May 2019

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 9 • Number 9

The Epicenter of Geophysical Excellence

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On The Cover...

May Journal cover is a picture of the Spring Symposium honorees - Brian Russell and Dan Hampson.

EDITOR'S NOTE

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

GSH JOURNAL DEADLINES

Sept 2019 ..... **July 12**
Oct 2019 ..... **Aug 15**
Noc 2019 ..... **Sept 12**

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A Word from the Board

Random Thoughts: Change, Technology and the Advantage of Professional Affiliations – (It's still about People)

By Kenneth Mohn – 2nd VP Elect

As most know, the GSH is about people (and technology). People includes volunteers, members and participants. I will get back to the people a little later. I really enjoyed the comments from Craig Beasley in the February 2019 Word From the Board issue. Our industry is coming out of a trough. I will not restate Craig's article here, but we do live in challenging times. We always have. We were never promised a stable commodity price, a lifetime job, and we work in an industry where the technology and application of technology is always changing.

Relative to our parents' standard and even more when compared to our grandparents' standard, we are on a technology rocket. In our industry, this rocket is developed by people and fueled by the price of oil. We have become so used to the modern technology all around us that we take this new technology for granted. Today, in our personal lives, just to mention a few, we have Venmo, Insta Cart, Spotify – and the availability to order nearly anything from Amazon or even your local grocery store. The list goes on. Users take this new technology for granted.

My Grandfather was born in 1905 in Western Kansas and rode a horse to a one room school house in grade school. He never went to college. He worked at and managed a grain elevator for over 50 years. During his lifetime, he saw transportation go from horses and mules to automobiles and tractors, two World Wars, man walk on the moon and the advent of the early computer age. He would comment about the changes he saw during his lifetime and he would say that we would probably not see technological advancements in our lifetime like he saw in his.

My father was a Chemical Engineer for Gulf Oil, which was bought by Chevron. His advice to me was the only constant in our industry is change. He would always say we must learn to embrace change and take on new challenges. He spent his entire career with one company. Times have changed.

In college I realized the changes we would see in our time would be huge, but on a much smaller scale, with a larger and more widespread impact. The computer age has now brought us hand held computers in our cell phones and the increased ability to process data and information.

This same technological advancement is also reflected in our line of work, from data acquisition to data processing to data analytics to data management. New technology and new applications of old technology are happening all around us. Faster computers and algorithms make the impossible of a few years ago, possible today. Clouds, drones for seismic and pipeline surveys. We must keep thinking how we can do our jobs better, more effective and faster. This is essential for our survival as an industry. As individuals, we should always try to grow, learn and adjust to change (Albert Einstein once said: Technological progress (Change) is like an axe in the hands of a pathological criminal). A visit to the Geoscience Center would provide insights into the changes in technology.

Learning can come from participation in technical organizations like the GSH and SEG, where one can meet a variety of leaders in our field and learn from new discussions. Active participation in the GSH and the SEG will put you in contact with leaders in our industry. This contact will usually lead to friendships and provide guidance as well as contacts for the future. This participation will help to develop your network, which is about people.

Attending and participating in a Special Interest Group (SIG) meeting or the Technical Meetings will help to build this network, as well as provide insights into the topic at hand. A list of the Technical Meetings can be found on page 2 of the GSH Journal.

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Another aspect of membership that can grow the network is volunteering to help others. Some members of our society participate in various educational programs. These programs help educate and inform teachers and students about our industry and science. Science Fairs and presentations to school groups are just some of the ways our members reach out to others.

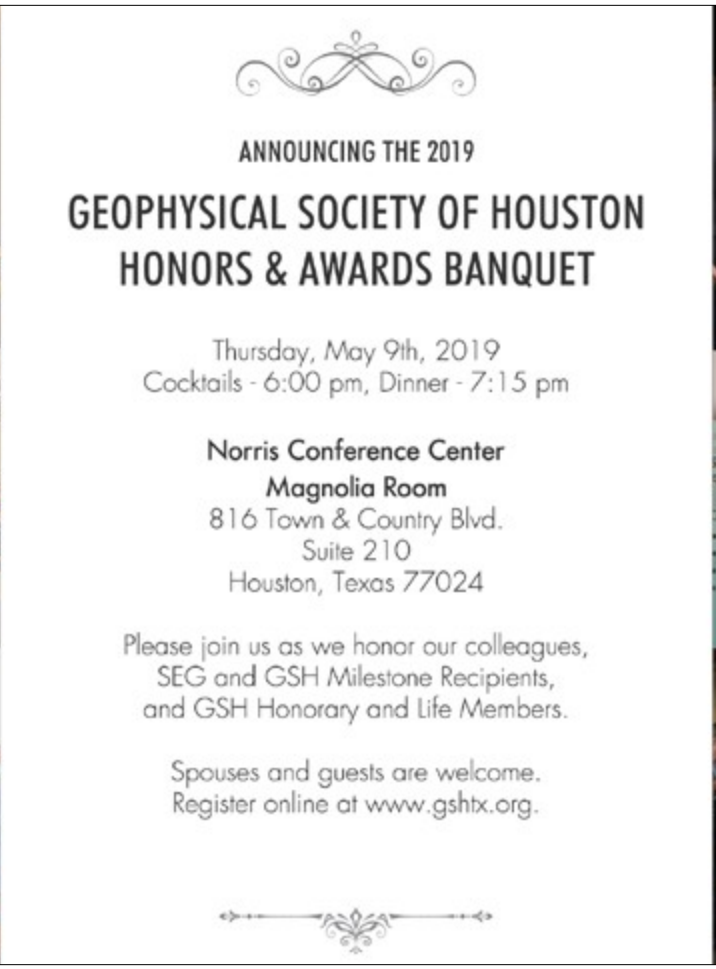
Today as 2nd VP Elect, and soon to be 2nd VP of the GSH I work with the social events. This includes the Ice Breaker, Fishing Tournament, Tennis Tournament, Sporting Clays Tournament, Golf Tournament and the Annual Honors and Awards Banquet. These events are important fundraisers as well as equally important social events for the Society. They are an excellent way to network with fellow Geoscientists.

The GSH events are run by volunteers who are members of the GSH. These Volunteer Committee Chairs plan a budget and execute these events on top of their own busy jobs. I understand the work involved as I am a former Chairman of the Sporting Clays Tournament. You can find a list of the current Chairs for these various committees on Page 3 of the online GSH Journal. Please thank the many volunteers who make these events successful. It is equally important to thank the many sponsors who make these events possible.

Just remember, when we are busy working and learning, with our noses in the computers, digital books and processes, we cannot forget about the importance of the professional network. It is still about people. Please consider joining the GSH if you are not a member. If you are a member please participate in a group where you have interest, or volunteer at the GSH to help build your network. As you will learn, Membership does have its advantages and you will benefit from your participation.

We look forward to seeing you soon.

Or said another way, "You miss 100% of the shots you don't take." – Wayne Gretzky! □



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

From the Other Side

By Lee Lawyer

I always look for interesting subjects. I tried for that when I discussed the history of the GSH. Bah, but that was necessary for our Esprit de Corps, so to speak. I enjoy reading Scott's experiences in the Doodlebugger Diary. Why didn't I have stuff like his? Actually, I did, but it was all in the US. As a consequence, I am going to relate my experience when I was transferred to the Standard of Texas (Chevron) office in Amarillo.

In the late 50's, the geophysicists were in a different organization than the geologists. We were both in an Exploration Department. The geophysicists had their own organization. The geologists were usually found in a Division composed of several Districts. Most of their data were well logs and sample logs. Occasionally, the District would request a seismic line over a prospect. The geophysicists went into action and acquired the seismic line and interpreted it. The District paid for it. Sounds sort of gross, doesn't it? It was. In 1959, the ice was broken by placing a Division Geophysicist in each Exploration Division. He (It was a he) didn't do much. He had no budget, staff, and no seismic data to interpret. He was on the staff of the Division Superintendent but didn't report to him. He was still in the Geophysical world. A year later, I became the first geophysicist to be sent to a Division. The Division was based in Amarillo. I reported to the lonely Division Geophysicist, who reported to the Chief Geophysicist in Houston.

That is enough background. It was during this time that oil companies started trading seismic and well log data to each other. If SOTEX (Chevron) had 50 miles of seismic data in Area B, they could trade it to another oil company for a similar amount in Area C. Remember, the seismic data at that time were on separate paper records. No money was exchanged. Consider what we were doing. Big Oil traded seismic data with SOTEX. Both benefited, but it didn't cost a dime. No nosey accountant was involved. We didn't need to acquire new seismic data. We could just trade for what we wanted. This was justified by comparing it to trading real-estate. Trading one house for another required no other reporting to IRS or other taxing agencies. There was a small difference between real-estate and seismic data. We traded a seismic line to company A, but we still had the seismic line. Ooops. However, data trading was common.

In stepped the Data Brokers. Instead of trading directly with another company, we could use a broker. The broker would come to us and say Company B had some data and wanted to trade. We didn't have anything to trade. We set up an account with the Broker. The Broker would be the only one to hold cash. With our account, we acquired more data. It went on and on. The numbers grew larger. No accounting.

I was tasked to map that 'newly' acquired seismic data, a huge volume of old seismic lines. Each record was annotated with line number and location. The original "Computer" went through the normal steps of adjusting the timing lines and calculating weathering corrections. An interpreter then picked the events and timed the outside traces and the center trace. There is no way an individual could handle the volume of that data. So, I arranged to have a card punch and verifier to get the picked data into a digital format. We would have a stack of punched cards for each line. These punched cards were sent to Houston where the data was migrated and plotted. I would get the data back in profile fully migrated and displayed. I would run several horizons and make contour maps.

That all sounds sort of crude today, but it was worth it. Our first test based on trade data was drilled to about 30,000 feet to the Elenburger. We cut a fault, but on the second test, we discovered Mills Ranch field, which was about 120 million bbls, OEG. The only exploration cost was my salary and the cost of

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computer time in Houston and postage. Oh yes, the technicians also had to be paid. Mills Ranch held the record as the deepest producing field for several years, well below 32,000 feet.

Oh yes, there was a nearby discovery based on the same trade data called Mobeetie field because it was close to an old Army post back in 1880 near the town of old Mobeetie. However, this field only produced a measly 25 million bbls of oil.

I guess I was a little out spoken on this method of exploration, i.e. no company seismic acquisition almost no budget, very little support, and very little credit! But that was life in a major oil company. I spent four or five years on this project. I did get a transfer to Oklahoma City during the industry downturn during that time period. The Amarillo office closed down. Long story short: Any job is better than no job. I kept mine with Chevron for almost 40 years.□

Technical Luncheons

Clustering, Visualization and Other Adventures in High Dimensions with Applications to Seismic Geomorphology

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch North

Speaker(s): Bradley Wallet, Aramco Research Center

Bradley Wallet

Westside

Tuesday, May 21, 2019
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, May 22, 2019
11:00 a.m. – 1:00 p.m.

NEW LOCATION this Month

Location: Chevron
1500 Louisiana
Houston, TX 77002

Northside

Thursday, May 23, 2019
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.

Biography:

Dr. Bradley Wallet has a B.S. in Mathematics from Hampden-Sydney College, a M.S. in Statistical Sciences from George Mason University, and a Ph.D. in Geophysics from the University of Oklahoma. He has been doing research related to computer vision, statistical machine learning, and data analytics since 1991. Currently, he is a Computational Geostatistician at the Aramco Research Center in Houston where his interests include seismic geomorphology, automated seismic interpretation, multi-scale data integration, and high dimensional data. He is also an associate editor and an editorial board member for the SEG journal Interpretation □

Technical Breakfasts

Neural Networks 101: Math, Not Magic

Register for Tech Breakfast North

Register for Tech Breakfast West

Scott Irwin Salamoff

Speaker(s): Scotty Salamoff, Chief Technical Officer
Actus Veritas Geoscience, LLC

North

Tuesday, May 14, 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, May 15, 2019
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

Neural network and machine learning technology have been a part of oil and gas geoscience analysis for longer than many people think. The underutilization (or non-use) of neural networks as critical components in subsurface interpretation workflows can be explained by a combination of not appreciating how the proverbial engine of a neural network functions, misunderstanding the output it is intended to provide, and overestimating the financial cost of implementation.

In this talk, we revisit basic mathematical principals of neural networks to provide a foundation for understanding the neural network process and analyzing results. A simple 2-layer sigmoidal neural network is used as an example to demonstrate the key components of neural network architecture, and demonstrate the mathematics and programming used to create one. While cloud-based deep neural net technology such as TensorFlow are very popular for large projects, our focus is instead on the creation of a simple neural net from scratch, which allows us to examine and discuss the elements used to build it. We discuss how input layers are created, define how hidden layers are generated, and how their numbers are constrained, and how activation functions and back-propagation of calculated error provide the fuel needed for the network to continue learning.

Some parallels between human brain structure and artificial neural networks – such as what synaptic chains are, why they are important for learning, and where they fit into a neural network – are discussed to bring into context the basics of what neural nets do and how they work. While we discuss the theory and mathematics of a simple neural network, we also show how one can build a neural network in Python so as to make the final jump from curious bystanders to AI practitioners.

Biography:

Scotty Salamoff is the owner and principal geophysicist and data scientist at GeoTerra Technologies as well as Chief Technology Officer at Actus Veritas. Scotty applies his passion, expertise and experience developing geophysical workflows and designing, implementing, and integrating

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neural networks for upstream oil and gas companies to deliver data-supported interpretation products with the goal of reducing pre-drill risk and identifying complete petroleum systems from seismic data. His workflows are designed to allow data to speak, and the interpreter to arrive at possible conclusions rather than attempting to model the data in order to fit a desired outcome.

Scotty is an accomplished classroom instructor and public speaker, having taught geophysical interpretation techniques at Chevron at SCM E&P Solutions. He has authored and co-authored papers about Fracture Detection from Seismic and AVO use to identify lithology. He has also presented technical talks about non-amplitude seismic attributes and how they relate and respond to hydrocarbon pore fluids and has presented several times at DHI consortium meetings.

He holds two Master of Science degrees in Geophysics and Structural Geology from Colorado State University □

Microseismic SIG

High Resolution Monitoring and Modeling of Hydraulic Fractures in Rocks

Register for Microseismic

Shahrzad Roshankhah, PhD

Speaker(s): Shahrzad Roshankhah, PhD,
Postdoctoral scholar at the California Institute of Technology,
Department of Mechanical and Civil Engineering

Thursday, May 2, 2019
11:30 a.m. - 1:00 p.m.

Sponsored by MicroSeismic, Inc.

Location: MicroSeismic, Inc.
10777 Westheimer, Suite 110
Houston, TX 77042

Abstract:

The analysis and optimum design of energy-related geo-systems, such as unconventional fossil fuel and deep geothermal energy reservoirs, and energy or waste geo-storage facilities require understanding of geo-materials' behavior under realistic conditions. Particularly, rocks' coupled hydro-thermo-mechanical response must be better understood given their complex internal structure interacting with fluids often under extreme temperatures, high-stresses, high-pressures, and various rates of excitations.

In this talk, I will share the results of our experimental and numerical studies on the behavior of natural rocks when they are subjected to in-situ high-stress condition and high-pressure fluid injection. Due to the presence of natural discontinuities in the rock structure, hydraulic fractures propagate in complex patterns, which is unpredictable by common linear, elastic, isotropic models. Direct and high-resolution monitoring of natural-hydraulic fractures' interactions reveal the involved physical phenomena during hydraulic fracturing. This is possible by utilizing the state-of-the-art optical and electromagnetic imaging techniques in the laboratory. Hybrid computational tools are also utilized to explicitly model the fluid flow through natural fractures and porous rock matrix and generate new fractures on any path. These physical and numerical simulations highlight the fabric- and boundary condition-dependent hydro-mechanical response of natural rocks even under high-stresses.

