January 2020

The Epicenter of Geophysical Excellence

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 10 • Number 5

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On The Cover...

Land Seismic Data Acquisition in Alaska.

Image courtesy of Global Geophysical.

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 Alvaro Chaveste, editor, at AlvaroChaveste@hotmail.com

GSH JOURNAL DEADLINES

Mar 2020	**Jan 10**
Apr 2020	**Feb 7**
May 2020	**Mar 13**

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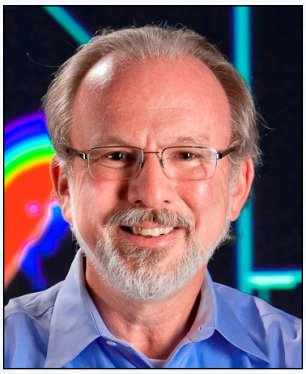
A Word from the Board

By Peter M. Duncan, 2019 – 2020 President-Elect



I am the "new kid on the block" of this Board. They call me "President-in-Training". It is often said that turnabout is fair play, so I guess President Beasley is having his day. He served as President-Elect on my SEG Board back in 2003 and now our roles are reversed. I am trying to remember if I treated him well … I am sure I did … I sure hope I did.

This is my first time sitting on the GSH Board. I was Continuing Ed Chair way back in ~1987 but did not attend Board meetings. In association with running the Challenge Bowl at the Spring Symposium, I have had the chance to see how that committee works and that has given me a flavor of the GSH style (pretty laid back, mostly very collegial). So, for the present, I view my role as an opportunity to listen and soak up as much as I can about the real issues facing the Board and the Society, so that I can be prepared to tackle them come next July when it is my turn to hold the gavel.

So far, what has become clear is that the BIG issue facing us is membership and, therefore, sustainable finances. Our membership at the time of writing sits at 1548 down from a high of 2277 in 2016 (and perhaps as high as 2500 back in the last century when General Hardy was leading the charge). We have a pretty good rainy-day fund but dipping into it needs to be the exception, not the rule.

I can think of 2 reasons that our membership might be down – the state of our industry and the value proposition (real or imagined) of membership in the GSH. Let's tackle these in order.

Unless you are just now arriving back in Houston from an extended sojourn off the grid, you well know that our industry in general and our profession are in a bit of a commercial ditch. Bankruptcies are up, stock prices are down, and layoffs are all too common. Oil prices are not terrible but appear to have reached a ceiling that will hold as production continues to rise while demand growth slows. Investors have come to believe that hydrocarbons are practically unlimited. How can we blame them? Every time reserves start to decline, we up our game and find more. Investors have decided that they will value oil ventures not on how well they do at replacing reserves but rather on how cheaply they can produce the next barrel. Oil companies, like most organisms, tend to do what they are incentivized to do. Consequently, the focus of most operators these days is not "find more" but rather "spend less". If the return on your wells is good enough, why spend a penny more? Not a happy circumstance for our community.

I believe this is not the end of the story. Rocks are heterogenous. Formations are discontinuous. Production will decline and the productivity of new wells will fall as development moves away from the "sweet spots". There will come a time when technology will be back in favor as operators are driven to protect their return on investment from shrinking. Take, for example this quote from a recent Deloitte study analyzing the disappointing results in the latest round of unconventional wells:

"To succeed, shale companies can utilize more sophisticated data analytics and balance experimentation and standardization. Technology is king, and knowing the reservoir is critical. Therefore, E&Ps should consider investing in advanced technologies such as microseismic monitoring, fluid tracking and tracer analytics, among others, to understand how and why the reservoir is behaving in a certain fashion and then augment the development approach".

Unfortunately, uptake of this fantastic advice is not likely to occur early 2020, or perhaps even in 2021, short of some unfortunate geopolitical upheaval. What does that mean for GSH and its members? If I can draw on my little enterprise by way of an analogy, in response to this market we are working hard to find different technologies (like machine learning for example) to reduce our costs. That is, to deliver our product faster, better and cheaper in recognition of the financial forces that

Word From the Board continued on page 5.

Dear GSH Journal readers,

Please feel free to contact us with any and all questions or suggestions that you may have. Contact me at the email address listed below. Additional Organization Contacts can be found on page 3.

Sincerely,

Alvaro Chaveste, Editor, at AlvaroChaveste@hotmail.com

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are driving our customers and in hopes of lasting until the turnaround comes. I promise you, your GSH board is actively doing the same.

If costs are in the denominator, it's certainly more fun to think about the numerator – that is how to improve the value proposition, so we generate more membership and more "sales". Keeping current members happy is important (think the new Fall Forum or the evolving SIG programs). It is equally important to find out what keeps other geophysicists in town from joining and becoming active in GSH. To that end we held a lunchtime meeting at MSI a couple of months ago and asked my staff that very question. Of the 20 or so folks in attendance, I believe only 3 were GSH members. The annual membership fee was not the issue since MSI covers that. We asked what programs would garner their interest and participation. It was very interesting to hear that most of what was brought up (day long courses and online courses for example) were things the GSH already offers. It became apparent that we are NOT doing a very good job of communicating our programs to that part of our professional community that is not already engaged with us. We must fix that.

On the social side, the group said they appreciated the opportunity to meet with some of the legends of the community at our usual social functions, but they would like to see and interact with more of their peers at social events. Coincidentally, and certainly in a very timely move, the GSH has authorized an early career program to be called the GSH NextGen. Their first gathering is to be at Bar Boheme on January 30th. A very passionate organizing committee has assembled themselves to drive this initiative. I look forward to great things coming from them and an influx of new energy into the GSH.

On that positive note, I will close this blog and make a request. I would expect that many of you out there (assuming someone does read this) will have ideas on how GSH can weather this storm and drive toward a brilliant (not just sustainable) future. I daresay that my readers here are already members, so you have recognized that the organization is important to you. How can we make it important to the rest of our community? Please let me know.... pduncan@microseismic.com □

From the Other Side

By Lee Lawyer

About 90 people attended the GSH Fall Forum on November 1st. You missed another great meeting, if you didn't attend. It was a non-technical meeting but there was substance worthy of attendance. I like the nomenclature we use regarding Shale objectives, Unconventional Reservoirs, horizontal drilling, fracking, etc… As far as geophysicists are concerned, we are in a production mode, not exploration. The 'pay' horizons are well known. A lot of vertical holes through them have been drilled and logged. The logs show that those formations are 'tight'. With horizontal drilling, instead of a hundred feet of 'tight reservoir', we have +/-5000 feet of reservoir. But low permeability comes into to play and fracking by sections is needed to make unconventional reservoirs productive. We have known all this starting back when the Fort Worth basin was being developed.

Rob Stewart was the keynote speaker (1st speaker). He emphasized the effect of the price of oil on the GSH/SEG. I (almost) quote from Rob: "There is a rough correlation of a barrel of oil to OTC attendance, SEG Annual meeting attendance and Undergrad UH geology majors. OTC attendance = WTI (West Texas Intermediate crude) x 1000; SEG Annual Meeting attendance = WTI x 100; undergrad UH geology majors = WTI. I looked at our annual meeting attendance to budget and reserve rooms, etc. Based on the correlations, I guessed in late Spring 2019, that our San Antonio SEG attendance would be around 5200 – this wasn't a very popular forecast. Final count for Annual Meeting was 5126." Rob published these statistical measures on the President's Page in TLE 2018. Several years ago, in FTOS, I compared reading the President page to watching paint dry, but I take it back (thanks Rob).

Back to the Fall Forum (FF). We can test the algorithm used above FF=WTI x 1.607. FF attendance would calculate out to 90 people registered. That is very accurate. 'Ya gotta' love statistics. The second speaker was Ms. Scorer with ConocoPhillips. She looked at what the future may hold for geoscience. Dr. Ge Jin from CSM said geophysics may find it difficult to create value in this production mode. Dr. Goodman with BEG TORA (Bureau of Economic Geology, Tight Oil Resource Assessment), studied tight reservoirs to produce unbiased, comprehensive-yet-granular results for environmental considerations and production forecasts. A very interesting talk on Market Fundamentals was made by Ms. Johnson. Especially interesting since I have never heard a Market Fundamental discussion before. There were three more speakers for a panel discussion. The panel discussions are always highly informative and interesting. This is not meant to be a report on the Forum, but next Fall, we may have the 2nd Annual Fall Forum, TBA (to be decided). Don't miss it. Put it on your 2020 calendar.

