometer.

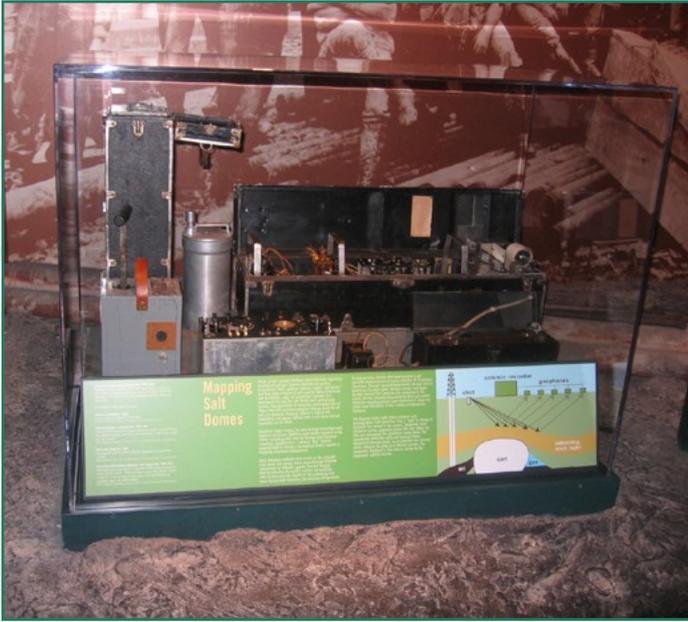
A picture is included with this article.

We continue to receive donations of book, periodicals, and training manuals. Among the periodicals are "Geophysics", "The Leading Edge", EAGE "First Break", EAGE Geophysical Prospecting", and the "AAPG Bulletin". These collections are almost complete. We would



Bullock Texas State History Museum

Geoscience Center continued on page 40.



Bullock Texas State History Museum

like for items in our library to be used and so these materials may be checked out or used at the Geoscience Center. If there is a subject that you need to learn more about, we probably have some materials that you could use. And many of them are not available online.

Our next Living Legends Doodlebugger social event will be on Thursday morning, May 9th.

There are always a few new artifacts and mystery items on display. You don't have to be retired, just interested in geoscience and visiting with others. Come and bring your friends!

All 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. □



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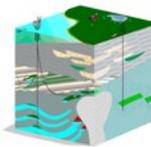
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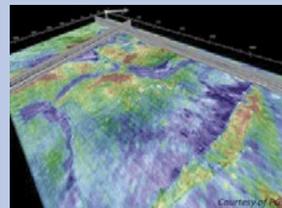
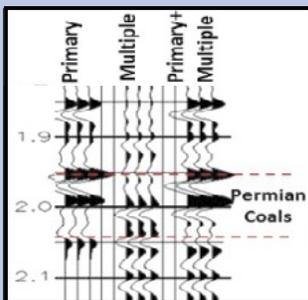
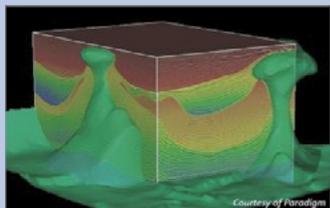
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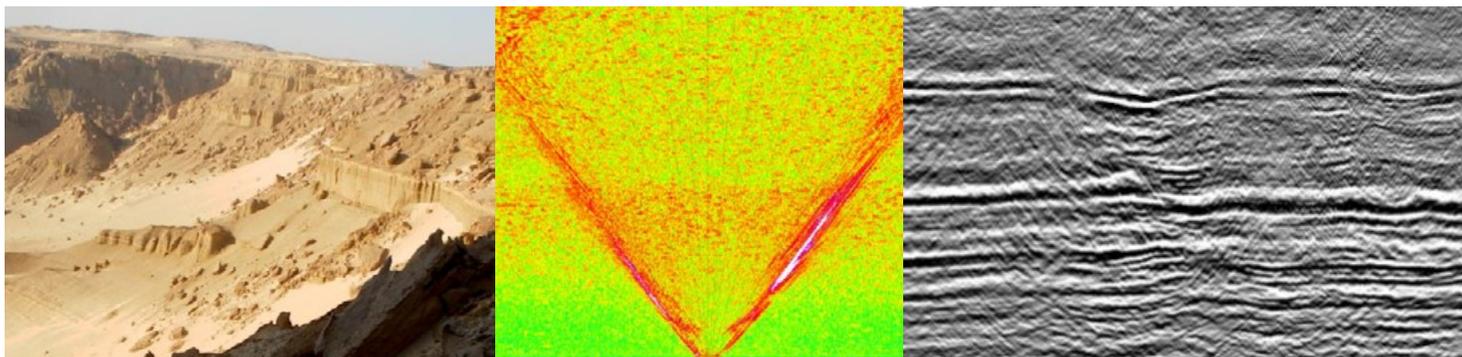