Biographies:

Dr. Shahrzad Roshankhah is a postdoctoral scholar at the California Institute of Technology, Department of Mechanical and Civil Engineering. Inspired by unprecedented challenges facing our era on energy and the environment nexus and ample opportunities for geo-engineers to solve them, Roshankhah is passionate to develop more accurate models for the hydro-thermo-mechanical behavior of geomaterials at extreme conditions (high-temperatures, -stresses, and -fluid characteristics). At Caltech, she studies the propagation of hydraulic fracture in pre-fractured rocks through experimental and numerical simulations. She also studies the elastoplastic behavior of particle impacts in granular flows and thermal properties of engineered particulate materials, which are important for the geotechnical resource recovery and storage. She has worked in engineering consulting companies for four years, where she analyzed and designed buildings and geo-structures.

Roshankhah is the recipient of several educational, research, and leadership awards and certificates (e.g., from NSF, GaTech, and Caltech) and has served in committees as a technical reviewer for specialized symposia, as a judge for scholarship distribution, and as a mentor for broadening the participation in STEM fields. Roshankhah received her PhD in geotechnical engineering from the Georgia Institute of Technology in 2015. □

Data Processing & Acquisition SIG

High Resolution Beam Tomography for Velocity Model Building

Register for Data Processing

Alexander Mihai Popovici

Speaker(s): Alexander Mihai Popovici, CEO, Z-Terra Inc.

Sponsored by Schlumberger

Tuesday, May 7, 2019
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

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

Abstract:

Beam Tomography (BT) is a novel high resolution, wide azimuth migration velocity analysis tool using Beam Migration. The high resolution updates are comparable to FWI results, with three orders of magnitude more efficiency. A 2000 sq km velocity model can be updated using 400 CPUs in less than 5 minutes. The Beam Tomography uses Beam Migration to directly output the velocity update matrix with a very high number (2000-10,000) of velocity update values at each (x,y,z) analysis point. This methodology bypasses the time consuming steps required for traditional tomography, including preparing the gathers for semblance analysis, semblance picking and back-projection picks QC. The method enables a very rapid estimation of the depth or time delays along each ray that can be used to produce a high quality alignment of the common-image angle or offset gathers. In addition, Beam Tomography output contains image point azimuth information and this allows the tomographic update to go beyond the current limitation of limited wide azimuth velocity updates. In summary, Beam Tomography allows for faster turnaround time for large 3-D seismic projects and at the same time increases the accuracy of the velocity model by using wide azimuth information that is typically unavailable in traditional tomography.

Biography:

Alexander Mihai Popovici is Chief Executive Officer and Chairman at Z-Terra Inc., a provider of state-of-the-art geophysical and geological technology, services and software for the upstream oil and gas industry. He holds Ph.D. (1995) and M.Sc. (1991) degrees in geophysics from Stanford University, and an equivalent B.S. (1985) in geophysical and geological engineering from University of Bucharest, Romania. He escaped from Romania in 1986 and spent a year in a refugee camp in Austria. Dr. Popovici was co-founder and CEO of 3DGeo Inc. He is the Honorary Consul of Romania in Houston.

He has nine patents in the field, over 100 publications in conference proceedings, books, trade journals, and research reports and has given numerous invited talks at conferences, geophysical associations, and geophysical workshops. He has been a member of the SEG Research Committee, served as Associate Editor (Seismic Migration) for Geophysics, and is past Chairman and founding board member of Geoscientists Without Borders, an SEG Foundation program that funds humanitarian applications of geophysics around the world. Currently he serves on the SEG Board and was the 2017 SEG Houston Technical Program Chairman. □

Potential Fields SIG

Shallow hazard detection and risk assessment through the acquisition and interpretation of Full Tensor Gravity Gradiometry in the Delaware Basin of Texas

Register for Potential Fields

Alan Morgan

Speaker(s): Alan Morgan

Thursday, May 16, 2019
5:30 p.m. - 8:00 p.m.

Sponsored by CGG

NEW LOCATION:

Location: The Black Lab Pub
4100 Montrose
Houston, TX 77006

Abstract:

Shallow hazards associated with dissolution karsting within the Castile formation of the Delaware basin of west Texas represent a significant drilling hazard. One operator encountered four karst related cavities within the first four hundred feet of section from two separate pad sites. The intersection of these dissolution cavities resulted in the loss of significant amounts of drilling fluids and concrete, resulting in the abandonment of the boreholes. Approximately 1100 line-km of Airborne Full Tensor Gradiometry (FTG) data are acquired at a nominal line spacing of 100m and drape elevation at 80m above the ground surface in order to rapidly identify and assess further risks to drilling in the adjacent lease acreage. 2.75D and 3D models are constructed to determine detectability and identify relevant wavelength and amplitudes based upon information collected from the karst cavities. Focused enhancements of the acquired data reveal correlation to the drilled cavities, but the wavelengths are too broad to assess drilling risks. Curvature analysis of the FTG data reveal a striking correlation to cavern analysis performed in outcropping areas of the Castile formation. Riskiest and safest drilling sites are identified by means of analyzing the curvature information.

Biography:

Alan is a subject matter expert in potential fields and has been involved in the integrated interpretation of potential field data since 2004. Prior to his potential fields experience, he attended the University of Louisiana at Monroe where he obtained degrees in Geology (B.S, 2002) and Geoscience – hydrogeology specialty (M.S., 2004). His global experience varies from mega-regional to prospect scale projects, primarily in areas where seismic imaging falls short in efforts to assess geometry risk. His specialties include 2D and 3D inversion, magnetic depth methods and plate kinematic modelling. He also is a contributor to a patent in the evaluation of plate kinematic models using potential fields methods. He has also served on the SEG gravity and magnetics committee and is the current coordinator for The Meter Reader for the SEG publication, *The Leading Edge*. □

GSH OUTREACH is looking for volunteers for:
***Science Fair Judges**
***Career Days**
***Earth Science Celebration**

Contact Lisa Buckner at: outreach@gshtx.org
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Effective Porosity Sensed Changing by Azimuth: A Linear Crossplot of Azimuthal P-P (Near-angle Amplitudes, AVO Gradients)

Heloise Lynn, Lynn Inc. and Bill Goodway, Consultant

Summary

The effect of porosity upon P-P Intercept-Gradient (I, G) plots is well known when lithology and pore fluid are held fixed (Hilterman, 2018). Expansion of this knowledge into the azimuthal world enables the comprehension of the effects of effective porosity sensed, as source-receiver (S-R) azimuth varies. The near-angle [5-15°] azimuthal amplitudes record the azimuthal variation in P-impedance (or Lambda Rho) contrast and the far-angle [23-45°] azimuthal amplitudes record the azimuthal variation in the contrast of S-impedance (or MuRho or Poisson Ratio). 3D P-P field data taken through Offset Vector Tile (OVT) prestack depth migration with a VTI velocity field, and then corrected for the HTI azimuthal traveltime variations are provided as examples to corroborate the intuitively clear [azimuth-blind] I, G crossplots. When the AVO gradient changes by azimuth, the near-angle amplitudes often change also, such that the intercept appears to vary by azimuth. When the azimuthal AVO gradient is crossplotted against its (floating) intercept, a straight line is usually seen. The azimuthal variations of near angle amplitudes are the result of the effective porosity sensed changing by azimuth. Alternatively, or additionally, there may be an azimuthal Q effect due to fluid-movement between macroscopic fractures and matrix porosity; or an azimuthal scattering effect. Azimuthal inversion programs that force the intercept to be azimuthally invariant can be compromised in their results.

Introduction

Dr. Fred Hilterman presented *Figure 1* at the 2018 Geophysical Society of Houston webinar, "Amplitudes."

Many such plots have been shown during the last 20 years. This particular plot was calculated for a shale-to-sand reflection and shows the effect of porosity increase, and pore fluid substitution. At porosity of 14%, for a fixed pore fluid content, the NI (normal incidence) amplitude is a maximum, and the B (Slope, or Gradient, computed using Shuey's, 1985, approximation) is a minimum, or most negative value. As porosity increases to 36%, the NI decreases in value, while the B becomes flatter (less negative). At some maximum porosity, here 36%, the NI is at the minimum, while the B is at its "maximum" (the more positive number).

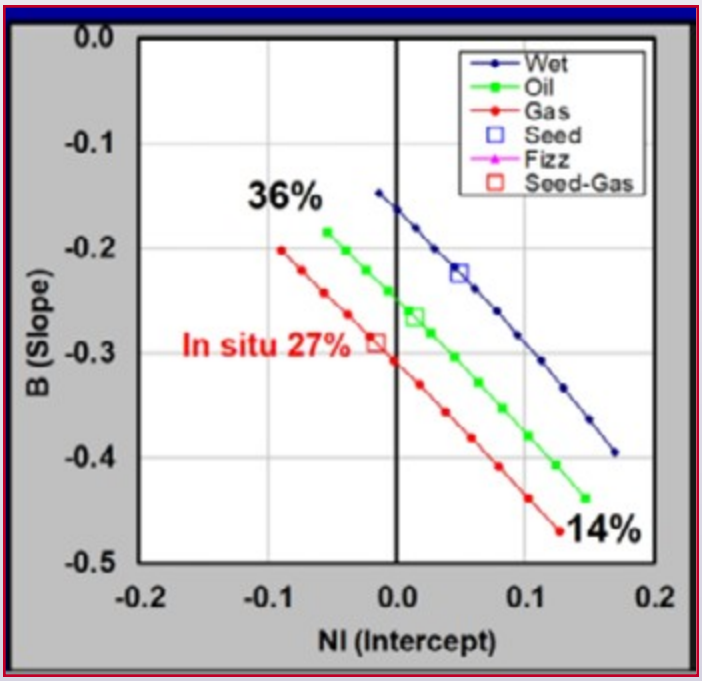

Figure 1. Crossplot of NI (Normal Incidence) and B (slope, or AVO gradient) for shale-sand model, as porosity and pore fluid is varied. For gas, oil, or water, as porosity increases, the NI values decrease, and the B values increase (becoming less negative), as caused by VP, VS, and density decreasing (as per rock physics principles). This model plot is azimuth-blind. When field data are evaluated using this technique, the given angle of incidence is summed over azimuth. (Hilterman and Graul, 2018)

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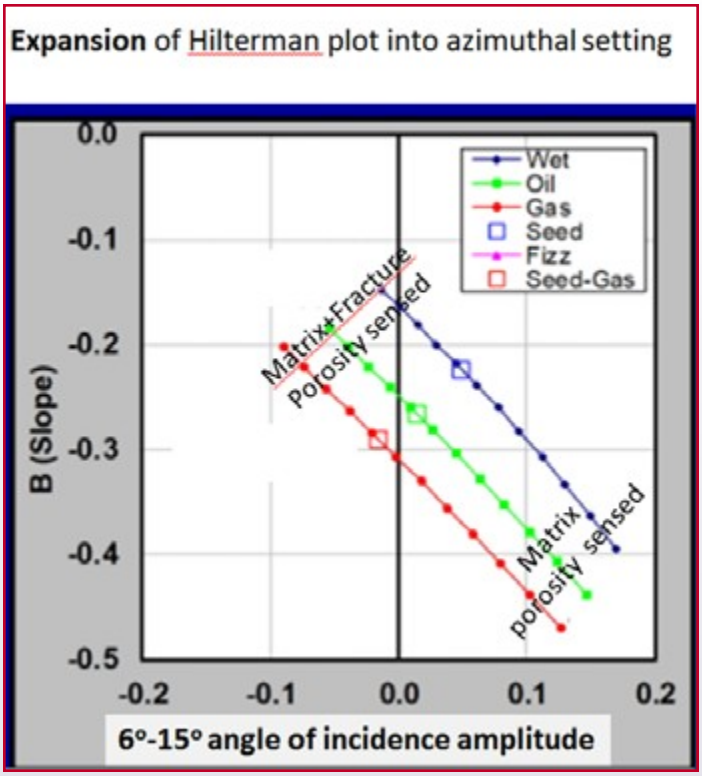

Figure 2. Expansion of Hilterman plot into the crossplot of azimuthal AVO gradient and azimuthal near-angle amplitudes. Each CIG bin has its az'l AVO gradient and its floating intercept calculated and posted. The fracture model is one set of vertical aligned fractures.

Application

This behavior, the linking of the brightest NI with the most negative AVO gradient, will be shown to exist when azimuthal (az'l) AVO gradients are examined. When the Gradient changes by azimuth, so does the (Near Angle Amplitudes) when the effective porosity sensed by the wave changes by azimuth *(Figure 2)*. In the fracture *perpendicular* direction, the effective porosity sensed is matrix plus fracture porosity and is the max-effective porosity sensed by azimuth. In the fracture *parallel* direction, the effective porosity sensed is matrix porosity (a lesser value than matrix+fracture porosity).

The presence of a straight line when the Azimuthal Near-Angle amplitudes are crossplotted against Azimuthal AVO gradient was reported by Lynn (2016). *Figure 3* shows such crossplot for a CIG bin of known fracture azimuth (N20E), known wide fracture apertures, and known high fracture density. A Star Trak resistivity image log in a horizontal borehole provided information on the fractures for a ~1500 ft length stretches in the top of a carbonate oil reservoir, known to flow oil when enough fracture density exists.

The azimuthal pairs of values shown in the crossplot of *Figure 3* were derived from *Figure 4*.

In *Figure 5*, two different methods to make the data comply with the Ruger (1997) and Ruger and Tsvankin (1997) requirement of a fixed-intercept at normal incidence are shown. The dashed lines *(Figure 5 (left))* are clearly not supported by the data. The consequence of employing the normalization technique *(Figure 5 (right))* is that the information in the azimuthal near-angle amplitudes is lost, and the AVAaz fit to the cos2theta is degraded.

Azimuthal near-angle amplitudes have been reported in the literature during the last 20 years *(Figure 5*, Lynn et al., 1995; *Figure 7*, Neves et al., 2003). Evaluation of the publications shows that the near-angle amplitude variations track the AVO gradient by azimuth in the fashion shown here. In the last 5 years, Lynn personally worked four high fold full-azimuth full-offset 3D PP surveys taken through azimuthal PSDM or PSTM, and routinely observes the results presented herein. The industry is persistently ignoring field-data observations seen in data around the world: either there is a systemic flaw in industry-standard full azimuth, full offset acquisition and industry-standard azimuthal processing, or there is geologic information (Lynn, 2018) to be extracted from the azimuthal variation of near-angle P-P amplitudes, which is now routinely ignored...and a theory update is needed.