Not all of you know the GSH has started another challenge fund to support the GeoScience Center. A total of $10,500 have been pledged by four donors, conditional on being matched by others. Several years ago, I was asked to solicit funds for an Oklahoma University reception during an AAPG convention here in town. To make a long story shorter, I asked each OU alumnae to donate $20. No more than that. The idea was to get many alumnae to donate a small amount instead of a few giving larger gifts. Many alumnae donated the twenty dollars and we easily covered the cost of the reception. Let's do something similar with this challenge fund. Let's all donate a relatively small amount (It's alright if someone wishes to make a larger gift). If 105 of us donate $100 we have met the challenge. With 210 donations of $50 we have met the challenge, and so forth. Since the $20 donation for the OU reception was over 30 years ago, it is reasonable to suggest we can probably afford a few dollars more. All moneys are graciously welcomed. One way to donate is to push a button on the GSH Web page calling for donations to the GeoScience Center. Choose it and It's done (with credit card). That will be a tax-free contribution since we are a 501.c3 organization. The GeoScience Center costs about $25,000/year. Except for donations, there is no revenue associated with the Center. Most of the cost is rent and utilities. There is an excellent cadre of volunteers to manage the artifacts and the library. The GeoScience Center is not a museum. Its purpose is "Preservation and Education". It is not open every day. Usually Wednesday is a workday at the Center. If you wish to visit, contact Bill Gafford at 281/370-3264 or email at Geogaf@hal-pc.org. It is easily arranged. □

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- Henry Ford

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Technical Luncheons

Joint Time-variant Spectral Analysis: Time-frequency and Time-phase

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch North

Ramses Meza

Speaker: Rames Meza,
Principal Geophysicist, BHP Petroleum

Westside

Tuesday, Jan 21, 2020
11:00 a.m. – 1:00 p.m.

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

Downtown

Wednesday, Jan. 22, 2020
11:00 a.m. – 1:00 p.m.

Location: Petroleum Club of Houston
1201 Louisiana, 35th Floor
Houston, TX 77004
(valet parking onsite)

Northside

Thursday, Jan. 23, 2020
11:00 a.m. – 1:00 p.m.

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

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

Abstract:

Using time-frequency and time-phase analysis we found that, for an isolated thin bed in a binary-impedance setting, there is no observable sensitivity in preferential illumination as layered net-to-gross (NTG) changes within the isolated thin bed, regardless of the way the internal layering is distributed — either uniformly or semi-randomly. The NTG signature is observed on the amplitude (magnitude) responses, rather than any specific frequency or phase component. On the other hand, external mutual thin-bed interference can significantly change the preferred phase component for each participating target. This phenomenon is largely driven by the embedded seismic wavelet that determines the nominal seismic response of an isolated thin layer and what phase component would preferentially illuminate it. For vertical separations between mutually interfering and elastically comparable thin beds in which mutual constructive interference is achieved, the target bed will be preferentially illuminated at a phase component that is very close to that of a total seismic isolation, whereas the occurrence of mutual destructive interference will cause a significant departure on the phase preferential illumination from that of an isolated seismic thin baed. All these observations can provide an avenue to yield more robust stratigraphic interpretations of seismic data and enhance the confidence on subsurface description.

The joint time-frequency and time-phase analysis applied to a field seismic data highlights lateral changes onpreferential frequency and phase

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Technical Lunch continued from page 8.

illumination at the target across secondary faults. Mutual thin-bed interference modeling suited for the case study area was performed using a well-tying, well-based extracted wavelet assumed to be representative of the wavelet embedded on the input seismic data. The long coda of this wavelet is also present on the corresponding thin-bed waveform, indicating the possibility of more complex mutual interference patterns between thin beds and mutual interference at farther vertical separations between thin beds compared with what would occur for an embedded wavelet with a shorter coda. The observed lateral changes on preferential frequency and phase illumination on the seismic data are attributable to collocated lateral changes in the stacking patterns and variable occurrence of vertically adjacent thin beds, which are interpreted as lateral sediment deposition changes induced by the syndepositional activity of the secondary faults. This is a geologic scenario that had not been previously considered on the area until the evidence of this case study provides indirect support for it.

Biography:

Ramses Meza is a Principal Geophysicist with BHP Petroleum. He obtained his PhD in Geophysics from the University of Houston, MsC in geophysics from the Colorado School of Mines (USA) and geophysical engineering degree from the Universidad Simon Bolivar (Venezuela). Early in his career he worked as a reservoir geophysicist at PDVSA in Puerto La Cruz, Venezuela; Harvest-Vinccler in Maturin, Venezuela and ConocoPhillips in Houston, USA. His responsibilities included support in terms of quantitative seismic interpretation for hydrocarbons exploration and production activities. Since 2012, he has been with BHP as a Subject-Matter Expert providing advanced geophysical support to all E&P assets with emphasis on integration of Quantitative Interpretation (QI) products, visualization, seismic attributes, QI quality assurance, seismic reservoir characterization, DHI analysis and risking. Ramses is member of the SEG, AAPG, EAGE and SOVG. □

Technical Breakfasts

Efficient Development of Unconventional Reservoirs Using 3G Workflows –Breaking the Silos to Achieve True Integration

Register for Tech Breakfast North

Register for Tech Breakfast West

Mark Morford

Speaker: Mark Morford, MSc - FracGeo

North

Tuesday, Jan. 7, 2020
7:00 – 8:30 a.m.

Sponsored by Oxy

Location: Oxy (formerly Anadarko Bldg.)
1201 Lake Robbins Drive
The Woodlands, TX 77380

West

Wednesday, Jan. 8, 2020
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

A 3G workflow relies on the synthesis of geophysical and geological information with geomechanical techniques to solve the engineering problems encountered during hydraulic fracturing.

There are multiple available techniques and algorithms in the 3G disciplines, but some are more valuable in the 3G workflow, especially those requiring minimal input data, those which deliver reliable results quickly, and those that can be validated with multiple measurements. Most importantly, these tools and their results must be easily relatable and transferrable to the next discipline or the ultimate recipient: a completion and/or reservoir engineer. To effectively accomplish these tasks, the workflows between the 3G disciplines must be seamless and fast.

A facies-constrained extended elastic inversion is applied, and the attributes generated, including the structural and spectral attributes, are used as input drivers to a supervised artificial intelligence algorithm to populate 3d geologic and geomechanical models. These models are then used as input for a geomechanical simulator, which considers interaction between hydraulic fractures and natural fractures, that is used to estimate hydraulic fracture propagation and frac half-lengths.

A frac simulator is then run using the geomechanical results as a constraint to better define the asymmetric frac half-length and the stimulated volume.

History matching and production forecasting can be performed using the frac simulation results to understand proppant placement and permeability.

Biography:

Mark received a BSc from Texas A&M and an MSc from the University of Houston in Geophysics.

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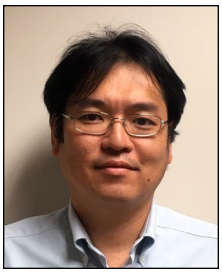
Microseismic SIG

Variation of Seismic Scalar Moment-corner Frequency Relationship During Development of a Hydraulic Fracture System

Register for Microseismic



Takashi Mizuno

Speaker: Takashi Mizuno, Schlumberger

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

Thursday, Jan. 9, 2019
11:30 a.m. - 1:00 p.m.

Sponsored by MicroSeismic, Inc.

Abstract:

We propose utilizing the corner frequency and seismic scalar moment relation as a new approach to monitor temporal changes of static stress drop as well as rupture velocity during development of a hydraulic fracture system.

We introduce a single parameter, M_1, to describe a seismic moment and corner frequency relation and analyze temporal variation of the two-parameter relation. In cases studies at Barnett Shale and Cotton Valley, we found that two types of fracturing processes exist: (1) stable rupture velocity and static stress drop during the development of rupture and (2) increase of rupture velocity and/or static stress drop while the fracture system develops. In the latter case, one possible scenario is increase of permeability at each fracture plane during development of the fracture system.