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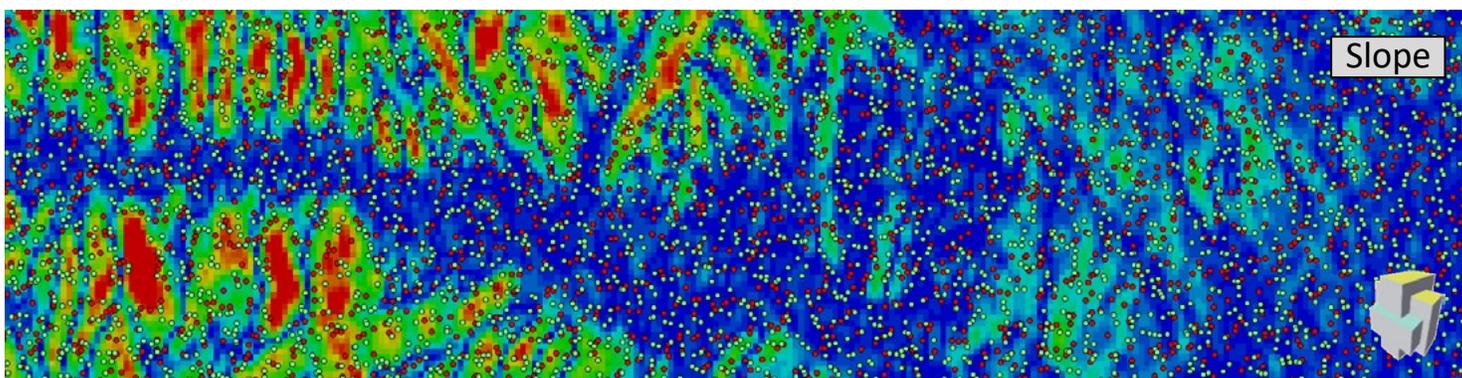


Speakers include global thought leaders such as Ted Manning (BP), Nick Moldoveanu (Schlumberger), Chengbo Li (ConocoPhillips), Ali Said (CGG), Dennis Yanchak (Apache) and John Archer (SAE). Additional speakers pending confirmation.

This informal and interactive event will be co-chaired by Dave Monk (Past President of SEG & Director of Geophysics at Apache) and Malcolm Lansley (Consulting Geophysicist)

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Doodlebugger Diary

Peru – Land of the Inca Gods

Part 4: Processing of the Talara 2D Survey in Lima

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.

When we left off in Part 2 (The Survey) I was describing the keen interest the PetroTech brass had in the brute stacks I was generating onboard the survey boat in near real time (meaning before we hit the dock for the next resupply run, *Figure 1*). During the second rotation I made on this crew they invited me to Lima to sit with their processors to discuss processing flows that might succeed in imaging beneath the successive gravel layers that were interfering with signal penetration. This is not an easy task. The gravel beds diffract downgoing rays in a million directions, making

it very difficult to filter these other rays out of the final solution and leave a coherent image of the underlying beds. This is illustrated by the cliffs overlooking the beach near where I stayed in Lima (*Figure 2*). Here we could see a coarse, gravelly section that formed bluffs over the beach due to their resistive nature. It's left up to one's imagination how that would affect a seismic wave trying to pass through it.