Method

Full-offset full-azimuth 3D P-P data are acquired in the field. After pre-imaging signal enhancement and noise reduction, the data are put through 5D interpolation for regularization and conditioning of the data. Either a 6-azimuth narrow spoke 5D interpolation approach or an offset-vector-tile (or COV, common offset vector) 5D-output approach is commonly used. The subsequent PSTMs or PSDMs of limited azimuth, limited offset, volumes which preserve azimuth and offset for further velocity

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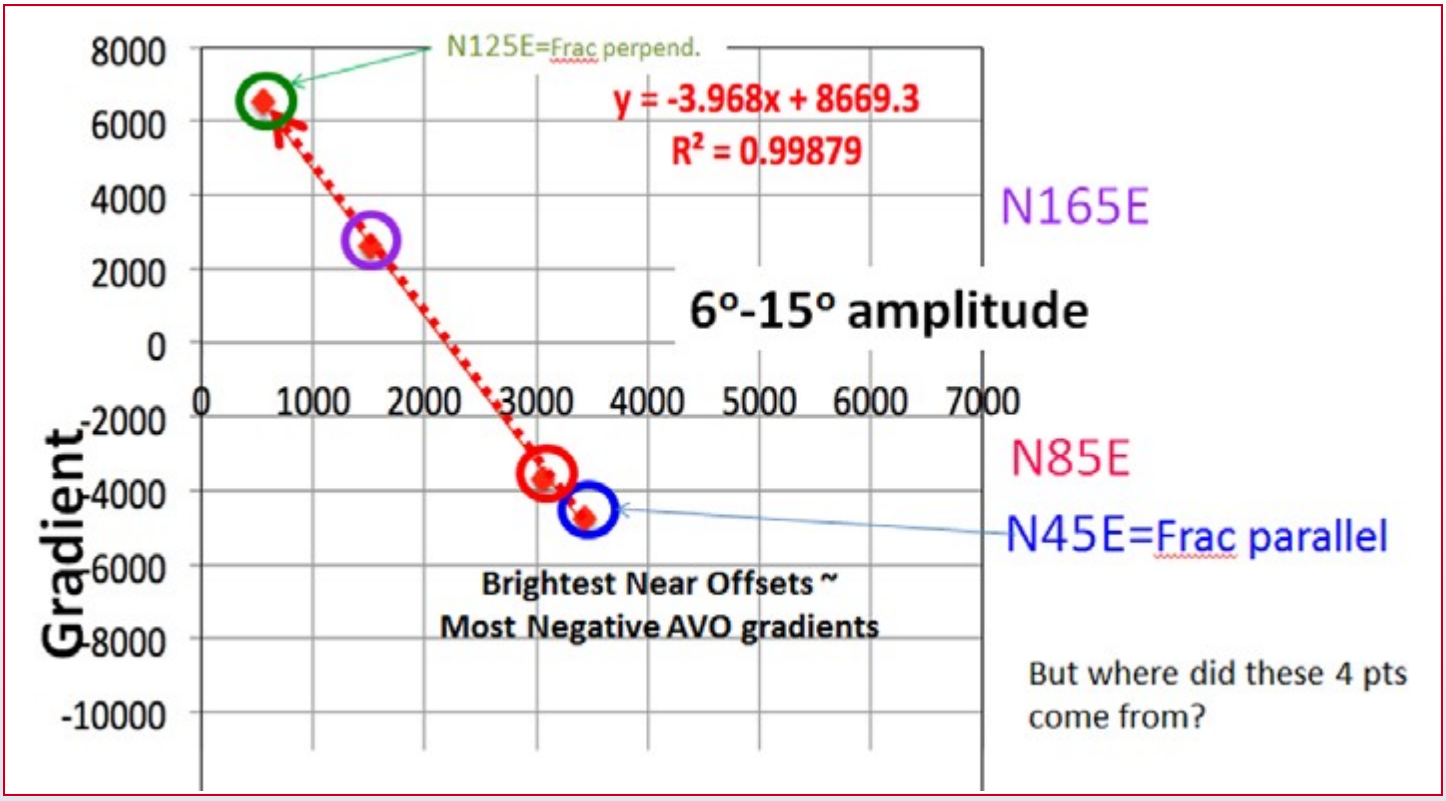

Figure 3. The crossplot of the azimuthal Near-Angle Amplitude and AVO Gradient for a CIG bin of known fracture az (N20E), known wide apertures, and known high fracture density. The slope of the posted line, -3.9, indicates that the azimuthal variation of the AVO gradient is ~4 times greater than the azimuthal variation in the near angle amplitudes. The azimuth of the most negative AVO gradient is consistently seen throughout the survey to also be the azimuth of the most positive Near-Angle Amplitude: this is the fracture-parallel azimuth.

and amplitude work are produced. Usually a VTI earth velocity model is employed for the first pass in order to flatten the gathers to a reasonable extent. Then, the azimuthal (HTI) time wobbles are picked, quantified, and removed. Recently, the re-migration using orthorhombic velocity fields is gaining in popularity. The velocity information is saved into velocity attribute volumes for the interpreters. Thereafter, as the gathers are more nearly flat, the P-P azimuthal amplitude analysis and gather conditioning can start.

P-P field data example.

The acquisition and processing history for this data are given in Lynn et al., 2014. Briefly, these 3D field data are high fold (1350 fold per 100 ft x 100 ft bin and were acquired with the UniQ™ acquisition system. Offsets greater than target depth for all azimuths were recorded. The carbonate produces commercial oil from high fracture density regions, so one of the goals of the study is to find the high fracture density. The data are clean with high S/N.

The cross plot of az-blind (I, G) for inline 14650, and a map area around the calibration data, is shown in *Figure 6* (see blue dots): the blue straight-line fit is posted. This linear trend is interpreted to be caused by an increase [from lower right to upper left] in total porosity sensed, as shown in *Figure 1*. The carbonate's wireline log matrix porosities in this survey span 6-8%. If the span of blue dots indicates the effect of matrix-porosity changing from 6% to 8%, then the span of either az'l colored dot CIG bin data indicates about a 1% change in effective porosity, a reasonable number. *Figure 6* also includes 2 different CIG bins where in the azimuth-dependent (Near Angle Amplitude, Gradient) is cross plotted as the dashed lines (red, pink). These 2 CIG bins are locations where the Trak Resistivity image log provides known fracture azimuth, fracture density, and fracture aperture information.

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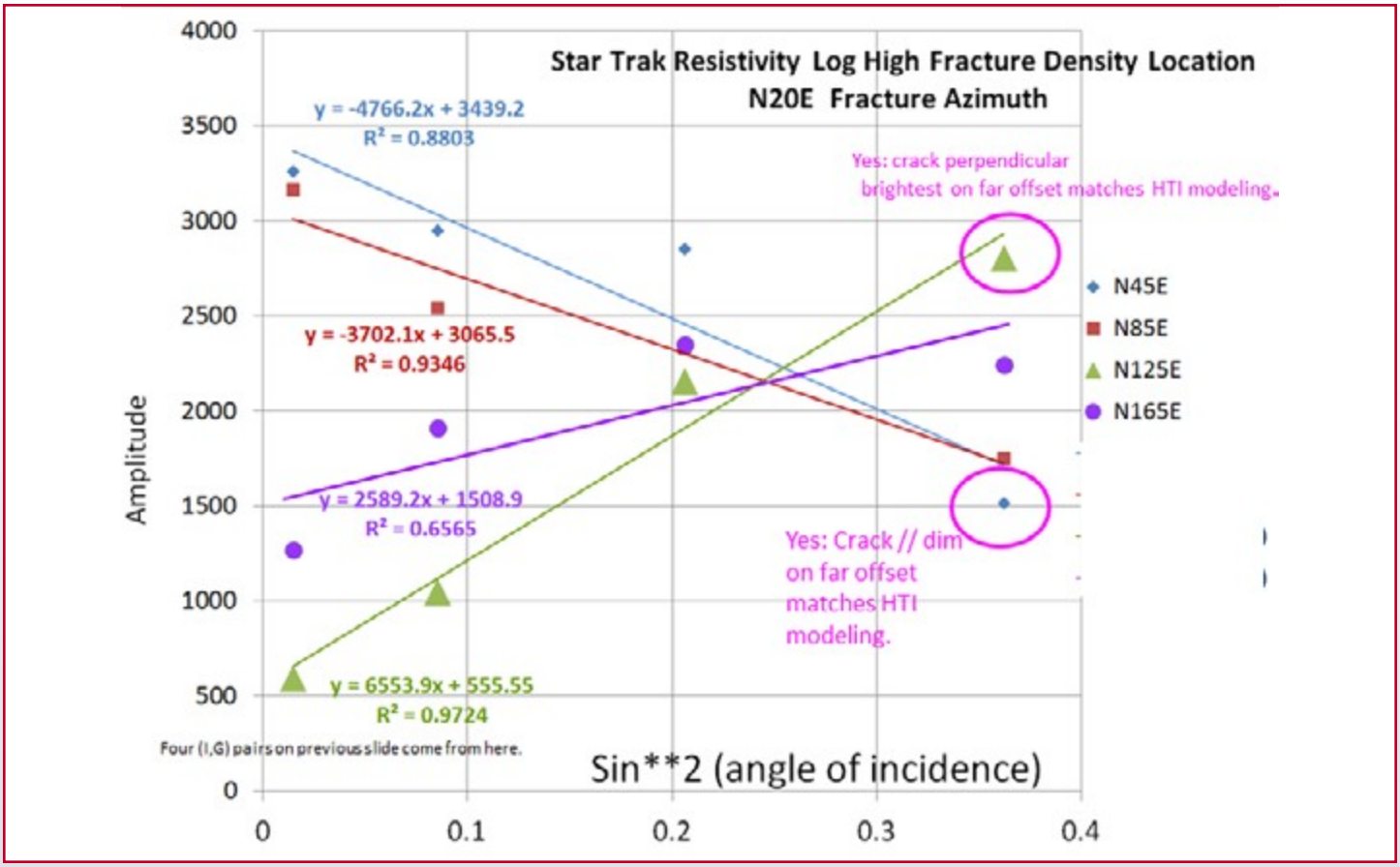

Figure 4. The amplitudes (limited-az., limited angle), for a CIG bin of known fracture az (N20E), known wide apertures, and known high fracture density. The solid lines show the straight line fit (Shuey, 1985) for the floating-intercept-AVO gradient calculation. Note the very good fits to lines.

The red dashed line of *Figure 6* is from *Figures 3, 4*. The pink dashed line is another bin of known fracture azimuth, fracture density, and fracture aperture (Lynn, 2014a, b; Lynn, 2015; Lynn, 2016).

Figure 7 presents the statistics from the entire survey, for the goodness of the line fit to the azimuthal (Near-Angle Amplitude, AVO Gradient) crossplot, on a bin-by-bin basis, for the Top/ Carbonate reflector. Half the bins (~32,150 bins) have an R^2 >0.76. One quarter of the bins (~16,900 bins) have an R^2 >0.92. The linear crossplots of az'l (Near-Angle Amplitude, AVO gradient) are observations widely seen throughout the survey, not "a fluke" or a "one-off weirdness".

Discussion

Allowing the near angle amplitudes to vary by azimuth, that is, the unpinning of the Mathematical Intercept from a fixed value at normal incidence, is necessary to accommodate the reality of effective porosity sensed changing by azimuth, when considering VP, VS, and density.

If the effective VP, or VS, or density change by azimuth, then the other 2 quantities must also change, by using the rules of rock physics (Mavko and Dvorkin, 2005). The reason that VP, VS, and density for a carbonate all change if one of the quantities changes by azimuth is that when the effective porosity sensed changes by azimuth, we are seeing a linked variability in the VP, VS, and density, for a fixed pore fluid and a fixed lithology.

The Mathematical Intercept is a numerical calculation, a convenience to project off the end of the field-data -measured angles of incidences to obtain a very important piece of information. To obtain an azimuth-dependent accurate AVO

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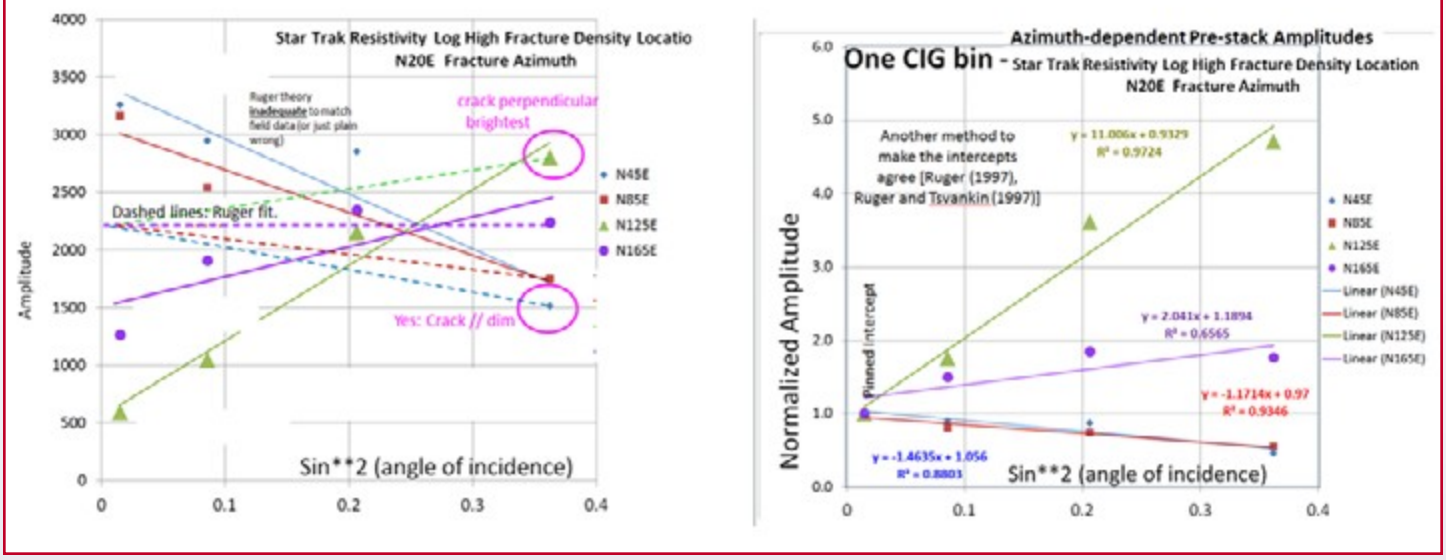

Figure 5. (Left) One method to impose pinned intercept to fit the Ruger (1997) theory. (Right) A normalization method (near angle ampl.) to impose pinned intercept to fit Ruger theory. Normalization suggested by J. Queen.

gradient, the unpinned intercept must be used. The near angle (6-15°) amplitudes are what we record in the field and send through processing. The true Zero-Offset reflection amplitude is proposed to be governed by the arithmetic mean of the fractured medium's VS1 + VS2. However, Zoeppritz theory and all approximations to the Zoeppritz equations are ray-based calculations, not wave-based calculations. The Fresnel zone of the P-wave of the zero-offset is the field data reality, and this Fresnel zone will have an areal extent with a cone of angles of asome few degrees. When the P-P wavefront is just a few degrees off vertical (~5°), sufficient angle on the wavefront is present to cause the P-SV system to be P-S1 in the fracture parallel direction; in the fracture perpendicular direction, the P-S2 system is sensed. The Fresnel zone involved with a given S-R would allow a certain angular polarization of the normal P-wave particle motion/strain.

The industry has mistakenly believed that *only* the shear modulus changes by azimuth: that is, only the far angles are allowed to have a different VS and a different VP. This concept prevents comprehension of effective porosity sensed changing by azimuth, and the consequential effect upon prestack azimuthal P-P reflection amplitudes. Effective porosity sensed by azimuth gives evidence of VP and VS and effective density changing by azimuth.

When one azimuth senses a higher effective porosity, while the orthogonal azimuth senses a lower effective porosity, an azimuthally- different effective density is needed in the equations. If vertical aligned fractures provide a greater sensed porosity in the frac-perpendicular azimuth, but a lesser sensed porosity in the orthogonal (frac-parallel) azimuth, then the azimuth of higher effective porosity is the azimuth of lower effective density. Effective porosity and effective density are incontrovertibly linked.