Biography:

Takashi Mizuno is a Senior Geophysicist and VSP Product Champion for Schlumberger. He is part of the Houston Formation Evaluation Technology Center located in Sugar Land, TX. His main responsibility is to develop and deploy VSP and Microseismic processing technology.

He joined Schlumberger in 2006 and pursued a career as R&D geophysicist for VSP, Microseismic, and sonic processing at Schlumberger's R&D centers in Tokyo and Houston. While in Tokyo, he was a Japanese technical board member of the International Ocean Drilling Program (funded by US and Japan). Before joining Schlumberger, he was awarded a Research Fellowship by Japan's Society of Promotion of Science and he worked in the Geological Survey of Japan studying inland active faults using downhole passive and active seismic measurements.

He earned a B.Sc. degree in earth and planetary science from Hiroshima University in Japan, an M.Sc. degree in earth and planetary science from Hokkaido University in Japan, and a Ph.D. in seismology from Kyoto University in Japan. □

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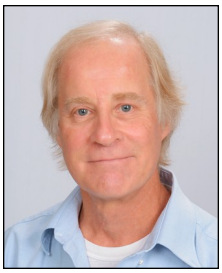
He has extensive geophysics experience mainly in the areas of velocity model building and depth imaging for Western Geophysical, Paradigm, and PEMEX. He has also worked in geomechanics on pore pressure prediction and wellbore stability projects with Geomechanics International and Shell.

Currently, Mark is with FracGeo as a sales manager and is involved in testing the geophysics and geomechanics applications as part of an integrated workflow to improve productivity in mainly unconventional and naturally fractured reservoirs. □

Data Processing & Acquisition SIG

Factors in the Seismic Method That Distort Determination of Poisson's Ratio

Register for Data Processing



Mark S. Egan

Speaker: Mark S. Egan
Consulting Geophysicist

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

Tuesday, Jan. 14, 2020
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

Sponsored by Schlumberger

Abstract:

Perhaps a more descriptive title for this presentation would have been, "Why is it that even when the seismic data we have are of good quality, Poisson's ratio values derived from those data don't necessarily tie the wells?". This was a question that was poised to me a few years ago by a major oil company. It was of serious concern in a high-profile, onshore field. I gave some opinions, and I did some limited analyses at that time.

Over the last few years I made a more concerted effort to investigate this. The causes I focused on were not the usual topics of noise, anisotropy, and imaging. Those already received much of the industry's attention. Instead, I looked at the pitfalls of linear inversion, as well as pitfalls of ignoring the effects of "surface angle projections". These latter effects refer to the angles at which seismic energy enters the earth at the source, and the angles at which the energy emerges at the receivers.

The methodology that was followed was to generate seismic gathers for 50 earth models that were constructed using well logs from all over the world. The true-amplitude gathers as well as the corresponding gathers that were perturbed by the angle effects alluded above were then inverted with linear and nonlinear inversion routines. The values of Poisson's ratios that were then derived from the inverted results were compared with the true values. Successes and failures were then analyzed to determine the reasons why Poisson's ratios are correctly computed in some seismic surveys, while not in others.

The findings will be discussed in the presentation. They impact everything from survey design to final inversion.

Biography:

Mark Egan is a consulting geophysicist. He worked for Schlumberger and its heritage companies from 1975 to 2016, at which time he retired. Egan's last position at Schlumberger was as global chief area geophysicist in the Land Unconventionals Group within the WesternGeco segment. His previous postings included chief geophysicist positions in North America, Saudi Arabia, Dubai, and London.

Egan holds a PhD degree in geophysics, an MS degree in acoustics, and a BS degree in physics and mathematics. He is a member of the SEG, the EAGE, the SPE, and various local societies. For several years, Egan has additionally been a member of the Editorial Committee for the Journal of Petroleum Technology – a publication of the SPE. He can be reached at egan9@hotmail.com. □

Potential Fields SIG

A Summary of the Latest Developments and Results from the Newest Generation of Airborne and Marine Gravity Meters

Register for Potential Fields

Nigel Brady

Speaker(s): Nigel Brady
Director, Dynamic Gravity Systems

Thursday, Jan. 16, 2020
5:30 p.m. - 8:00 p.m.

NEW LOCATION:

Location: Churrascos
2055 Westheimer Rd.
Houston, TX 77098

Abstract:

The LaCoste and Romberg Dynamic Gravity Meter developed in the 1950s and 1960s demonstrated that airborne and marine gravity measurements were feasible to a reasonable degree of accuracy and led directly to commercial development of dynamic gravity meters for exploration surveys. The following 50 plus years have seen several major advances in both gravity measurement and positioning technology with advances in electronics and, more recently, high accuracy GPS. The original heart of the L&R meter - the 'zero length spring' balancing a mass on a beam has remained essentially unchanged during that time and continues with the latest version of the system built by Dynamic Gravity Systems. This new generation of airborne and marine gravity systems combine a full feedback system for the gravity sensor with GPS aided control of the gimbal platform to provide higher accuracy, better repeatability and lower noise than ever before.

The advanced technology system has now been thoroughly tested and has provided results on a number of surveys for both geophysical research and oil and gas exploration. The meters have been used on aircraft ranging from a Cessna 180 to a Lockheed C-130 Hercules and a 20ft pontoon boat to multi streamer seismic vessels. The results obtained have validated the hoped-for improvements in data quality and reliability of the new meters as will be shown in this discussion.

Biography:

Nigel Brady is a director at Dynamic Gravity Systems in charge of Operations and Customer Service. He has a BS degree in Physics and Geology and a Graduate Diploma in Business from the University of Auckland. Since 1990 he has worked in geophysics running gravity instruments for surveys in boreholes, on land, ships and aircraft for companies like Edcon-PRJ, Micro-g Lacoste and the National Geodetic Survey on all seven continents. More recently he is a founding partner of Dynamic Gravity Systems where he provides most of his operational and trouble shooting advice from the comfort of his office in Denver.□

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Solving Trinidad's Imaging Challenges Through Orthorhombic and Least Squares Q Migration of High-density Full-azimuth OBN Data

Kareem Vincent, Pedro Paramo, Bertram Nolte, Sean Cardinez, Katrina Packer, John C. Naranjo, Jim Mika, Imtiaz Ahmed and Hu Jin, BP

Summary

In 2016-2017, BP Trinidad and Tobago (BPTT) realized a significant uplift in seismic imaging through acquiring a high-density full-azimuth ocean bottom node (OBN) survey in the Columbus Basin in Trinidad. While full-azimuth and long offset data offered imaging benefits in terms of better illumination and undershooting complex overburden, they at the same time posed a challenge due to strong azimuthal anisotropy in this area. This imaging challenge was further compounded by significant structural complexity and strong absorption due to the presence of shallow gas. We present how we addressed these imaging challenges by employing advanced processing technologies which include orthorhombic velocity model building to address the azimuthal anisotropy, and least squares Q (LSQ) migration to compensate for the attenuation. The final orthorhombic image shows a step change in data quality with improved depth structural accuracy validated by well control and increased resolution and signal-to-noise from the LSQ migration.

Introduction

The Columbus Basin offshore Trinidad is considered one of the world's most prolific hydrocarbon provinces which still has untapped exploration potential. However, this area suffers from imaging challenges related to strong absorption caused by the presence of gas in the shallow overburden. The area is also known to have strong azimuthal anisotropy (Mathewson et al., 2015) which adds further complexity for resolving the velocity model for imaging full-azimuth data.

In 2011-2013, we exploited the significant imaging benefits that can be gained from high-density full-azimuth ocean bottom data, when we acquired the Phase 1 ocean bottom cable (OBC) campaign over our southern acreage. This was the first phase of our ocean bottom seismic (OBS) acquisition campaign that successfully utilized Independent Simultaneous Source ISS® technology, providing a significant improvement in operational efficiency. This survey, shown in the green polygon on *Figure 1*, provided a step change in data quality compared to our legacy towed streamer seismic (Paramo et al., 2013), and delivered tremendous business value for the region in terms of exploration discoveries and progression of development opportunities.