The meetings in Lima went well. Their processing guys were fairly young and enthusiastically accepted any assistance they could get. They wanted to know my brute stack processing sequence (which was designed for quick turnaround) and I wanted to know how they were doing the final processing (which involved more time-intensive steps). The processing team and I got along well, and as I mentioned in Part 2 I knew the



Figure 1: Yours truly wearing an extra-large PetroTech shirt and cap, showing off two of my brute stacks on the walls of the ship's galley. I was pointing at the strata on the flank of the Talara Anticline where two rather large faults offset the strata. Note that on top of the anticline there were not many continuous coherent reflectors. It was definitely one of the more challenging imaging problems I had ever faced.

Doodlebugger continued on page 46.

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



Figure 2: The beach front in Lima. The bluffs are formed by coarse and gravelly sediments that are resistant to erosion. Underlying the coarse sediments are fine-grained sediments. These bluffs were formed by uplift along the fore-arc thrust front as the South American plate over-rode the Pacific plate.

exploration manager from a previous job elsewhere. The sum result was they asked me to come back to work with the processing group on a consulting basis. This posed a rather delicate problem. I was working for Energy Innovations (EI) who wanted me to continue rotating on the seismic boat but at the same time this was an opportunity that just couldn't be passed by. Yes, it is true that I could have approached EI to ask them if I could work in the PetroTech processing center, which they would have likely agreed to because they merely would have gotten another processor to work on the boat and then charged PetroTech a consulting fee for me to work in their processing center.

But I had other concerns in my life at that time. My wife had told me early in this project that she was pregnant. We had been trying for several years and

weren't sure it would work, but here she was pregnant. I had no intention of continuing to work away from home while raising a family, so I knew I was going to quit very soon. During my breaks back in Houston I had interviewed with several companies and accepted a job with Jason Geosciences (as they were known at that time). I told them I would start at the end of summer, which they were OK with, then quit EI and told PetroTech I would consult for them from May through the summer. Was this risky? You bet. Did that stop me? No way. Risk was a way of life for doodlebuggers. Were there smarter ways of handling this situation? Most likely.

Lima: PetroTech's offices are located in the San Isidro district of south-central Lima, fairly near the coast. This and the Miraflores district bordering San Isidro to the

Doodlebugger continued on page 47.

south are two of the most upscale districts in Lima. But whereas Miraflores is mostly residential, San Isidro has become the premier financial and commercial center for Lima. It also holds a large number of embassies and consulates.

More specifically, the PetroTech office building was on the edge of Parque El Olivar de San Isidro, or the San Isidro Olive Grove Park. This was a rather large park that had olive trees planted in a regular network throughout the entire park. Walking through it reminded one of being in Italy. The apartment they reserved for me was on the other side of the park, meaning each morning and evening I got to walk through the park to and from work. It was very pleasant and calming.

That is, of course, except for armed police or military posted at every street corner throughout the district. This was because of the insurrection by the Shining Path, a conflict that had been going on since 1980. Although its leader and founder, Abimael Guzman, was captured in 1992 in an apartment in the Surquillo district of Lima (which adjoins San Isidro on the west), the insurrection continued, although the Shining Path was seeing a greater number of battlefield defeats and loss of territory. Oscar Ramirez, who took Guzman's place as the leader of Shining Path after Guzman's capture, was himself captured in 1999, leading to even further fragmentation of the remnants of the Shining Path. So it was in this context that it was necessary to have security personnel at every street corner in the key financial and business district of San Isidro.