Likewise, the P-wave velocity is deeply dependent upon porosity. When the effective porosity sensed is increased, the VP decreases. Sandstones with round matrix porosity are more easily comprehended. Truly round pores look the same to all azimuths, and increased porosity decreases VP. But, carbonates with their wide variety of pore shapes present much more challenge. The crack-like pores (vertical pancakes) are more compressible than round pores, to the P-wave traveling orthogonal to the crack-like pore(s). When one set of vertical aligned fractures is present, shear-wave splitting is observed, with its two different shear moduli. The one set of vertical aligned fractures can have a significant effect upon the VP and the density for waves traveling in the fracture perpendicular direction, and so alter the amplitudes azimuthally.

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If the lithology contrast is known, and if the layer with the likely higher fracture density is known, then the ambiguity of fracture azimuth from P-P prestack azimuthal amplitudes is removed. Three simple modeling steps will establish it: 1) for the given higher fracture density layer, decrease the shear wave velocity 10% then 20% to change the AVO gradient but not the intercept. The 10% decrease in VS mimics moderate fracture density in the fracture-perpendicular direction; 20% mimics high fracture density. 2) model the effect of delta, epsilon upon the fracture parallel AVO gradient; model a decreased value of delta and epsilon in the fracture-perpendicular direction. 3) Use rock physics predictions for the effect of increasing porosity decreasing the VP, VS, and density in the given lithology. Calculate the model (Intercept, Gradient) for the P-P reflector as porosity increases. Compare the results to the observed data. Fracture parallel is always "the reference".

There may be an azimuth-dependent scattering effect that we are neglecting. Parallel to the fractures, we might expect less scattering. Perpendicular to the fractures, we might expect more scattered energy. If the near-angle fracture-perpendicular P-wave were to be more scattered than near-angle fracture-parallel, then the argument would be: in the fracture-perpendicular direction, we have an anomalously low P-P reflection amplitude that is not

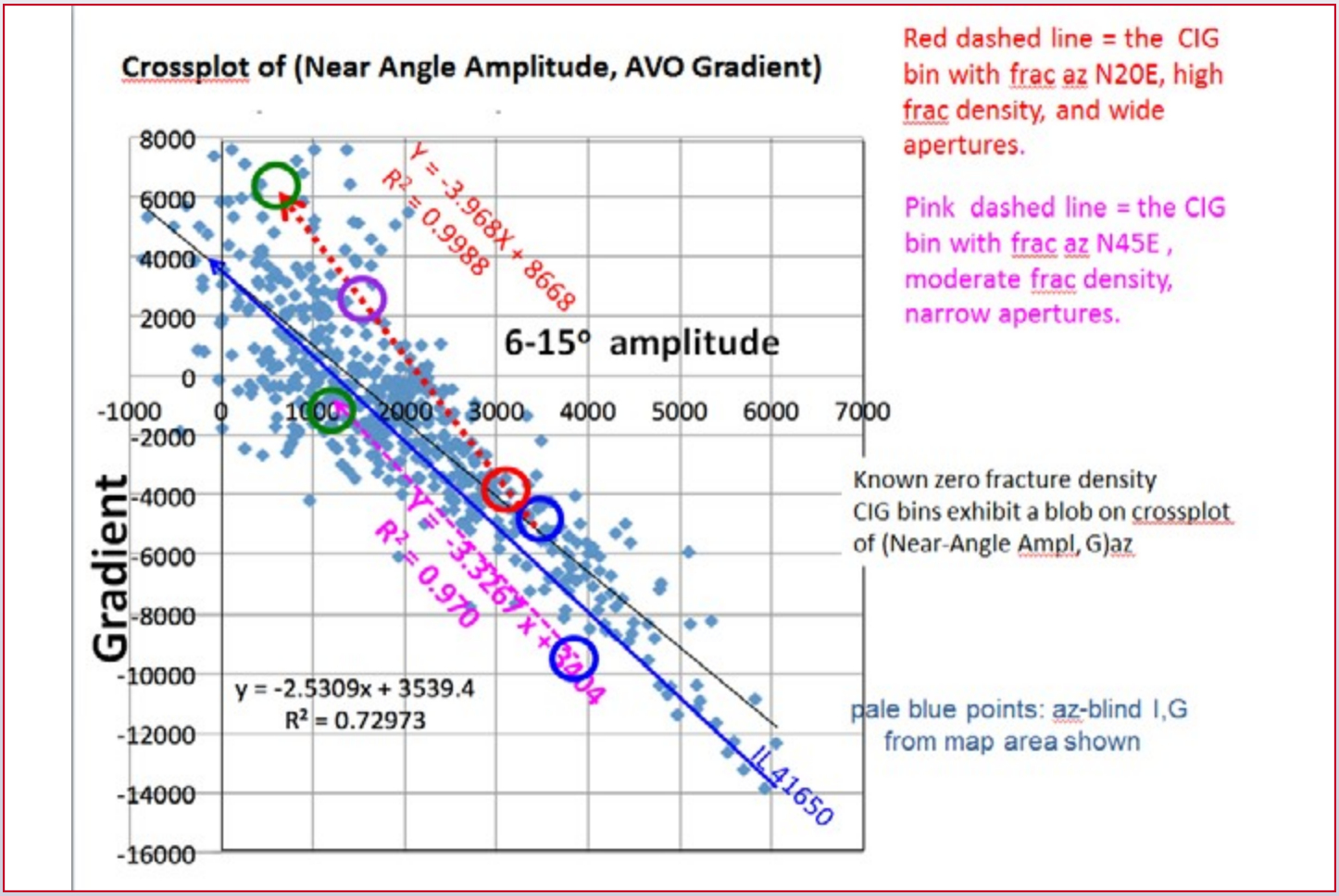

Figure 6. The blue dots are the azimuth-blind values in a map area provided in Lynn, 2014a, b). The best fit slope to the az-blind I, G values is -2.5, which is in moderate agreement with the two slopes of the azimuthal (Near-Angle Amplitude, Gradient) crossplots. The azimuthal (Near Angle Amplitude, Gradient) CIG data lines added [dashed pink line, dashed red line] are at bins with known fracture azimuth, fracture density, and fracture aperture. In the middle of the colored dashed lines, a given blue dot is expanded into its azimuthal parts, as shown by the circles and the dashed lines.

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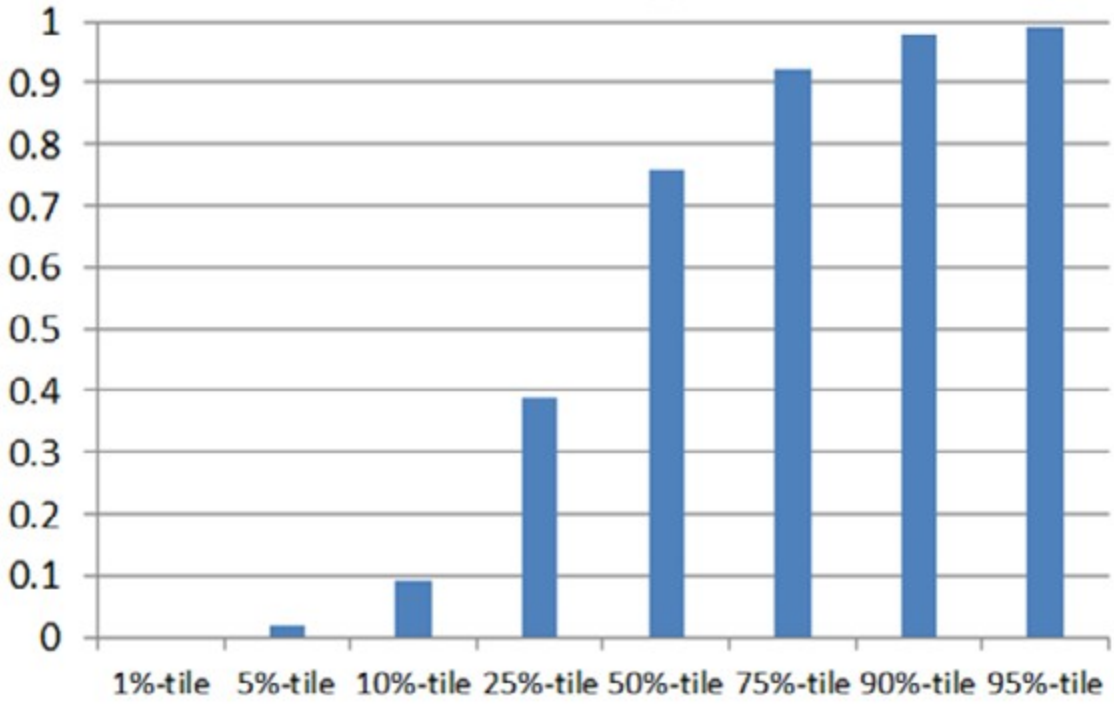

Figure. 7. The R2 of the Top/ Carbonate reflector's azimuthal (Near-Angle Amplitude, AVO gradient) crossplot, for the 64,368 bins of the survey.

governed by the P impedance contrast, but rather a diminished amplitude due to losses into the scattered wavefield. Also, there may be an azimuthal Q effect, such that perpendicular to the fractures, attenuation of the near-angles is large. Or, another wave (Biot, Scholte, etc.) is generated, involved, and not accounted for. The crux of this paper's argument is that when P-P reflection amplitude is proportional to contrast in P impedance, then the azimuthal variation of the near-angle amplitudes carries geologic information (azimuthal variation of P-impedance contrast).

Conclusions

The effect of increasing porosity upon the (Intercept, AVO Gradient) crossplot, for fixed lithology, and fixed pore fluid, is to move on the line from lower right to upper left *(Figure 1)*. The effect of increasing effective porosity sensed (by azimuth) upon the (Near Angles Amplitude, Gradient) azimuthal crossplot is to move from the lower right to the upper left, along a line of increasing sensed effective porosity *(Figures 2,3,6)*. A line in (Near Angle Amplitude, Gradient) azimuthal space for a fixed lithology contrast, here, shale over carbonate, indicates a change in the effective porosity sensed by the waves of different azimuths. The "Low Porosity" sensed number is in the lower right (Fracture Parallel, matrix porosity sensed); the "High Porosity" sensed number is in the upper left (Fracture Perpendicular, matrix+fracture porosity sensed). In azimuthal amplitude analysis, the VP, VS, and density can (or might) change by azimuth, and this needs to be allowed in the analysis codes. The near angle azimuthal amplitudes sense the azimuthal P impedance (or azimuthal lambda-rho) contrast. The far angle azimuthal amplitudes sense the azimuthal S impedance contrast (or azimuthal Poisson Ratio, or azimuthal mu-rho). The azimuthal variation of the

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near-angle amplitudes is interpreted as an azimuthal effective-porosity-sensed effect.

Acknowledgements

Fred Hilterman's plot from the GSH webinar, "Amplitudes" is pivotal to this paper. John Sherwood and Walt Lynn are gratefully acknowledged for improving the communication of this abstract. John Queen generously gave of his time to hear this presentation and provided keen insights to improve this paper. Lynn's client is gratefully thanked for permission to publish. □

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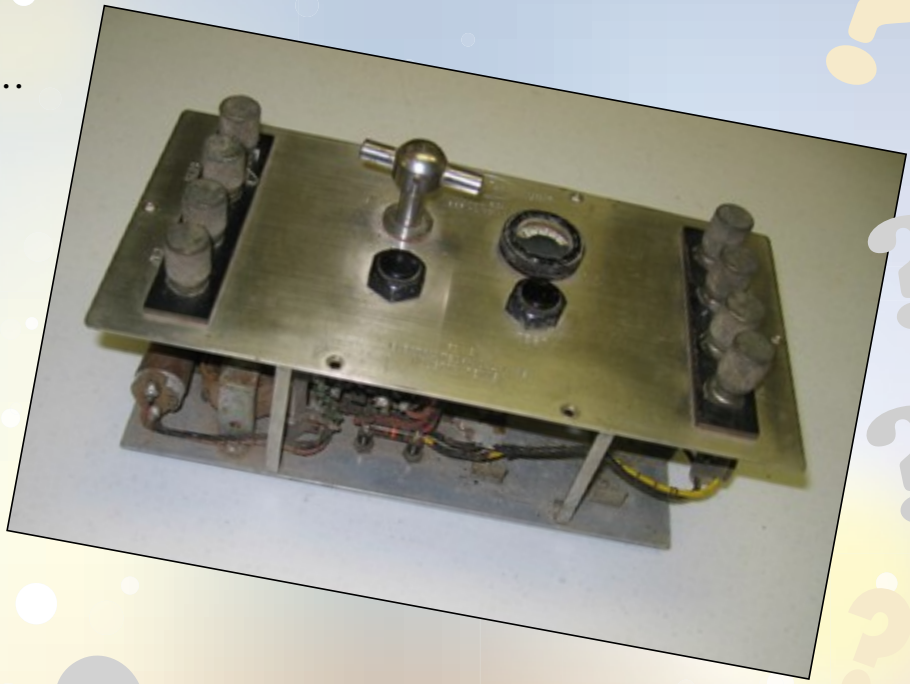

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GSH Outreach

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

TGS-Middle-School-Visit-Connie VanSchuyver

I was contacted by Maryam Lumpkin, an educator at The W.I.D.E. School, who found the GSH Outreach page through internet search. She was looking for scientists to help one of her 6th grade students with his Investigate Science project. His original question was "Why isn't Greenland a continent?" but she asked him to revise it to be more general, so it became "What makes a continent a continent?" He was not allowed to search the internet to find the answer. He was expected to investigate by interviewing people. I sent an email request to the GSH Outreach Volunteers asking if anyone would like to be interviewed by the student, Connie VanSchuyver (TGS) stepped up and here's what she says happened next.

I received a request from Lisa Buckner asking if I would consent to being interviewed by this student. I thought it sounded like fun, so I said yes and contacted the teacher directly.

Talking to Maryam, she told me she had looked at our (TGS') web site and thought it looked like an interesting company. She almost immediately asked if she could bring her whole class! I said I would check and talked to several people to ask if it would be OK with TGS. Fortunately, both HR and Zhiming Li, Senior VP of Imaging, thought it was a great idea and encouraged me to have them over. I took them down our main hall, past the fossil collection (slowly) and over the seismic section on the floor to our conference room to talk to them. On the way one of them noticed that our phone room was named "Teleportation Room"

WIDE School Silly-Group and Connie VanSchuyver

WIDE School visits TGS and notices name of Phone-Room

and wanted to try it! Of course, it was a reference to Harry Potter, the phone rooms were named by a contest.

Next, we went into the conference room and for nearly 2 hours we talked. I did give them a short talk on what we do here, and then they asked questions! It was so much fun to see such curiosity. And after the session, hugs all around, they took a picture with a silly pose. It was definitely a fun morning for me, and I understand they were all excited, too.

As for the original question? I hope I get to see what he comes up with. Right now, Greenland is considered the largest island, about 1/3 the size of Australia which is the smallest continent. And Greenland is considered part of the North American continent. But who knows in the future?