Following on from the success of Phase 1, a decision was made to acquire a second phase of high-density full-azimuth OBS to replace our legacy towed streamer data covering our northern exploration acreage. The Phase 2 OBS survey, shown by the red polygon in *Figure 1*, was completed in 2016-2107 and achieved significant improvements in operational efficiency, trace density and offset/azimuth distribution compared to Phase 1 through optimizing the survey design by using nodes instead of cables.

A reprocessing effort performed on the legacy towed streamer datasets acquired in different azimuths provided an early indication of the main imaging challenges that we would encounter in the processing of the Phase 2 OBN data. The legacy reprocessing highlighted that the area had strong azimuthal anisotropy, and we would therefore need to adopt an orthorhombic approach to the velocity model building and imaging strategy. Shallow gas attenuation was also prevalent in the legacy seismic, which made us consider different Q compensation applications.

Acquisition and Processing

The Phase 2 OBN survey utilized a nodes-on-a-rope deployment with a nominal inline receiver interval of 50m and a crossline spacing of 300m. Two

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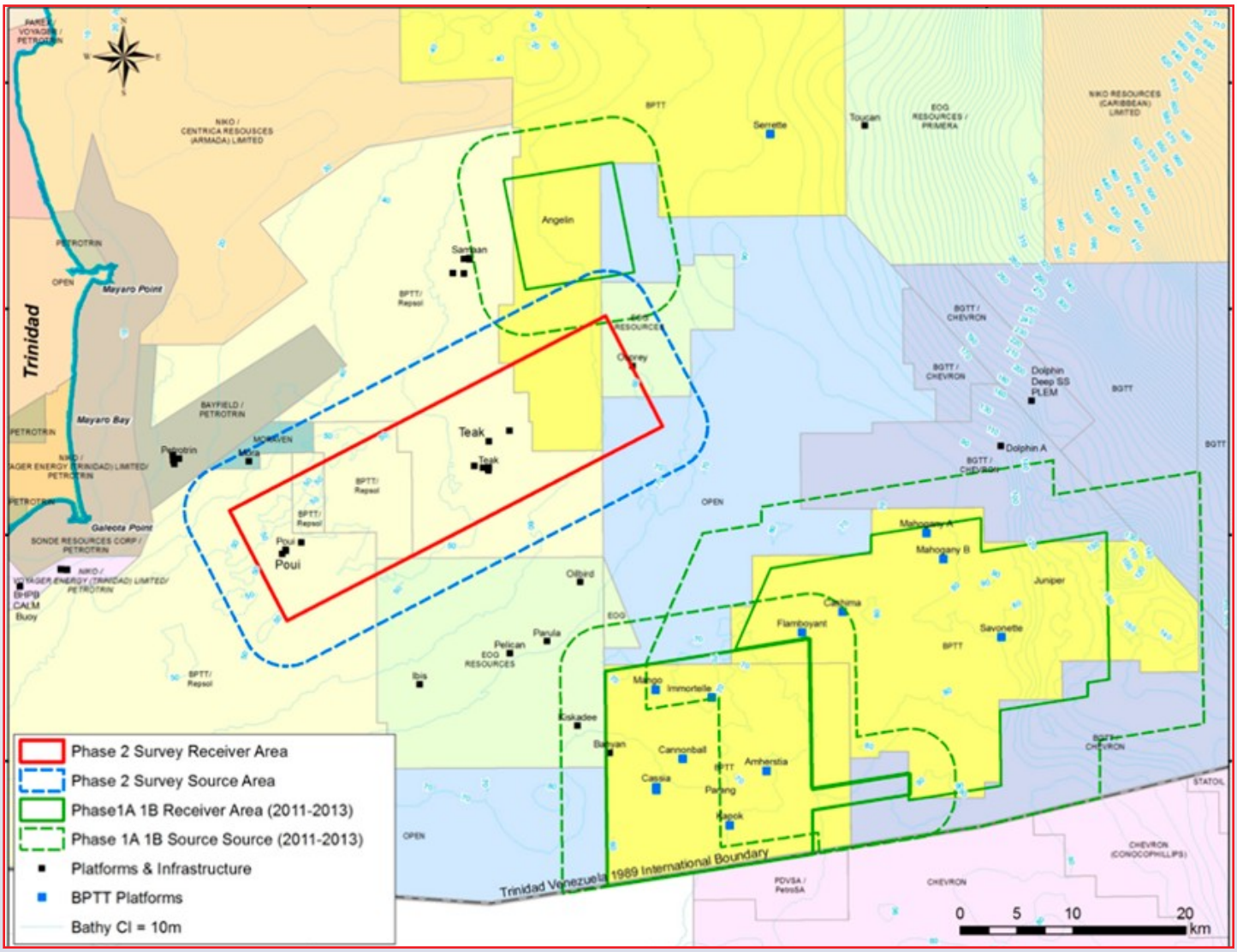

Figure 1 - BPTT Offshore acreage shown with recent OBS acquisition surveys. The Phase 1 areas are shown in green while the Phase 2 survey receiver area is shown by the red polygon with source halo blue.

dual source vessels were shooting simultaneously, generating a dense source grid of 50x50m. The survey was designed to have a minimum source offset of 4km from the edge of the receiver patch, with maximum shot-receiver offsets exceeding 18km (See *Figure 1*). This survey configuration resulted in a very high trace density (6.8 mil/sq km), long offsets, and full-azimuth coverage which are ideal for estimating high resolution FWI velocities for imaging.

The pre-processing included the following main steps: simultaneous source deblending of P and Z component data, noise attenuation, PZ summation to derive the up-going wavefield, wave equation demultiple, node amplitude correction, direct arrival attenuation, offset vector tile (OVT) binning.

The final imaging was a tilted orthorhombic anisotropy (TOR) least squares Q Kirchhoff PSDM with the following main post-migration processing steps: radon demultiple, residual moveout correction, dynamic warping, offset spectral balancing.

Velocity Model Building and Imaging

The starting velocity model was derived from the legacy towed streamer PSDM which was updated with VTI FWI and TTI reflection tomography. Using the raw hydrophone OBN data, this initial model

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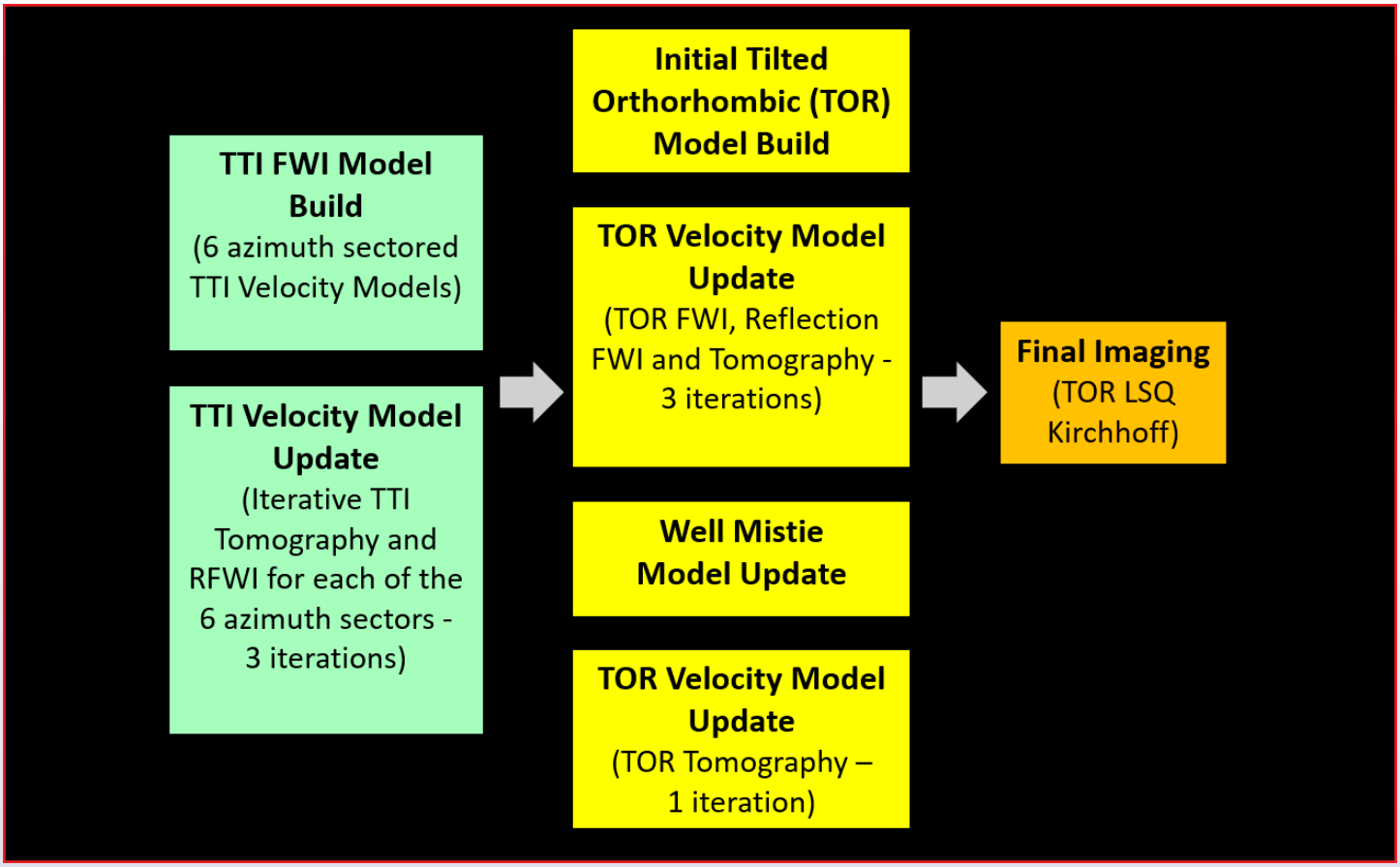