Processing: The PetroTech processing team was using ProMAX software on a central workstation server with remote terminals connected to it, as was customary at that time. The team consisted of three younger processors who had been trained on using ProMAX and were following the workflow they had been given. This workflow had an element in it that I was not familiar with – surface consistent processes. I never had a need to use this technique working offshore, although I was aware the land processors had long ago adopted this for noisy and low fold land data. Their methodology was to sort the data volume into source, receiver and offset volumes (one at a time) and then run various noise clean-up algorithms. This was the time-intensive methodology I referred to earlier. It typically would take overnight to sort one of these volumes and then at least the next day or longer to run the noise clean-up processes. Then they would resort into the next surface type and repeat the clean-up.

In the beginning I was very skeptical of their methodology. I had always operated in the offset domain, applying gapped predictive deconvolution and then only if needed would I apply a radon or a τ -p demultiple. Rarely would I need to resort to an F-K or an FX filter because the offshore data I was processing was always well-behaved and it rarely made sense in a preliminary brute stack to spend the time on those processes. But as I have mentioned previously, the data on top of the Talara Anticline was pretty crappy because of the gravel beds. So when I first started working with the PetroTech processors we ran some baseline tests using both of our workflows. Mine was far quicker and the data on the flanks of the anticline looked just as good as with their processes. But on top of the anticline they were able to bring out reflectors that I was simply unable to. Therefore, in the core area on the anticline, I adopted their surface consistent methodology and then we proceeded to test various noise reduction algorithms in each surface type, eventually developing the final workflow to use.

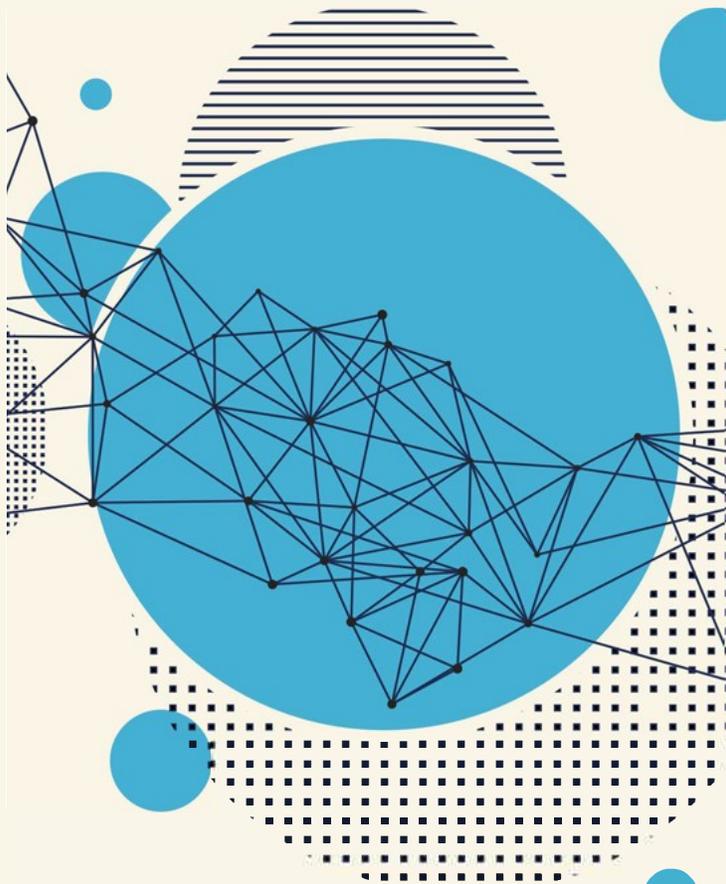
Of course, given the excruciatingly slow speed of their main workstation computers, arriving at this final workflow took much of the summer. But by the time the summer was drawing to a close I was confident I was leaving them with a good workflow and that I had given their processing team further training on ProMAX processes. We were generating processed sections of 2D lines that I saw hanging up in several of the exploration team's offices, which made us really proud. I still didn't like the quality of the data on the anticline but as I said previously, it was apparently far better than they had seen to that point and because of that it was generating a bit of excitement, which is all we could ask for.