Connie VanSchuyver

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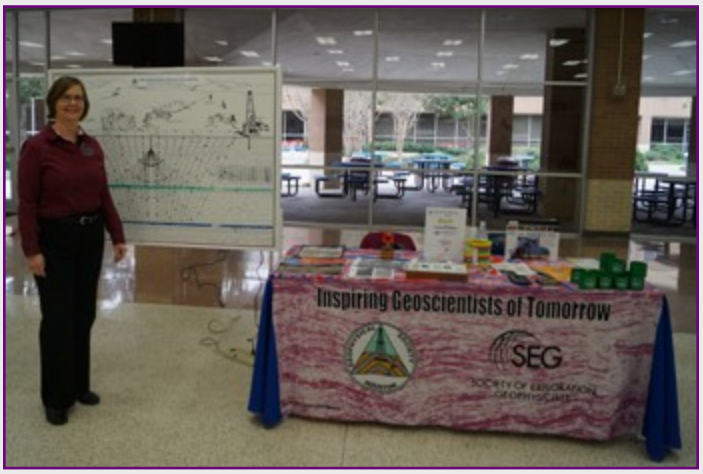

2019 Dulles Diamonds Booth

GSH was invited to host a booth at the **Dulles Diamonds STEM Camp on Saturday, February 19, 2019**. The event was held at Dulles High School, FBISD where a group of high school girls called Diamonds, mentored a group of elementary school girls called **GEMS**, under the direction of the adult program directors. They conducted some hands-on science experiments as well as visited 5 hands-on STEM community booths. I demonstrated P & S wave motion and explained seismic data acquisition, processing and interpretation. Attendance was low due to a conflicting school district STEM event so I only gave away 15 coiled toy springs.

2019 Bellville Science Night - George Laguros explains seismic data acquisition

On the evening of **Monday, February 11, 2019 GSH hosted a booth at the 5th annual Bellville Family Science Night.** GSH outreach volunteer George Laguros carpooled with me and we gave away 85 coiled toy springs to inquisitive students. Four students from the Texas A&M SEG Student Chapter also hosted a booth and brought some geophysical equipment to share with the students and their families. It was a great event as always with students and families who are familiar with seismic survey and drill crews working on their properties.

2019 GEMS at HMNS

The **Girls Exploring Math and Science (GEMS)** was held at the **Houston Museum of Natural Science on Saturday, February 16, 2019**. The event is organized for Girl Scouts and the general public and was attended by over 2,250 museum visitors. The GSH geophysics booth as manned by volunteers: Catalina Llano Ocampo, Heather Cousson, Huw James and George Laguros who gave away 200 coiled toy springs. They also judged science fair type student projects created by the girl scouts. The third place winners were "Using Haptics to Help Astronauts." They created a model of a haptic sock to address sensory deprivation in astronauts! In second place, the Jersey Village High School robotics team "Jersey Voltage." They created a robot to accomplish certain tasks and that the girls could control! And finally, the first place group was "EMF-The Invisible Sea we Swim in Everyday"! The group of girls explained and understood EMF and found solutions on how to protect ourselves from EMF waves using interesting solutions. It was a great demonstration of the scientific method and they did a wonderful job describing the project for guests of all ages! The girls were so proud of their project and excited that they earned first prize!

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2019 Roberts Road ES Science Night - Lisa Buckner explains seismic

2019 Roberts Road ES Science Night - Chuck Meeder and students Drilling for Oil

On the evening of **Tuesday, February 19, 2019** the GSH participated in the **2nd Annual Roberts Road Elementary School Family Science Night**. This Waller ISD school is located in Hockley. Ilena Krupala, a HGS Teacher of the Year award winner, teaches science at this school and helped them organize the event which is similar to the Bellville Family Science Night that she organized previously and at which she still volunteers. Chuck Meeder and I, hosted the GSH geophysics exhibit table. The students were interested in the rock samples, especially obsidian which is in the game Minecraft, and the seismic data lines. The Drilling for Oil game was very popular and we gave away 103 GSH coiled toy springs.

GSH Outreach volunteers participated in two events **EYH and SEFH on Saturday, February 23**. See **article by Gokay Bozkurt for information about the Science Engineering Fair of Houston (SEFH**). Connie VanSchuyver, Marjosbet Uzcategui and I co-presented 2 of the 104 classroom hands-on activity student workshops at the **AAUW Expanding Your Horizons (EYH) in Science and Mathematics conference**. The conference was attended by about 400 middle school girls, teachers and parents, most of which were bused from school districts all around Houston. The girls attend a keynote talk followed by two morning workshops, lunch, two afternoon workshops and closing session with door prizes. There were 12 girls in our first

2019 EYH Selecting a drilling location

2019 EYH Building the Earth models 1

2019 EYH Building the Earth models 2

2019 EYH Building the Earth models 3

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2019 Mark Twain ES Science Night - Mac Hooton and Patricia Henderson

2019 Mark Twain ES Science Night - Mac Hooton_Patricia Henderson_Lisa Buckner

session and 17 in the second session. We divided them into 4 teams and did the Exploring for Oil using geophysics activity. The girls filled paperboard shoe boxes with layers of sand and gravel a hid a balloon, prefilled with black food coloring and water "oil reservoir". They traded their box with another team. Then they conducted a seismic survey to find the "oil reservoir" by tapping on the box lid with their hands (source), listening with their ears (receivers) and processing with their brains. They used a bamboo skewer to "drill for oil". Some found it on the first try!

On the evening of **Thursday, March 7,** GSH participated for the first time in the **Mark Twain Elementary School Math and Science Night**. We were allotted two tables so Mac Hooton used one for his rock and mineral samples. Patricia Henderson and I used the other table for the "Drilling for Oil" which had a constant line of students waiting to drill and receive a coiled toy spring. We gave away 100 springs. While waiting in line, we explained seismic data acquisition using the light animated ray path poster. The HISD school is located inside the loop on Braes Boulevard. □

Upcoming Outreach Events

Upcoming Event – June 8 – Gustavia Pearls Women's Outreach STEM Festival

Do you want to be added to the GSH Outreach Volunteers email distribution list or know of a school that has a career day, career fair or science night at which GSH might be able to host an exhibit booth? If so, please contact Lisa Buckner at outreach@gshtx.org and we can work together to bring awareness of geophysics and geology to the students.

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Outreacch continued from page 30.

GSH Outreach

60th Annual Science and Engineering Fair of Houston

By Gokay Bozkurt

Youth Education is one of my passions and I try to engage in a variety of K-12 educational community outreach programs in and around Houston. There is one that I particularly feel connected to and feel really excited about: The **Science and Engineering Fair of Houston** (SEFH).

SEFH is a world-class youth STEM program known to be the largest of its kind in Texas. It serves as the regional fair for all public, private, charter and home school Junior and High School students in Harris County and 22 surrounding counties throughout Southeast Texas. It is a wonderful platform for students to showcase their research ideas alongside with like-minded peers passionate about math and science. In many cases, it is a student's first attempt to experience a major STEM event outside the classroom. Every project is judged by a number of reviewers who are experts in their subjects. The judges interact with the students, listen to their presentations, provide feedback and also help select projects for awards and scholarships. The educational activities sponsored by SEFH include a Writing Contest and a Technical Poster Design Contest, as well. GSH proudly supports this event as a Special Awarding Agency together with 36 other professional societies and organizations in Houston.

This year SEFH reached a major milestone and celebrated its 60th anniversary. The event was held at the George R. Brown Convention Center on February 23rd Middle and High School exhibitors showcased over 800 research projects (393 Junior and 436 Senior) spread over 7 technical categories.

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

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

Senior - 1st Place

Lochana Kalyanaraman, Young Women's College Preparatory, Houston ISD, Houston, TX

The Quest for Oil: A Statistical Analysis

Senior - 2nd Place

Sarim Aleem, Seven Lakes High School, Katy ISD, Katy, TX

Novel Feature Extractor for Repetitive Spikes using a Wavelet Based Approach

Junior - 1st Place

Abigail Rivera, Drew Academy, Aldine ISD, Houston, TX

Which type of Sedimentary rock is best for storing oil?

Junior - 2nd Place

Lucy Abu, Garcia Middle School, Fort Bend ISD, Sugar Land, TX

The Effect of Temperature on the Viscosity of Honey

Outreach continued on page 30.

Outreacch continued from page 30.

The Awards Ceremony for the 2019 Science and Engineering Fair of Houston was held on Saturday, March 2nd 2019, at the Cullen Performance Hall at the University of Houston. The auditorium was packed with students, parents, teachers and guests. Dr. Laura Jacobs with the UH STEM Center was the emcee and she led an up-beat and exciting program. Educational and Industry keynote speakers were Dr. Jarrod Henderson with UH and Colonel Michael Fossum, a NASA astronaut currently with Texas A&M University at Galveston. They delivered inspiring messages and shared very interesting life experiences of how they got involved in STEM. The program moved forward with the presentation of SEFH Teacher of the Year Awards by the Executive Director Dr. Heather Domjan, and the Special Awards by the representatives of the respective sponsoring agencies.

GSH Judging Coordinator and Lead Judge Gokay Bozkurt is on stage with award recipients Sarim Aleem, Abigail Rivera and Lochana Kalyanaraman, joined by SEFH judges Ahmet Murat Alyaz and Carolina Mejia Hernandez.

GSH Special Awards Judging Committee. From Left to Right: Huw James, Peter Lanzarone, Cory Quinn, Emmanuel Ubaha, Gokay Bozkurt, Syed Mehdi, Alan Foley, Mfon Udo-Imeh, Ahmet Murat Alyaz.

I was joined on stage by Carolina Mejia Hernandez and Ahmet Murat Alyaz, SEFH Judges, during the presentation of the GSH awards to our winners. Three of our winners were present to personally receive their Certificates of Accomplishment and gift cards ($50 for 1st place; $25 for 2nd place).

I would like to acknowledge my team of GSH judges who have generously devoted a good part of their Saturday diligently reviewing projects and interacting with the brilliant minds of our future. This year's GSH Special Awards Judges were: Gokay Bozkurt (Judging Coordinator), Ahmet Murat Alyaz, Alan Foley, Huw James, Peter Lanzarone, Syed Mehdi, Emmanuel Ubaha, Mfon Udo-Imeh and Cory Quinn.

I would also like to take this opportunity to acknowledge Lisa Buckner for all her guidance and Karen Blakeman for all the support. They have been an integral part of this effort. Thank you! □

A GSH/SEG Web Symposium

Survey Design: Past and Present

By Dave Ridyard

On Wednesday May 29th, the GSH, in cooperation with SEG, is hosting a web symposium on the subject of 3D Seismic Survey Design, "New Tools for New challenges". The event addresses the latest technologies that are driving modern survey design. In this article Dave Ridyard of ACTeQ uses examples from the past to illustrate why it's so important to continuously reassess the latest practices in survey design.

Introduction

I shot my first 3D survey offshore Gabon in 1980. We had a single streamer and a single source, and each vessel pass created one 2D line. Data processing comprised a traditional 2D processing sequence through stack, followed by an in-line migration, and finally a crossline post stack migration. Much has changed since then, but the changes fall into three broad categories.

1. Data acquisition technology. Changes in hardware and software technology have made things possible that were inconceivable 40 years ago .... And there is no sign that the pace of change is slowing down.

2. Data processing and imaging technology. In 1988, while getting ready for our first circle shoot, Bill French told me that everything is noise until you understand it. Once upon a time, we considered variations in source-receiver azimuth to be noise, but today azimuth related variations of signal are used to extract critical information. Years ago, we often threw away signal in the process of reducing noise prior to recording. Today we can generally record the full wavefield (noise + signal) and "processing can fix it".

3. Objectives. Perhaps most important of all, our objectives have changed. Back in 1980, our goal was simply the correct 3D placement of the reservoir structure. Today, we are often seeking small targets with marginal economics, and we are required to estimate reservoir properties, even in complex structural settings. Our objectives have also had to be adapted to modern expectations of health, safety and the environment, which plays a growing role in the selection of data acquisition techniques and survey designs.

Let's consider how these factors play into onshore and offshore survey design.

Land

Broadband wide azimuth recording, with its requirement for dense sampling is driving much of the thinking in this area. Multiple simultaneous sources and high channel count systems are now routinely delivering very high trace densities, approaching 100 million traces per square kilometer. Given sufficient sampling to record and remove noise, the need to use source and receiver arrays is increasingly being challenged. Is it better and/or cheaper to record 3 point receivers rather than a single array of 12 geophones ?

Most traditional land survey designs use dense source lines orthogonal to dense receiver lines to obtain dense 3D sampling. These geometries can be efficiently implemented in unobstructed areas using cabled systems, but as recording spreads become larger, operational issues, especially in obstructed or environmentally sensitive areas can cause problems. The appearance of low cost, highly reliable autonomous nodes has enabled a whole range of different geometries. Rather than seeking rigid grids of shots and receivers, many survey designers are now looking at some distribution of randomized receivers, with shots being acquired where they are easy rather than on a regular grid. (See sidebar "What do mediaeval peasants have to do with survey design ?")

Seabed

For many years, seabed seismic was an expensive complement to towed streamer acquisition, used in marine environments deemed unsafe for towed streamers due to shallow water or large numbers of obstructions. Over the last few years, seabed has emerged as an increasingly adaptable tool. For production and development applications,

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Web Symposium: Survey Design continued from page 33.

where mobilization is a significant component of overall survey cost, seabed seismic offers a practical alternative, with added benefits such as the availability of multicomponent, wide azimuth and ultra long offset recording.

For exploration surveys, it is the appearance of autonomous nodes that has triggered a mini-boom in the business. Traditional seabed cable systems have always suffered from the risk that a single failure to power or communications can cause downtime, making large scale operations, particularly in deep water risky. Autonomous node systems can be deployed and recovered with minimal risk, either one at a time using a Remotely Operated Vehicle (ROV) or using a Node On A Rope (NOAR) system. Years ago, survey designs were often based on (a) a desire to match the offset and azimuth distribution of a neighboring towed streamer survey and (b) availability of a very limited inventory of seabed cables. The result was an acquisition geometry with small numbers of deployed cables, with shot lines towed "inside" the receiver spread. Increasingly today, wide patches of receivers are deployed, with even larger patches of shots acquired over the spread. The result is a very high trace density, often producing spectacular data quality.

The recent appearance of new systems and service providers has created a whirlwind of innovations and new ideas in survey design. Perhaps the next wave will involve some form of self guided node.

Towed streamer acquisition

Towed streamer acquisition is ridiculously fast and efficient. In the 1980's, digital cables ushered in streamers up to 12 km in length. In the last few years, multisensor streamers appeared with a promise to address the biggest challenge in marine : "How can we get crossline sampling to match our naturally dense in-line sampling ... at reasonable cost ?"

Marine towed streamer acquisition has always been about efficiency. In general, this has involved ever bigger vessels towing 8, 12, even 20 streamers. This has been a very successful approach, but there are fundamental limits, because as the streamers get further out, the near trace offset can become unacceptably long. But there are answers to this problem too. Some contractors are now towing up to 6 sources. With simultaneous shooting and deblending, these can be used solve the dense crossline sampling problem, or they can be deployed wider to solve the near trace offset problem. Several contractors now have enough faith in their streamer control devices that they are employing a shooting vessel deployed over the towed streamer spread to generate short offset data and minimize infill.

Multivessel acquisition used to be seen as a necessary evil to obtain data under obstructions, but today multivessel fleets are being used to generate wide azimuth data sets. Most surveys are still acquired in straight lines, but there has been a resurgence of deviated, sinusoidal, circular or even cycloidal vessel tracks.

Mixed mode acquisition

Most projects are acquired using a homogenous acquisition technique, but sometimes that just isn't possible. Data processing companies are now increasingly capable of successfully merging different acquisition types. Ocean bottom nodes deployed around a platform can be used to infill holes in towed streamer coverage. Borehole deployed DAS receiver systems can be combined with surface seismic to provide additional information in unconventional plays.