Figure 2 - Phase 2 OBN velocity model building workflow.

was then updated with TTI FWI by BP's subsurface technology group. Due to the strong azimuthal anisotropy, the TTI FWI using the full-azimuth OBN data as input produced a degraded velocity model and non-flat gathers. To overcome this challenge, the OBN data was split into six 30-degree azimuth sectors and TTI FWI was run on each sector producing six velocity models. The imaging of the individual azimuth sectors with their respective velocity models produced better focusing of the energy and much flatter gathers. These six TTI FWI velocity models were used to produce a fast-track image and served as the starting point for further velocity model building by the processing contractor.

The six-azimuth sectored TTI FWI models were first updated with TTI tomography and reflection FWI (RFWI) (Gomes et al., 2017), ran iteratively for shallow and deep updates. These six TTI models were then used to create an initial TOR model which was updated with TOR FWI and RFWI, and three iterations of TOR tomography. The full velocity model building workflow and the final orthorhombic velocity model used for migration are shown in *Figures 2 and 3*, respectively. A raw depth migrated TTI OVT gather using the average of the six TTI FWI models is shown in the left image of Figure 4. This TTI gather is sorted in spiral order to highlight the strong azimuthal effects at larger offset which is observed as significant jitter that will degrade stack quality and pre-stack attributes. The TOR OVT spiral gather is shown in the right image of *Figure 4*, where we can observe that the jitter is greatly reduced which translates into better focusing of energy in the stack.

The benefits of Q-tomography and LSQ Migration have already been proven in a previous study using our Phase 1 OBC data (Shao et al., 2017). We expected to gain a similar imaging uplift in the Phase 2 area by using these technologies to compensate for shallow gas attenuation and illumination effects without boosting high frequency noise. The initial Q model was a constant Q

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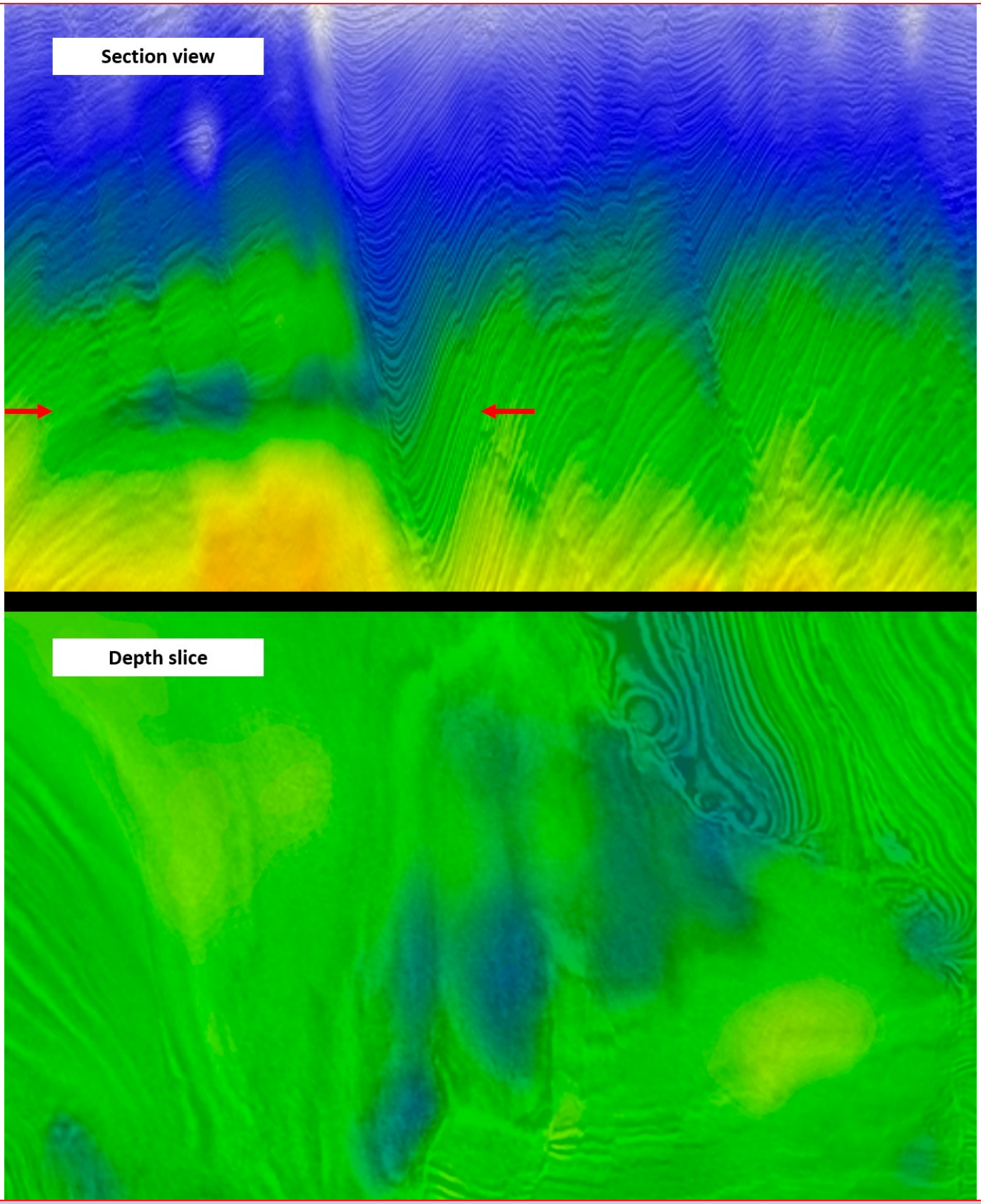

Figure 3 – Final orthorhombic velocity model (V0) with seismic image in the background. Section view above and depth slice below. Red arrows on the section indicate the area for the depth slice.