Towards the end of the summer there were other changes happening as well, and these changes were both good and bad. My wife was now in her second trimester and was showing. The PetroTech guys insisted I bring her down to Lima, a prospect that had the female employees abuzz with excitement. At the same time my secret had gotten out and my former boss at El found out I was down there working with PetroTech. He got so upset that he has refused to speak to me ever again.

But that's a story for the next installment.

Next month: Part 5: Lima, Cuzco and beyond □

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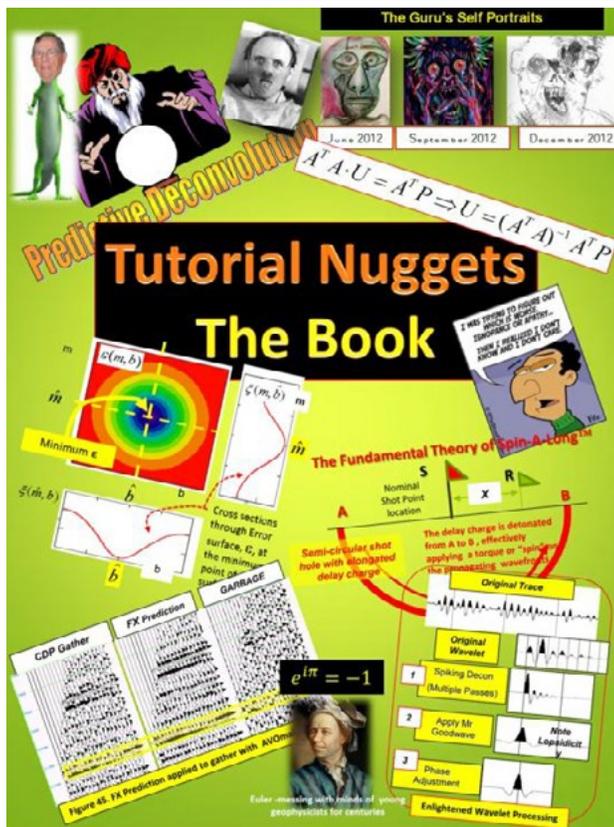
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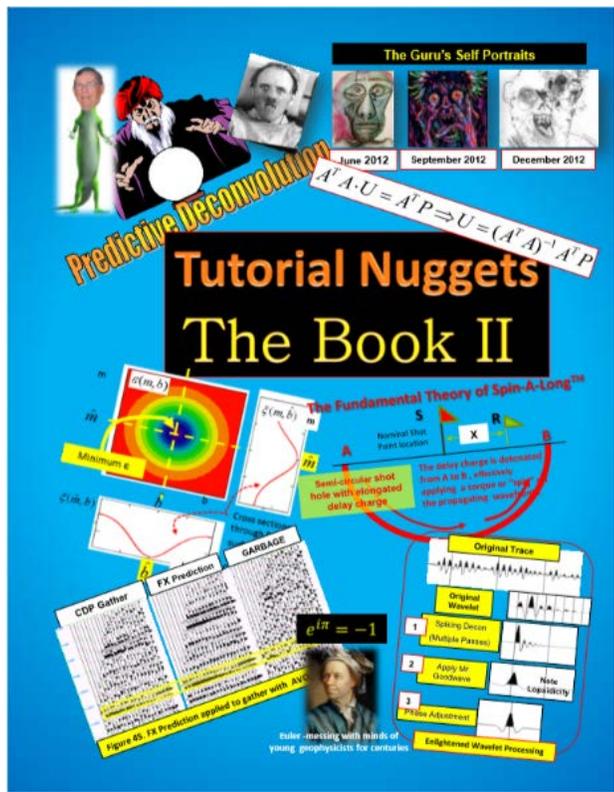
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