Conclusion

Changes in acquisition and processing technology have created great opportunities to deliver more cost-effective imaging. Survey designs must continue to evolve to keep up with the changing requirements of our customers. Designing a 3D survey today requires a knowledge both of the operational limitations of the available acquisition technology and the capabilities available in processing and imaging. The one word answer to all these survey design challenges is "more". Denser (and smarter) sampling. Longer offsets. Broadband. Wider azimuths. But the 3 word answer is "more for less" !

Each of the speakers at the GSH Web Symposium on survey design will cover one important topic on how technology is enabling, and sometimes driving changes in the way we design surveys. I highly recommend this event as a way to make sure that you apply all the best tools to your next survey design.

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"What do mediaeval peasants have to do with survey design ?"

I've recently been involved with three survey design projects in Europe. Although each project presented unique challenges, I noticed a striking similarity in that a key goal was to avoid conflict with the local community. For this reason, our approach to the survey design was to start off by looking at the roads as a preferred location for our vibrator points. In each of these surveys, I was pleasantly surprised to find that the pattern of roads and navigable tracks fitted our needs very well. A bit of research revealed that this was not a co-incidence.

In Europe, in the middle ages, peasants farmed lands owned by a local aristocrat. The size of these plots was generally between 20 and 30 acres. Any less than 20 acres was not sufficient to support a peasant and his family, so there would be no surplus to support taxes to the landlord. Any more than 30 acres could not be farmed by a single family, resulting in under utilized land, and lost taxes to the landlord. Consequently, all over rural Europe agricultural dwellings appeared 250-350 meters apart ... and tracks connecting these dwellings appeared at the same spacing.

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A GSH/SEG Web Symposium

3D seismic survey design
New tools for new challenges

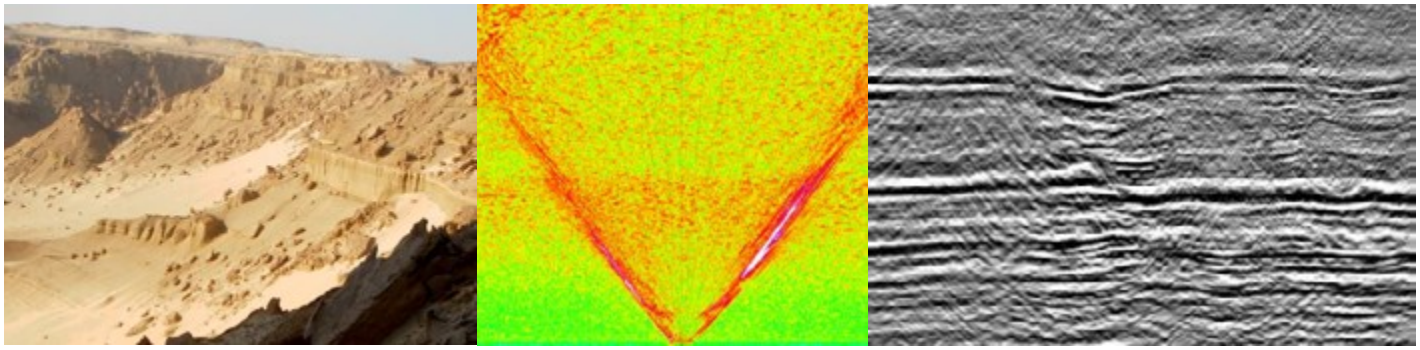
As geophysicists, we are faced with ever increasing challenges in conventional and unconventional exploration and development. This symposium will explore the challenges and opportunities represented by new technologies such as high density, wide azimuth, long offset, broadband acquisition using compressive sensing, nodes and full waveform inversion.

Wed. 29th May 2019
9:00 am to 1:00 pm (CST)

Registration

General public	$125
GSH/SEG Members	$ 90
Students	$ 25

Who should attend ? : Geoscientists, technical managers and field operation specialists seeking to remain current with the latest technology developments. The program has a land bias, but is very relevant to wide azimuth marine applications.



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.

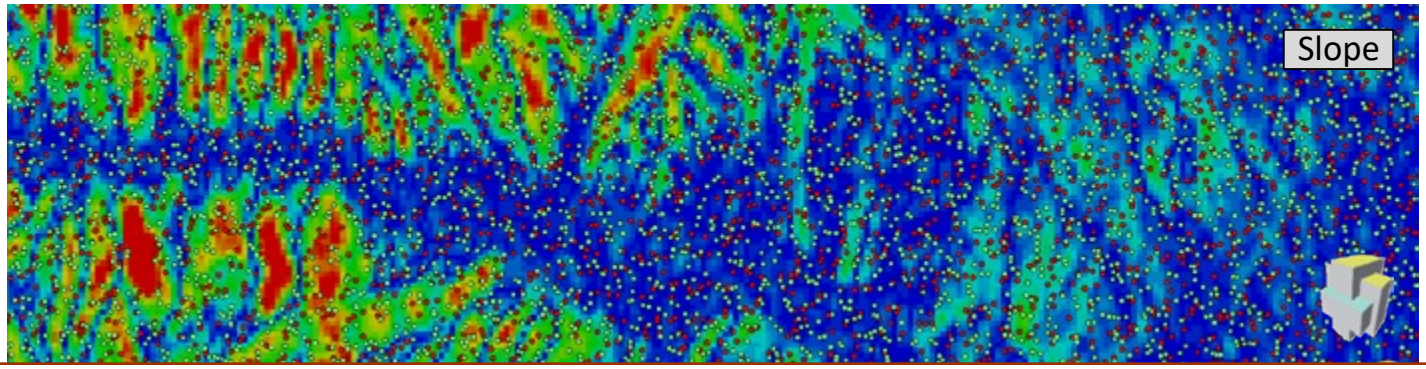
This informal and interactive event will be co-chaired by Dave Monk (Past President of SEG & Director of Geophysics at Apache) and Malcolm Lansley (Consulting Geophysicist)

Visit gshtx.org, Events Tab to register and see full presenter information (when available)

Event sponsors

ACTeQ Advanced Survey Design

rps Making complex easy



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A GSH/SEG Web Symposium
Agenda

Title	Speaker	Affiliation
Introduction. Recent changes in data acquisition	Malcolm Lansley	Consulting Geophysicist
Land nodal acquisition and why we need a new nimble node	Ted Manning	BP
METIS: Enabling Carpet 3D Land Seismic Surveys with Swarming UAVs	John Archer	SAExploration
Compressive Seismic Imaging: Changing the Mindset in Seismic Acquisition	Chengbo Li	ConocoPhillips
New design and acquisition solutions for old challenges	Nick Moldoveanu	Schlumberger
De-blending of continuous recording data towards a quantum leap in seismic imaging in the Western Desert of Egypt	Aly Said	CGG
The Challenges of Unconstrained, Broadband Land Acquisition: A Case History from the Western Desert of Egypt	Dennis Yanchak	Apache

A GSH/SEG Web Symposium
Bios

Malcolm Lansley **Consulting Geophysicist**

Introduction. Recent changes in data acquisition

R. Malcolm Lansley received a BSc/ARCS in physics/mathematics/geophysics from Imperial College of Science and Technology in London in 1969. Ten years ago Malcolm joined Sercel as VP of Geophysics, where he advises on the geophysical usage of all Sercel equipment including survey design, data collection, data processing, and interpretability of the resultant data. Prior to joining Sercel he had worked for more than 35 years with Geophysical Service, Inc., Halliburton Geophysical Services, Western Geophysical and PGS in all areas of the world, both onshore and offshore.

Mr. Lansley research interests include 3D technology (both land and marine), marine data acquisition, wavelet processing, multicomponent recording and vibrator theory and usage. He also teaches a variety of courses on vibrator theory and usage, 3D survey design, data acquisition and data processing for SEG.

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A GSH/SEG Web Symposium

Bios

Ted Manning BP

Land nodal acquisition and why we need a new nimble node

Ted joined the industry in 1995 following a postgrad HDip in Computer Science (UCC), MSc in Geophysics (Durham University), and BSc in Geology (UCD). After leading seismic processing projects and a dedicated processing centre in BP Sunbury for WesternGeco, he joined BP in 2004 and led R&D projects on Multi-Azimuth marine acquisition and processing, Land seismic efficiency (ISS) blending and deblending, field trials for high density land and OBS acquisition, among other seismic delivery projects. From 2011 to 2016 he worked in Jakarta, where as a Seismic Delivery Manager for the Asia Pacific region he was responsible for the design, contracting, safe delivery (NEBOSH certified) and processing of seismic and survey operations. He currently leads a team of geophysical researchers both UK and US based, including projects like nimble land nodes, seismic sources and processing, including machine learning applications. He is a member of SEG, EAGE and PESGB.

John Archer SAExploration

METIS: Enabling Carpet 3D Land Seismic Surveys with Swarming UAVs

John Archer recently joined SAExploration as their Vice President for Technology. Prior to this he was VP for Business Development and Technology at Geokinetics, where he co-invented the Symphony® technique. A geology graduate from Durham University in England, John has been working as a geophysicist for more than 30 years. He started with Western Geophysical as a seismic Data Processor in their London Center in 1987, before joining land seismic crews in Chad and Yemen. He joined Grant Geophysical, (which would later become Geokinetics), in 1990 working on transition zone operations in the Niger Delta, and has been involved with technical proposals, bidding, crew financial modeling and technology development ever since.

Nick Moldoveanu Schlumberger

New design and acquisition solutions for old challenges

Nick started his career with Schlumberger in 1989, and had varying assignments in data processing, software development, geophysical support for acquisition and processing, seismic survey design, and the development and commercialization of seismic acquisition and processing technologies. Currently, Nick is a global geophysical advisor. Before Schlumberger, Nick worked for Geological and Geophysical Oil Prospecting Company (IPGG), Bucharest, Romania, as field geophysicist, seismic interpreter, seismic technology analyst, data processing manager and technical director of the IPGG seismic computer center. Nick has a diploma in geophysics from the Romanian Oil, Gas, and Geology Institute, Faculty of Geology and Geophysics, and a diploma in mathematics from University of Bucharest. Nick has over 60 published technical papers, and many patents.

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A GSH/SEG Web Symposium

Bios

Chengbo Li — ConocoPhillips

Compressive Seismic Imaging: Changing the Mindset in Seismic Acquisition

He joined ConocoPhillips in 2011 as a research geophysicist in the Technology and Subsurface Organization after completing his Ph.D in Computational and Applied Mathematics from Rice University. His recent work focuses on geophysical applications of compressive sensing, including seismic data reconstruction, optimal survey design, and simultaneous source acquisition for both marine and land. Now he also leads the effort in developing machine learning solutions for seismic processing.

Li co-invented ConocoPhillips' proprietary technology: Compressive Seismic Imaging (CSI). The technology received the SPIRIT of Performance Award in Innovation in 2016, the SPIRIT of Performance Award in Technology Champion in 2018, and the OTC Asia Spotlight on New Technology Award in 2018. His paper on CSI was selected to receive the award for Best Paper in The Leading Edge in 2017. He also received the SPIRIT of Performance Award in Outstanding Early Career Technologist in 2019.

Aly Said — CGG

De-blending of continuous recording data towards a quantum leap in seismic imaging in the Western Desert of Egypt

Aly Said is Geophysical Advisor at CGG specialized in seismic processing and imaging industry, where he integrates with R&D and processing members to conduct technical studies and tests in order to validate new technologies and methodologies definition which could be implemented. His experience comes from different areas from Europe and Middle East regions, with a long record of successfully major imaging projects.

Recently he was part of the team of the integrated solution for Unconstrained Blended Acquisition & Processing ensures that the full value of high-density seismic investment is realized.

Dennis Yanchak — Apache

The Challenges of Unconstrained, Broadband Land Acquisition: A Case History from the Western Desert of Egypt

Dennis Yanchak is currently a Senior Geoscience Advisor for Apache Corporation based in Houston, TX. He has over 40 years of industry experience and is a member of the GSH (currently serving as president), SEG, and EAGE. His educational background includes an MS in physics from Carnegie-Mellon University and an MBA in technology management. Dennis began his career in the oil business in 1977 with Gulf R&D near Pittsburgh, PA. In 1985 he joined Amoco, working in their International Technology Group in Houston. Within Amoco and BP, he worked around the world in exploration, development, and production. His experiences cover assignments in Denver, Houston, Cairo and Moscow, Russia. □

Memorial Tribute

A Tribute to Dave Agarwal

By Tommie Rape and Les Denham

The geophysics profession and the Geophysical Society of Houston (GSH) have lost a stalwart member of our community. Davendra "Dave" Kumar Agarwal passed away on January 6 after a short illness. Dave was born in Moradabad, India in 1936. He graduated as the top student in the first graduating class of the Geology and Geophysics Department from the Indian Institutes of Technology Karaghpur (IIT KGP) in 1956; his degree was presented to him by Prime Minister Nehru, the first Prime Minister of independent India. He subsequently obtained a Master of Science degree in Geophysics from Imperial College in London; there his degree was presented to him by the Queen Mother. While at Imperial College, Dave met the love of his life, an Iranian student, Roshanak Zarrabi. After graduation from Imperial College, he went to work for Geophysical Service Inc. (GSI) in 1959. After some internal training, he volunteered for a field assignment in Iran. While in Iran, Dave met Roshan's family, and he and Roshan were married in 1961. Dave worked for GSI for about 14 years in Iran, Saudia Arabia, Lebanon, and England. Dave split time between working in the office and in the field doing both refraction seismic and reflection seismic work. In 1973, Dave went to work for Cities Service Oil Company. In 1978, Cities Service transferred Dave and his family to Houston where he became the manager of the Technology Service Group. Dave continued work with Cities Service until they were bought out in 1983. After working as a consultant for over a year, Dave took a position as Chief Geophysicist for Newmont Oil Company in 1985. Dave was one of the key figures in establishing computerized 3D seismic interpretation at Newmont.

When Newmont Oil was sold in 1988, Dave joined with his friend and geophysical cohort, Les Denham, to form their own company, Interactive Interpretation & Training, Inc. (II&T). Their company occupied several different locations in Houston for 24 years. Their company conducted seismic interpretation on projects all around the world for many different companies. They planned and supervised surveys around the world. The company was also very active in training many geophysicists in the art of computerized seismic interpretation. Les related that Dave was not bashful and was the one that spread himself around the industry and brought in most of the company's business. Dave seemed to know everyone at industry meetings and everyone seemed to know him. Dave retired in 2012 after nearly 54 years in the industry.

During and after his professional working career, Dave also was an important asset to the Geophysical Society of Houston (GSH). He worked with several committees and technical events; in 1995, he initiated the GSH Technical Breakfasts that are still very popular today. In 1996, he was elected First Vice President. Dave was President of the GSH 2001-2002. But his important contributions to the GSH continued even after his term as President. For a number of years Dave was the chair of the Office and Staff Committee. Utilizing his experience of running his own office and company, Dave filled a critical role in this position of the GSH as he oversaw many key administrative functions and requirements. For instance, Dave was key in securing office space for the GSH when it ceased sharing office space with the Houston Geological Society. In this endeavor he also brought in his wife, Roshan, who, with her real estate experience, helped the GSH select a location and then arrange leasing contracts. Dave and Roshan continued to help in these efforts even through the recent lease renewal. Dave was also key in hiring our current office staff and maintaining insurance, contracts,

Memorial Tribute continued on page 41.