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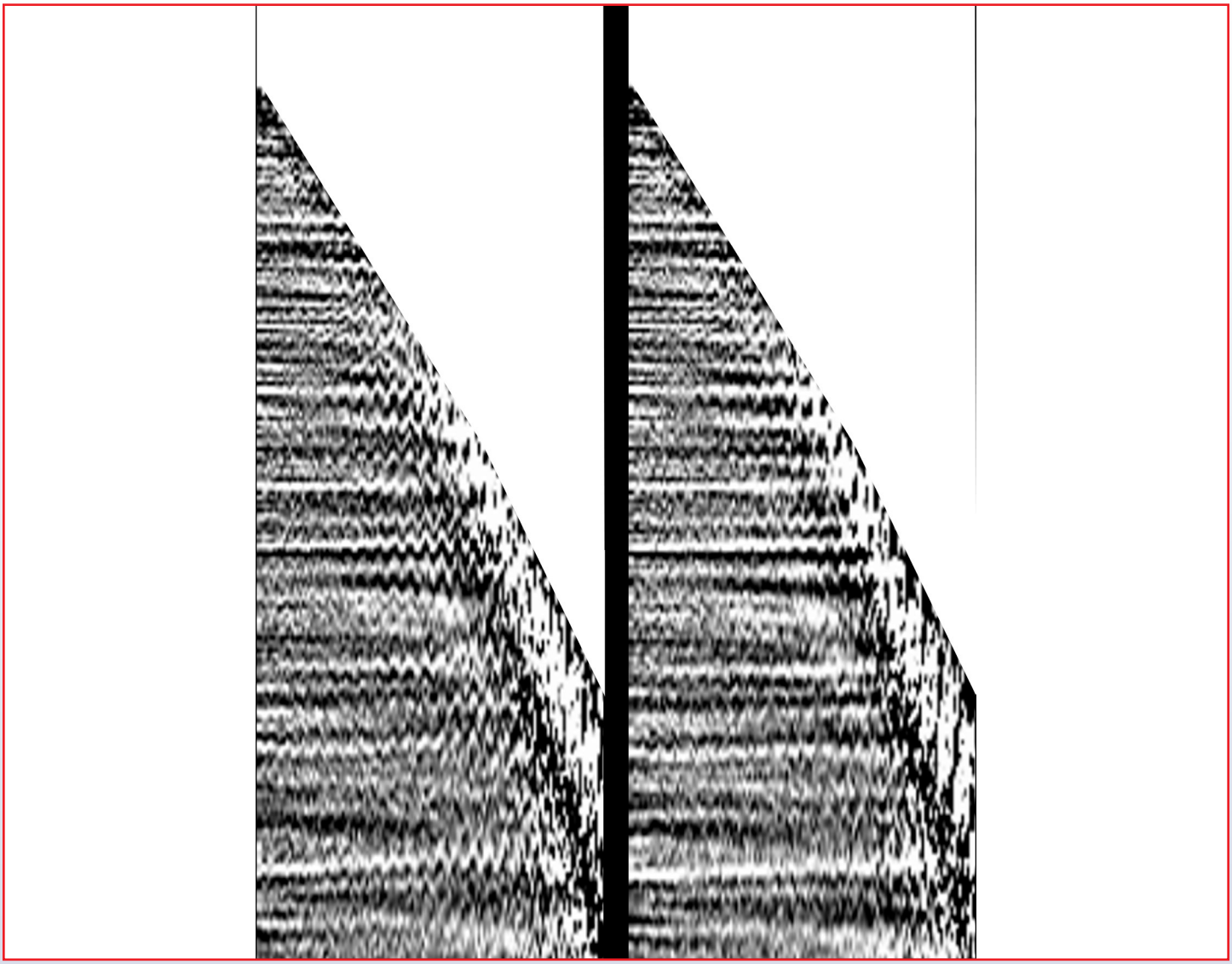

Figure 4 – Raw OVT depth migrated gathers sorted in spiral order. TTI on the left and TOR on the right.

derived post-stack using the spectral ratio method. The initial Q model was then updated with one iteration of Q-tomography (See *Figure 5*) and applied within the TOR Least squares Kirchhoff migration for the final imaging. *Figure 6* shows a comparison of the raw migrated stack image between a conventional Kirchhoff and Least Squares Q Kirchhoff. Overall, we observed a significant uplift in resolution and signal-to-noise with sharper fault and reflector definition. There was also an improvement in recovering amplitude masked by shallow gas.

The final Phase 2 OBN image is superior in quality compared to the legacy towed streamer seismic (See *Figure 7*). By utilizing advanced processing technologies, we achieved a final product with higher resolution and improved amplitude fidelity. We also validated that the depth structure was accurate by obtaining misties of less than ~20 m at well control.

Conclusions

We have demonstrated that high-density full-azimuth OBN data coupled with applying advanced processing technologies can deliver superior seismic images and overcome some of the main imaging challenges in the offshore Trinidad Columbus Basin.

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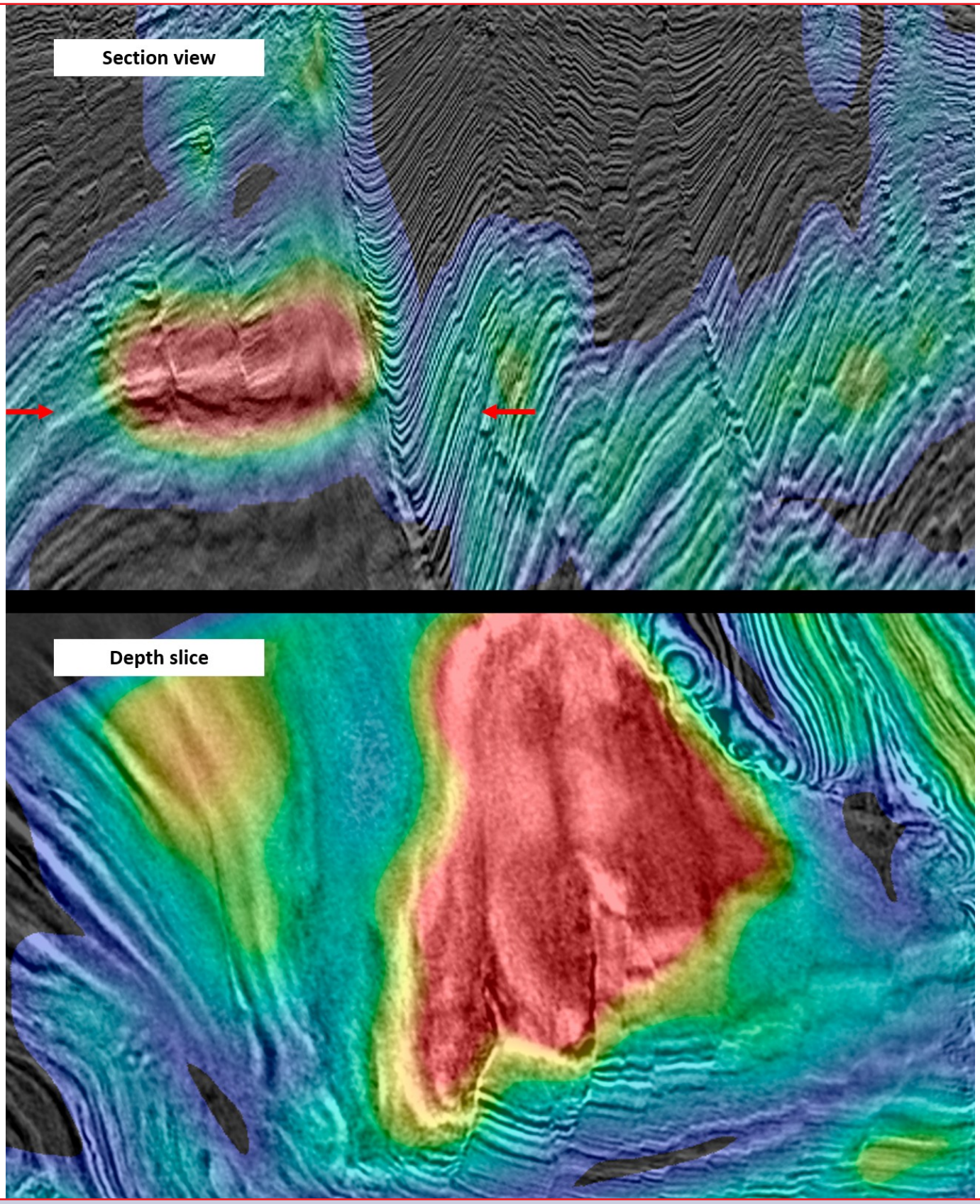

Figure 5 –Q model derived from Q-tomography with seismic image in the background. Section view above and depth slice below. Red arrows on the section indicate the area for the depth slice.