Memorial Tribute continued from page 40.

and licensing requirements for the GSH. In recognition of his many efforts for the GSH, he was awarded a Life Membership status. Dave was also an active member of the SEG, the AAPG, and the North American Chapter of the Society of Petroleum Geophysicists, India (SPG-NA).

Dave is survived by his wife Roshan Agarwal, his children Rita Agarwal, MD (Jon Burch, MD) in Palo Alto, Cal.; Ravin Agarwal, MBA (Dina) in Chicago, Ill.; and Bijan Agarwal, MBA, PHD, (Negin Samizadeh) in Jakarta, Indonesia. Dave is also survived by seven grandchildren, several nieces and nephews, and many other friends and relatives. Dave worked and traveled in many, many countries of the world, gaining experiences that enlightened his personal and business acumen and that could be shared with family and friends. Dave was a brilliant, kind, thoughtful, considerate man who cared for others and went out of his way to help those around him. He will be missed by many. □

The Mystery Item
on page 25
is an
early blaster cut-a-way
made by Electro Tech Labs.

19th Annual GSH/HGS Saltwater Tournament

TopWater Grill Marina
Friday, October 11, 2019
815 Avenue O, San Leon, TX

Bring your family and friends to help GSH fund growth, further education, student memberships and STEM educational outreach!

Cash Fish Pots And Captains Meeting!

Cash/Trophies will be awarded for the heaviest Redfish (Non-Tagged), Speckled Trout, Flounder, Redfish Spot Pot and Stringer*
**(max of 1 Redfish, 3 Speckled Trout, and 1 Flounder)*

EARLY REGISTRATION OPTIONS

(prior to Sept. 27th)

Individual $75
Individual on Guided Boat/*full day* $350
Non-fisher $25

Registration also covers:
Launch Fee, Meal, Refreshments, Trophies, and
DOOR PRIZES!

REGISTRATION OPTIONS OFFER LIMITED SPACES ON PROFESSIONALLY GUIDED BOATS

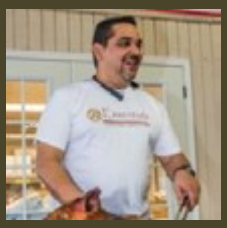
PLEASE REGISTER AND VIEW ALL RULES ONLINE AT:
http://www.gshtx.org
Upon Registration, each participant will be provided by e-mail with a copy of the specific tournament itinerary, rules and disclaimer.

For more information, please contact:

Nathan Lenz E: Nathaniel.lenz@tgs.com
C: 281-468-5459
Bobby Perez E: rdphtx@aol.com
C: 281-787-2106

33rd Annual Sporting Clays

A BIG THANKS to everyone who came out to the Geophysical Society of Houston's Sporting Clays Tournament last month. The weather cooperated and rain was able to hold off until we all got back to the pavilion. Thanks to everyone that participated, we were able to raise over $32,000 for the GSH!! Another big thanks to our Course sponsors, Magseis FairField & Dawson Geophysical. As well as Rill Energy for sponsoring breakfast & lunch this year. Speaking of breakfast & lunch, Chef Martinez and his amazing staff at Essential's Catering Services did another fantastic job. Also thanks goes to Jonas Harrell for donating the sausage for lunch, everything was absolutely great. Without the support of all other sponsors, we wouldn't be able to hand out a number of nice door prizes to the shooters. Other sponsors include: Seitel, Buckley Powder, FairField, Team FOTB, PSI, Weir Consulting, Anadarko, CGG, SAE, EPI & Mitcham. Not to forget the man of the hour, Merrick Manister for always coming thru with the cold beer! I look forward to another successful shoot next year & hope you all can make it.



By Ryan Marshall, GSH Sporting Clays Chair

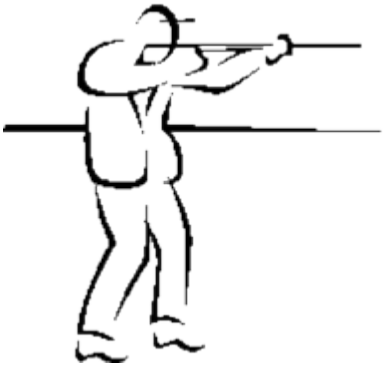
Sporting Clays continued on page 44.

Sporting Clays continued from page 43.

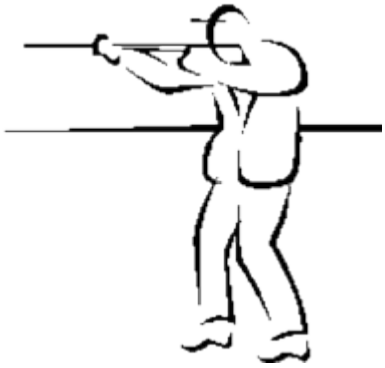
33rd Annual Sporting Clays

Winners are as follows:
HOA – Greg Nassar
HOA Lady – Morgan Gilmore-Hawkey
Class AA – John Foley
Class A – Major Smith
Class B – Mike Naughton
Class C – Kyler Clark
Winner of the Pointer Wingshooter Argentina hunt – Steve Zehner.

By Ryan Marshall, GSH Sporting Clays Chair



HGS
SKEET SHOOT



Saturday, June 8, 2019

Greater Houston Gun Club
6702 McHard Road, Missouri City

- **This tournament is a 50 target event.**
- **Shells are provided, however you must bring eye and ear protection.** *Greater Houston Gun Club and National Skeet Shooting Association safety rules will be in effect.*
- **Trophy winning shooters will be determined by the Lewis class system.**
- **Door prizes will be awarded by blind drawing after the conclusion of shooting.**
- **All competitors are automatically entered into the door prize drawing, but you must be present at the time of the drawing to win.**

BBQ lunch will be provided from 11:30 until 1:30.
Refreshments will be available throughout the day.
Non-shooting guests are welcome to enjoy lunch and refreshments at a cost of $20 per guest.

*HGS recognizes that 2019 is a lean year in the oil patch, and sponsorship for events like this is hard to find. For **$150, you'll receive paid entry for one shooter and one guest** (total value of $120) and be listed as a **platinum sponsor** on the webpage and at the event.*

We are limited to 160 shooters in four rotations. Entry fee is $90 per shooter for registrations received by **FRIDAY, JUNE 1st.** After June 1, registration will be strictly on a "space available" basis and the entry fee will be **$120 per shooter.** *Register early!!*

****

For more information, contact: Andrea Peoples at (713) 463-9476 or office@hgs.org

For directions to the club, visit www.greaterhoustongunclub.com

ONLINE REGISTRATION INFORMATION AT: https://www.hgs.org/civicrm/event/info?id=2078

****

ALL SHOOTERS WILL BE REQUIRED TO SIGN A DISCLAIMER OF RESPONSIBILTY BEFORE THEY WILL BE ALLOWED TO SHOOT!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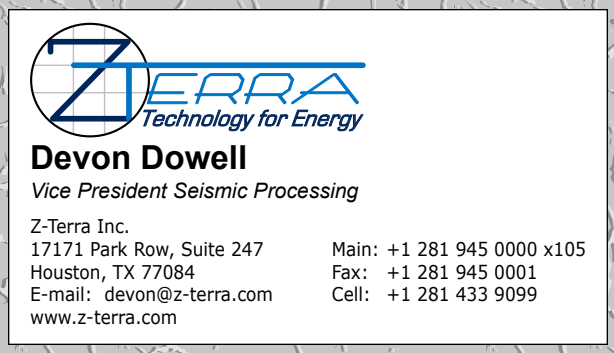
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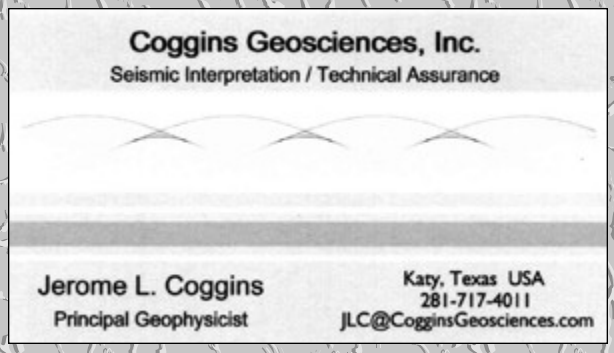
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U of H Wavelets

SEG Wavelets Hosts Special Guest Lecturers *By Matthew Sexton*

Dr. Felix J. Herrmann presenting to faculty and students.

On February 22nd, the SEG Wavelets hosted Dr. Felix J. Herrmann as SEG's 2019 1Q/2Q Distinguished Guest Lecturer. Dr. Herrmann presented "Sometimes it pays to be cheap – Compressive time-lapse seismic data acquisition" where he spoke about the benefits of using compressive sensing methods to acquire seismic data as well as using convex optimization to remove subsampling artifacts. Dr. Herrmann's talk included many examples of how we can reconstruct sparse signals from random subsampling and do so with fewer samples than prescribed by the Shannon-Nyquist theorem. Dr. Herrmann also mentioned how the recent developments in data science and machine learning can be applied in this process because there are hidden redundancies in the seismic data.

On March 6th, the SEG Wavelets hosted Dr. Klaas Koster from Occidental Petroleum Corporation. Dr. Koster presented "Opportunities for a geophysicist to make an impact in an EP Company" where he spoke about the work students might experience in the areas of seismic acquisition, processing, and quantitative interpretation. Dr. Koster explained the quality and cost factors associated with seismic acquisition/processing, and even expanded upon Dr. Herrmann's talk on compressive sensing, adding that it can be as good as data acquired on a dense grid and cheaper. Dr. Koster also provided examples of how attribute analysis is a routine task for geophysicists to perform to visualize faults and stratigraphic features and make determinations on rock/fluid properties. □

Dr. Klaas Koster presenting to faculty and students.

Geoscience Center

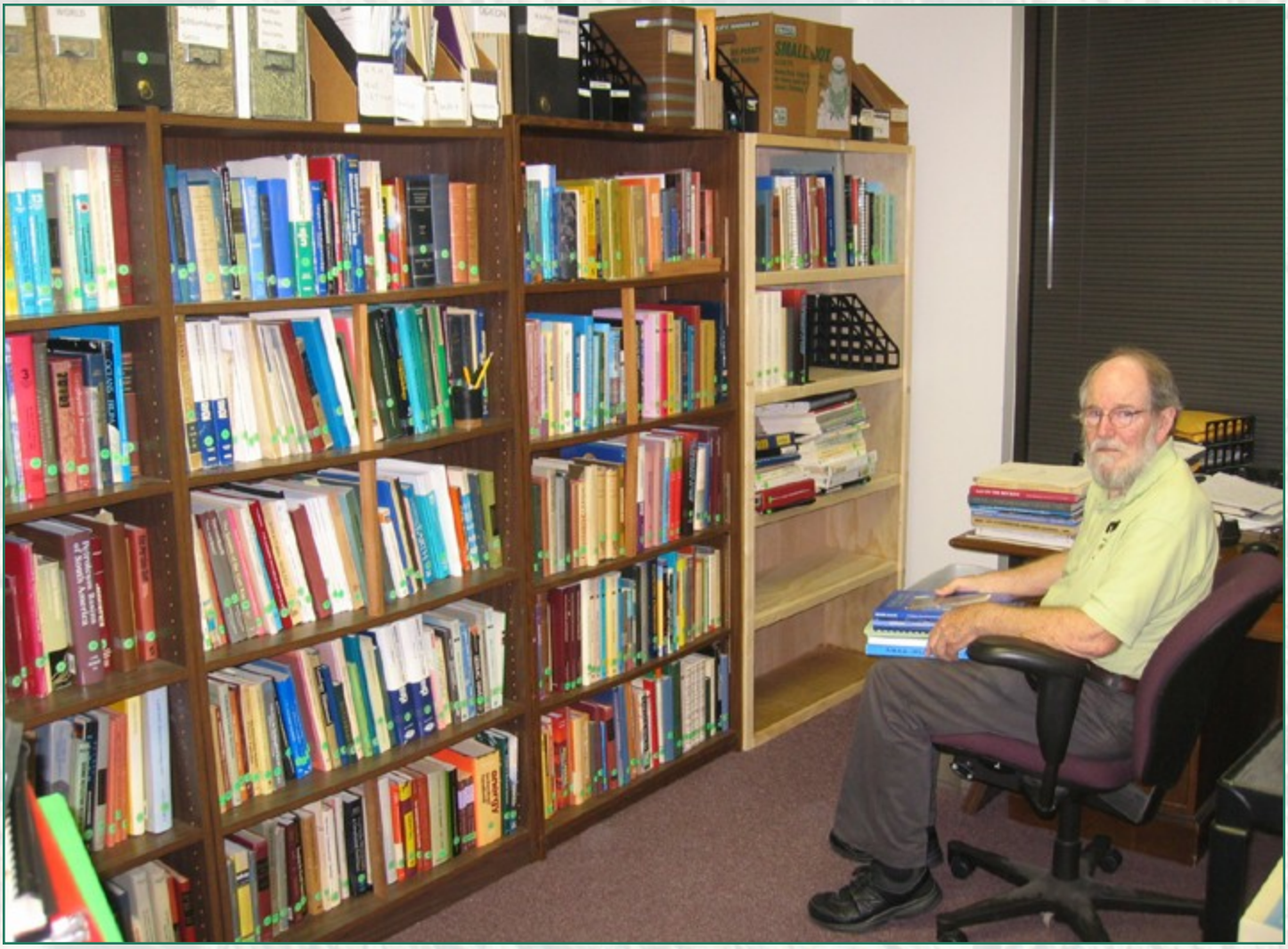
The History of Geophysics *By Bill Gafford*

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

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

These free quarterly events require no registration. They provide an opportunity to visit with some of the Legends of our industry and view some of the Mystery Items that have been featured in the GSH Journal, as well as other geoscience artifacts from our Museum collection. There will be light snacks, coffee, water, and soft drinks. Some duplicate books from our library will be available for free also. Everyone is invited.

Last year we provided some 1950's era paper seismic records to MIT for a project on geophysical history. An article was recently published in a newsletter of the Department of Earth, Atmospheric, and Planetary Sciences at MIT, and included one of the paper records we provided. The title of the article is "The Birth of Digital Seismology," and it explains how the Geophysical Analysis Group (GAG), at MIT performed the first digital seismic processing in the 1950's. Here is a link to the article: https://erlweb.mit.edu/announcements/birth-digital-seismology-mit.



Les Denham working on the library inventory

Geoscience Center continued on page 49.

Geoscience Center continued from page 48.

We are continuing to update the inventory of our Museum Collection and Ed Lengel and Karl Schleicher are working with Andrew Geary at the SEG to add portions of our inventory and pictures to the SEG Wiki. We do not have much information on some of the items in our inventory and we are hoping that once the information is available on the Wiki, people will add comments and fill in some of the information gaps in the inventory. Ed, Karl, and Les Denham are shown in the picture below discussing the SEG Wiki.

A few months ago we received about seven boxes of files from Tury Tanner's family. The files were neatly organized and included many folders of research materials from technical talks and articles that Tury had written over his career. Gene Womack and Don Adams are shown discussing some of the files. We also continue to receive donations of books, publications, and periodicals for our Bob Sheriff library. Les Denham is shown working on the library inventory.

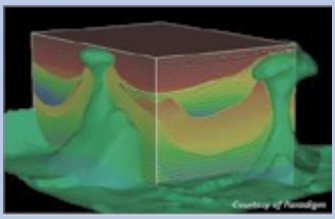
We still need volunteers to help with a variety of projects at the Geoscience Center. Visitors are always welcome on Wednesday mornings from 9:00 until noon or by appointment. Please contact me at geogaf@hal-pc.org or at 281-370-3264 for more information. □

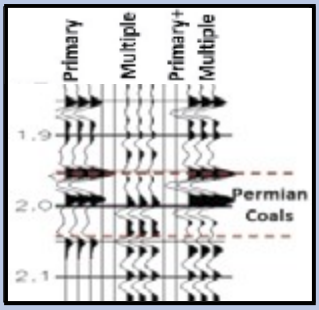
Gene Womack and Don Adams review the Tury Tanner files

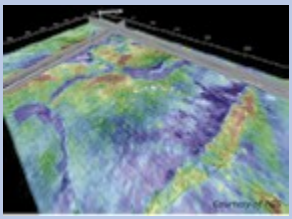
Les Denham, Karl Schleicher, and Ed Lengel discuss the SEG Wiki

The GSH - SEG Webinar Series is Online

Access the recordings of these webinars originally presented live from the convenience of your home or office and according to your own schedule.







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• Seismic Modeling, Migration, and Inversion	Bee Bednar
• Beyond AVO to Quantitative Inversion Interpretation QII	Bill Goodway
• Affordable S-Wave Reflection Seismology	Bob Hardage
• Simplifying and Lowering the Cost of S-Wave Reflection Seismology	Bob Hardage
• Carbonate Essentials	Chris Liner
• Basic Seismic Interpretation	Don Herron & Bob Wegner
• 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
• Applied Azimuthal Anisotropy-Azimuthal 3D P-P Seismic: Why Bother?	Dr. Heloise Lynn
• Understanding Seismic Anisotropy in Exploration and Exploitation	Leon Thomsen
• An Introduction to Borehole Acoustics	Matthew Blyth
• Topics in Land Seismic Data Acquisition, Processing, and Inversion	Oz Yilmaz
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Doodlebugger Diary

Peru – Land of the Inca Gods

Part 5: Completion of Processing in Lima *By Scott Singleton*

This month's Doodlebugger Diary is a continuation of the series Scott Singleton started in February 2017 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.

My contract with PetroTech had been designed to last over the summer but no further. So as the summer started drawing to a close the processing crew and I began wrapping up my effort there. We had already been processing with an approved workflow for over a month so in reality all this entailed is me wrapping up the portion of the survey I was working on and handing that over to the PetroTech processors. Of course there were the requisite meetings with management but we had been having those all summer long anyway so this was really an anticlimactic event.

Of course, during this time the boat had continued acquiring more 2D lines and the guy in PetroTech's office who was in charge of coordinating with them was a Brit that I knew from previous offshore surveys. And I recall that I also knew the VP of exploration, who was an American that I also knew from previous surveys. So, yes, you would be correct in the general impression this was like a mini expat community down in Lima. We had a great time. That is, until during one of the calls with the Energy Innovations office in Houston (my previous employer), the surveying coordinator let it slip that I was down there in the Lima PetroTech office. I kept drawing my finger across my throat, indicating he should not be saying that, but did he get that message? Of course not, and as quick as you could say 'doomed' I was in really hot water with my previous employer. Living life on a knife's edge, as it were. Anyway, with each subsequent call to both the EI Houston office and to the boat, everybody soon knew I was there and rumors started flying about how much trouble I was in.

There is a term that started on sailing ships in the olden times called 'scuttlebutt' and this is where it came from. The guys on the boat, all of whom I knew from working on the survey during the spring, all began starting rumors about me and with each round the rumors got worse (and more ridiculous). Of course these rumors were dutifully passed to the onshore coordinator in Lima, who would not waste 2 seconds before he sauntered down to the processing offices to tell all of us about them. So, yes, for at least a month at the end of summer I was the butt of jokes with predictions of doom and gloom should I ever set foot in the US again. To hear the boat guys tell it, the Secret Service would be waiting to take me off to prison in shackles. Real funny…

But while the guys on the boat were having their laughs, I had more serious things to think about. The rumors about my wife being pregnant circulated around the PetroTech office equally as quickly as scuttlebutt on the boat. I could hardly pass through the reception or to the processing floor without the women all telling me that I had better not leave Lima without bringing my wife down and introducing her to everyone. The managers also got into the act, working with me on the timing

Doodlebugger continued on page 54.

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

Doodlebugger continued from page 53.

Figure 1: A very pregnant Eileen Singleton standing in front of one of the most popular photo ops in Sacsayhuaman, an ancient Inca citadel, or fortified city core, on the outskirts of Cusco, circa summer 1998.

Figure 2: Eileen standing in almost the same spot in Sacsayhuaman as in her 1998 photo (Figure 1), circa 2016.

of completion of my processing efforts while allowing enough time for her to come down and for us to see Peru. So I dutifully did as requested – I arranged with my wife to spend an extended period in Peru before both of us would fly back to Houston. Her doctors gave her clearance; she was in her second trimester and was not having any problems. But she was definitely showing quite a bit.

Lima by Limo: The managers at PetroTech insisted I take their company car and driver to pick up my wife from the airport, which I did. The next day I brought her into the office and had to leave her because she got mobbed by all the women. I went up to the exploration floor where the exploration VP insisted that we continue using the car and driver for as long as we were in Lima. So we spent a couple of days touring around the city. Of course there were the main museums for which Lima is known, including the Gold Museum, or Museo del Oro and Armas del Mundo, and the main cultural museum, Museo Larco. One key site was the main central square, Plaza Mayor, which has the Presidential Palace on one side. In fact, we were sitting outside a little café on one of the spurs leading away from the plaza, me tasting their exquisite ceviche and my wife having a Lomo Saltado (she didn't want to eat ceviche while pregnant), when amazingly enough a group formed to protest in front of the Presidential Palace. The police kept a respectful distance, making sure no one entered the palace grounds, and by the time we left they were still out there yelling and making a commotion.

Doodlebugger continued on page 55.

Doodlebugger continued from page 54.

Figure 3: Eileen and Scott sitting on the lawn of the Central Plaza area of the Machu Picchu ruins, circa 1998. Note that when we visited in 2016 all lawn areas were off-limits to human pedestrian traffic. Only llamas allowed.

Since I always shop in every foreign place I visit, there were two types of stores I had targeted to go while in Lima. One was a rock shop. The Andes, and Peru in particular, are known for certain types of minerals, specifically pyrite with and without associated quartz crystals, which tend to be long and needle-like. I did find a huge 20 lb pyrite specimen, which I did buy and my wife made me carry it back to Houston in my backpack. It is on display at my house to this day. The second type of shop was for llama pelts and rugs. This is a well-known export of Peru and these furs are thick and soft. They are also expensive. I can remember choosing one and getting our driver to negotiate with the store owner. This took a really long time because I wanted a good price and the store owner and I couldn't come to terms. The conversation between him and the driver was rather animated with lots of yelling going on. Basically the store

Figure 4: Scott with the obligatory photo op standing with his llama buddy, circa 1998.

Doodlebugger continued on page 56.

Doodlebugger continued from page 55.

Figure 5: Eileen and Scott on the upper reaches of the Machu Picchu ruins overlooking the city core, circa 1998. This is probably the most famous photo op location in the ancient city.

Figure 6: The Singleton family at about the same location overlooking the Machu Picchu ruins as in Figure 5 (circa 2016).

owner was telling the driver that he should be taking his side, not mine. I'm sure I put him in a tough spot. But I ended up getting my Llama rug, which I still have to this day.

Cusco, Machu Picchu: A trip to Peru is not complete without a stop at the famous Machu Picchu and its traditional jump-off point of the ancient Inca capital of Cusco. So we flew to Cusco and stayed there for several days to acclimate to its 11,000' elevation. It's a beautiful place and very laid back, mostly due to the volume of visitors it gets. The main plaza, Plaza de Armas de Cusco, is quite obviously the center of town and is beautiful. The Iglesia de la Compania de Jesus church anchors one end of the plaza and is a favored hangout of native women dressed in Inca garb with their baby llamas for photo ops, of course for a fee. Outside of town are a series of Inca fortress ruins, the most well-known of which is Sacsayhuaman which is an essential stop on anyone's itinerary *(Figures 1 and 2)*.

Travelling up the Urubamba Valley, or the Sacred Valley of the Incas, one first passes Pisac with its huge and very popular outdoor market, and then Ollantaytambo which was a ceremonial center for the Inca and thus has a huge terraced temple on the side of the river valley. Then following the Urubamba River, one travels up steep gorges to Aguas Calientes which lies at the base of the switchbacks leading up the side of the mountain to Machu Picchu. We decided to spend the night in Aguas Calientes which at the time was a sleepy little place with a railroad running through town on the river.

Travelling up switchbacks to get to Machu Picchu is amazing in itself, but being on top of a mountain in an Inca ruin is phenomenal. Truly awe-inspiring *(Figures 3 and 4)*. Just make sure you're in good shape and ready to walk. The walking tours throughout the complex can take a few hours and there are two peaks that you can also walk up (the haystack-shaped Huayna Picchu and Machu Picchu Mountain). In the upper reaches of the main complex of buildings, as you exit Inti Pinku (the Sun Gate) along the Inca Trail towards Machu Picchu Mountain, lies an overlook to the entire ruins. It's the famous picture that defines this archeological site *(Figures 5 and 6)*.

Epilog: In the summer of 2016 my daughter got a job working in the Santuario Animal de Cochahuasi, which is a wildlife animal sanctuary about half way between Cusco and Pisac. We were very proud of her for doing that and decided that when she finished her time there we would retrace the steps of our trip 18 years previous. *Figures 2 and 6* are from that trip. We visited the market in Pisac and spent 2 nights

Doodlebugger continued on page 57.

Doodlebugger continued from page 56.

there taking in the culture. We spent a night in Ollantaytambo and were in the upper terraces on the side of the mountain for Inti Raymi, the annual Sun God Festival.

Then we went to Aguas Calientes and realized that some things had changed. The sleepy town we stayed in 18 years previous was no longer there. In its place was a fully commercialized jump-off point for Machu Picchu, complete with ritzy hotels everywhere you looked and tourist shops and restaurants packed all the way up and down the side of the mountain. The railroad tracks were no longer running through town but on the side of the town near the river. The Mercado Artesanal (artisans market) was so huge that you could get lost in the labyrinth of shops, which was precisely where the rail station dropped everyone off.

We also found that in the intervening 18 years tourism to the Machu Picchu ruins had increased so much that in 2011 the Direccion Regional de Cultura Cusco established entrance restrictions of 2500 visitors per day in two time slots (morning and noon) to the main ruins and limited passes to climb Huayna Picchu to 400 per day and Machu Picchu Mountain to 800 per day, both in two morning time slots. In addition most of the green spaces, such as the expansive Central Plaza in the center of the ruins, were off-limits to anyone but llamas. So my wife and I agreed that our second visit was nowhere near as cool as our first visit but nonetheless did bring my family full circle to where we began.

So with that I'll sign off with *Figure 7*. Happy trails to all those following the exploits of Doodlebugger Diaries. We'll be back in the fall with more hair-raising adventures! □

Figure 7: The Singleton family on top of Machu Picchu Mountain, circa 2016. The elevation posted on the sign is 3061.28 m or 10,043 ft.

SAVE THE DATE

GSH ICEBREAKER

The Geophysical Society of Houston (GSH) 2019 icebreaker will kick off at **Saint Arnold Brewing Company on September 5, 2019 from 6:00PM - 8:00PM.** Mingle with industry colleagues and meet the GSH board while enjoying the finest local craft beers at this award-winning brewery. Tickets are available through the GSH website events tab. For more information or sponsorship opportunities, please contact the GSH office at 281.741.1624 or Tony LaPierre at tony.lapierre@rpsgroup.com.

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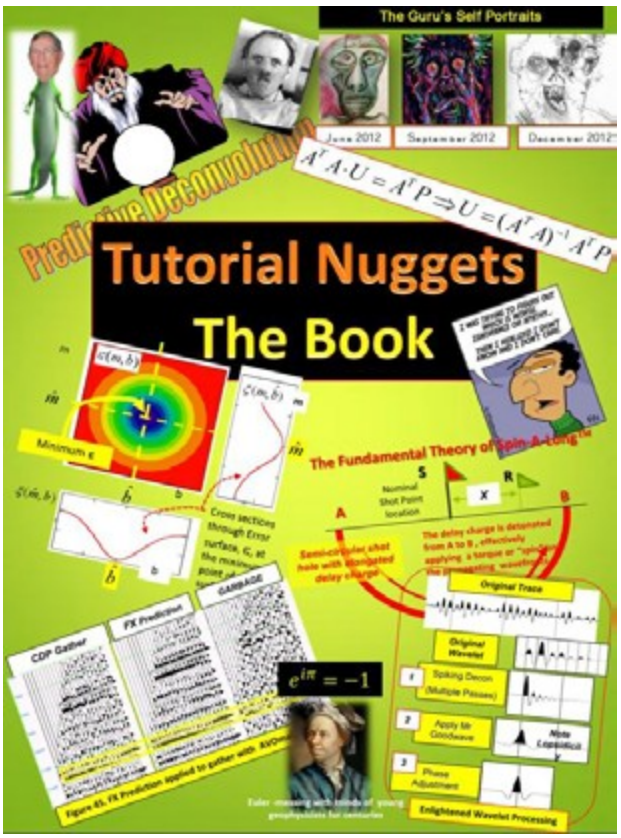

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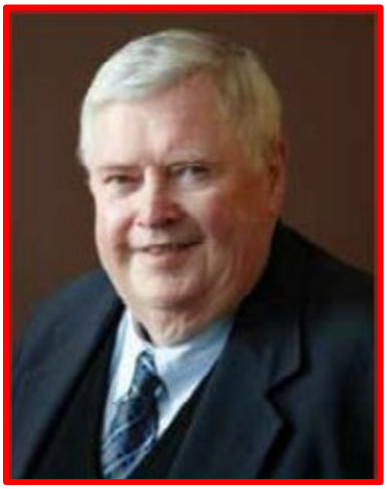

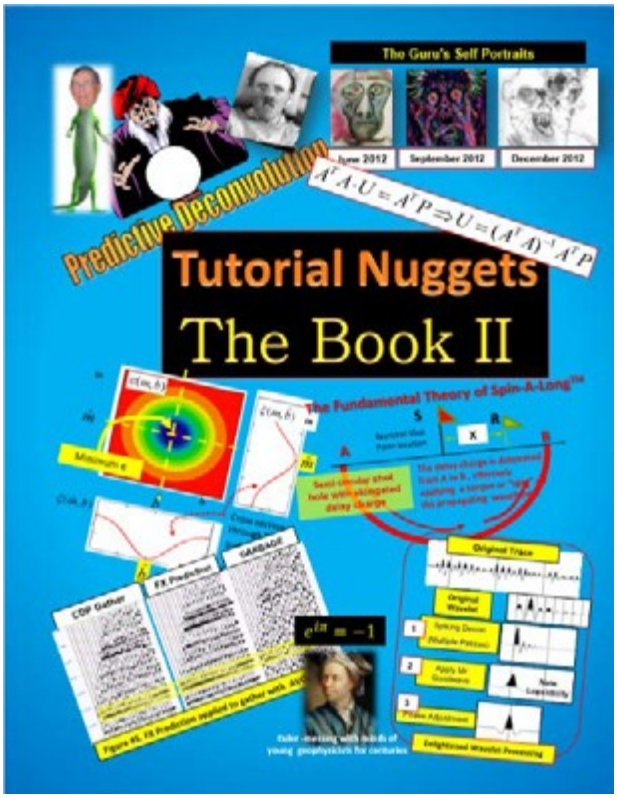

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