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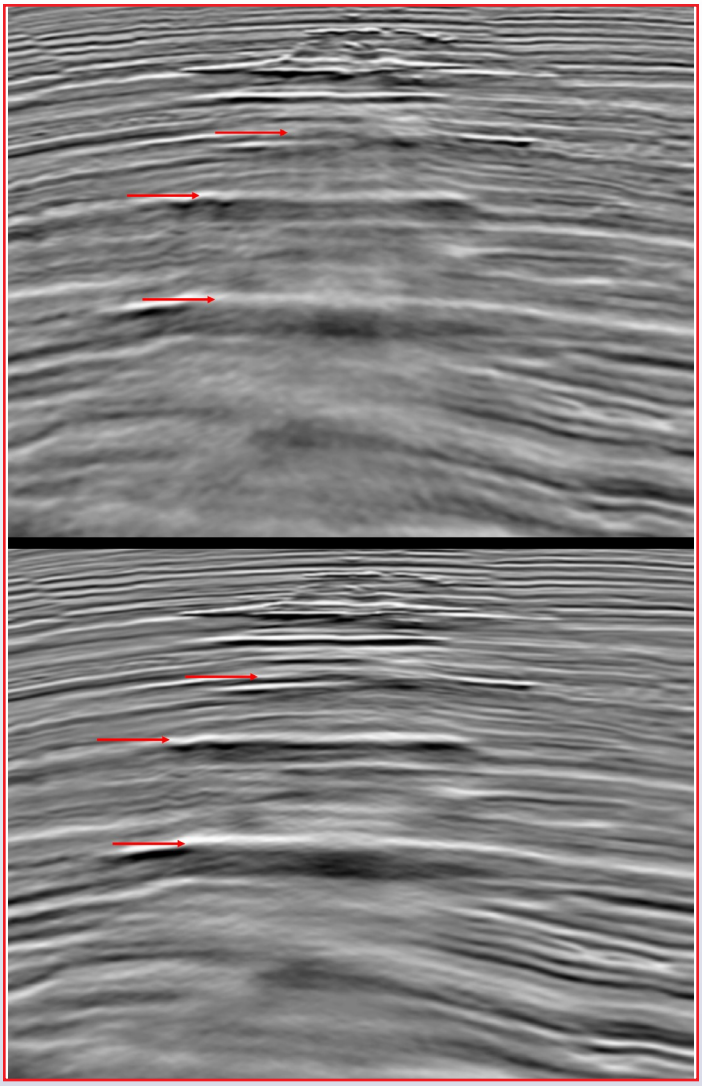

Figure 6 – Comparison of Phase2 OBN conventional raw Kirchhoff migrated stack without Q (top image) and least squares Q Kirchhoff stack (bottom image). Red arrows highlight areas of imaging uplift.

The orthorhombic velocity model building and imaging strategy adopted was the key enabler for addressing the strong azimuthal anisotropy encountered in the area which could not be handled with a traditional TTI approach. By utilizing LSQ-Migration, we also gained the benefits from both imaging technologies by improving the resolution through compensating for attenuation and increasing amplitude fidelity by accounting for illumination variations.

The result of this OBN processing effort delivered another step change in seismic imaging. The final orthorhombic image shows a significant uplift in data quality, with improved depth structural accuracy validated by well control, and increased resolution and signal-to-noise from the Least-Squares Q migration.

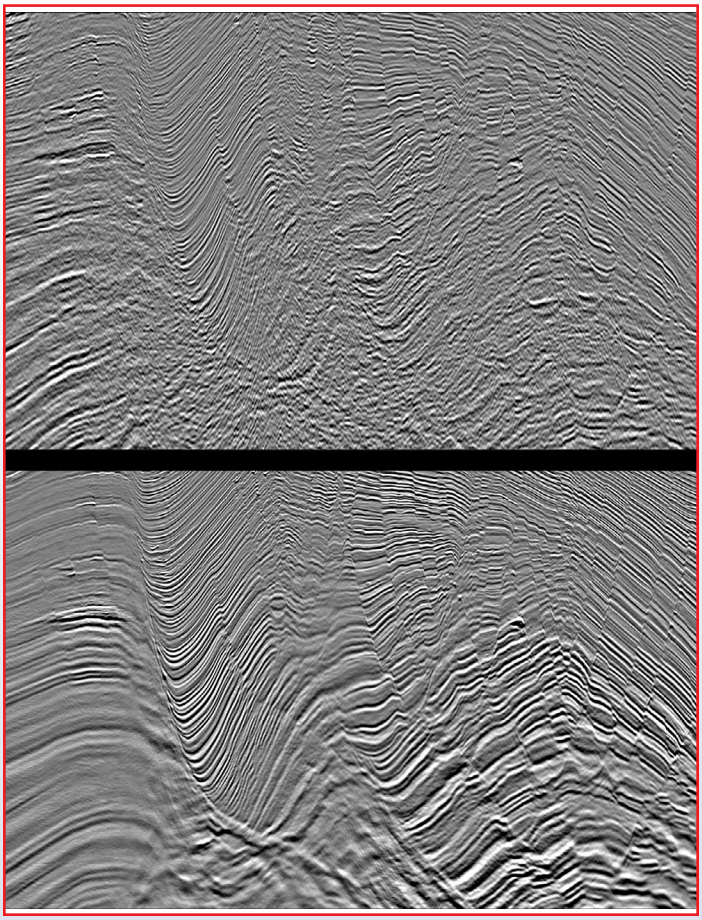

Figure 7 – Comparison of migrated images of the legacy streamer data (above) and Phase2 OBN data (below).

Acknowledgements

The authors would like to acknowledge BP and partners EOG Resources Trinidad Limited for permission to present this paper. We wish to thank Fairfield Nodal for safely acquiring the Phase 2 OBN survey, and CGG's Houston processing center for processing the data. We would also like to recognize BP's Subsurface Technology group and High-Performance Computing Center for their work on building the initial velocity model. ISS® is a registered trademark of BP p.l.c. □

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Permalink: https://doi.org/10.1190/segam2018-2994996.1

GSH Outreach

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

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

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Thursday, January 16, 2020
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Friday, January 17, 2020
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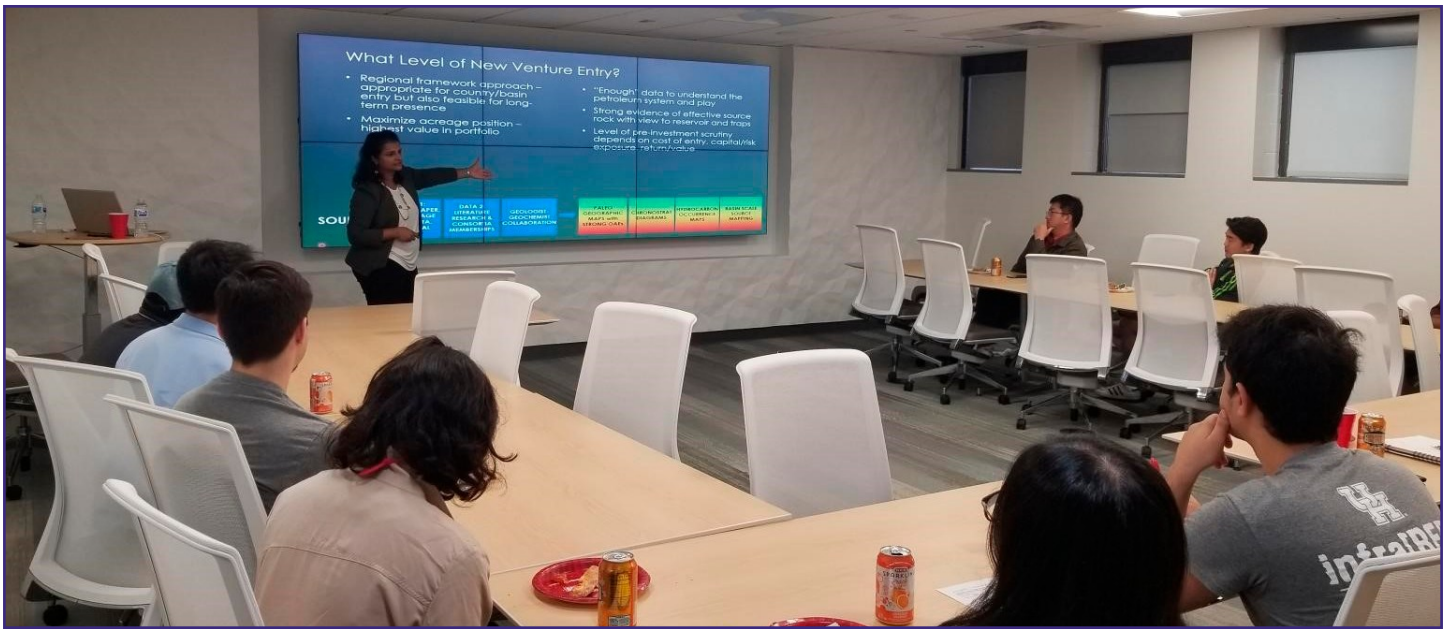
U of H Wavelets

SEG Wavelets Brings Geoscience to Kids and Hosts Technical Talks *By Zhongmin Tao*

In October, SEG wavelets brought geoscience to children at the Houston Museum of Natural Science during the annual Earth Science Celebration event. This amazing event was organized by Houston Geological Society at the renovated permanent exhibit. Interactive attractions were featured, ranging from plate tectonics, petroleum exploration, reservoir/pipeline engineering, and more! SEG wavelets had a great time teaching the children about petroleum generation and giving them hands-on experience with geophysical instruments; some of these used for land seismic acquisition and GPR. We were excited to introduce Geosciences to the youth, and we hope we stimulated their interest!

SEG wavelets people explaining rock samples to kids.

Besides off-campus events, we hosted lots of interesting talks given by industry experts to students. We invited Maitri Erwin from CNOOC International to speak about "New Ventures Exploration and the Future Geoscientist." She provided information on the exploration process and the roles that different types of geoscientists play to contribute towards the goal of discovery. A student said after her talk: "I am



Maitri Erwin from CNOCC was illustrating the exploration process.

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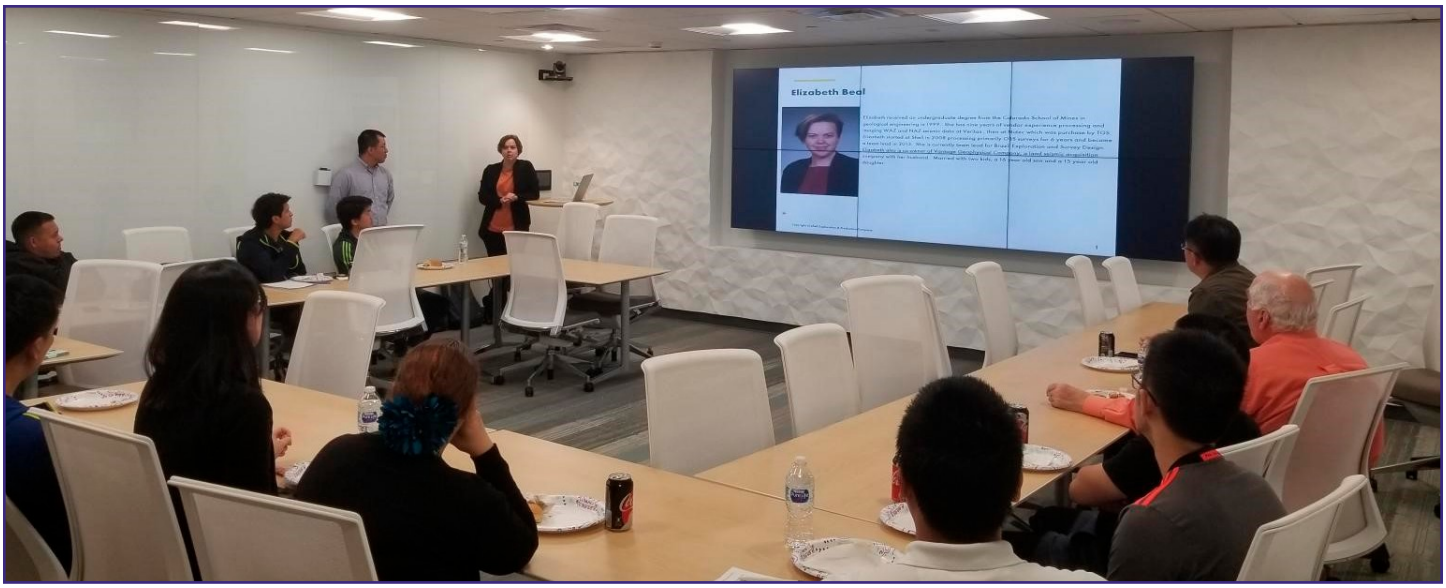
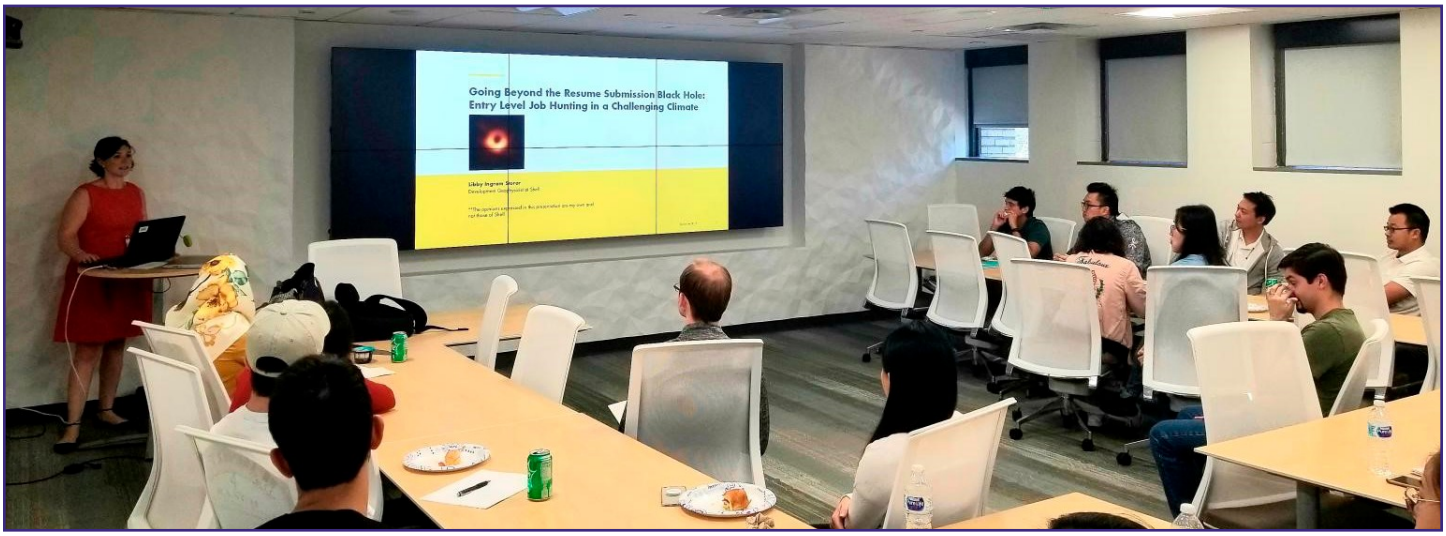
new to this topic, but her explanation is clear and easy to understand. I enjoyed hearing Maitri present a good summary."

In November, SEG wavelets were honored by hosting Shell two weeks in a row for great talks. The first talk, presented by Elizabeth Beal, was on 4D seismic acquisition and processing in the Campos Basin. Besides technology, she introduced the career pathways available to geoscientists at Shell.

The second talk, delivered by Libby Ingram, covered critical job-hunting techniques in the energy industry. Libby is a UH alumnus and she gave students great tips derived from her own job-hunting experiences. Her suggestion to students was to make connections with industry professionals. After her talk, she stayed for an extra 45 minutes to answer questions. She made 7 new connections with students! We look forward to future events together! □



Elizabeth Beal from Shell was explaining 4D seismic to students.



Libby Ingram from Shell was presenting to students.

U of H Wavelets

Elevated Education: Geophysical Field Camp at Enchanted Rock, Texas

By Robert R. Stewart, Casey Kuo*, Mike Allison+, and Li Chang#*

**University of Houston, +Raptor Aerial Services LLC, Houston, # DownUnder GeoSolutions, formerly University of Houston*

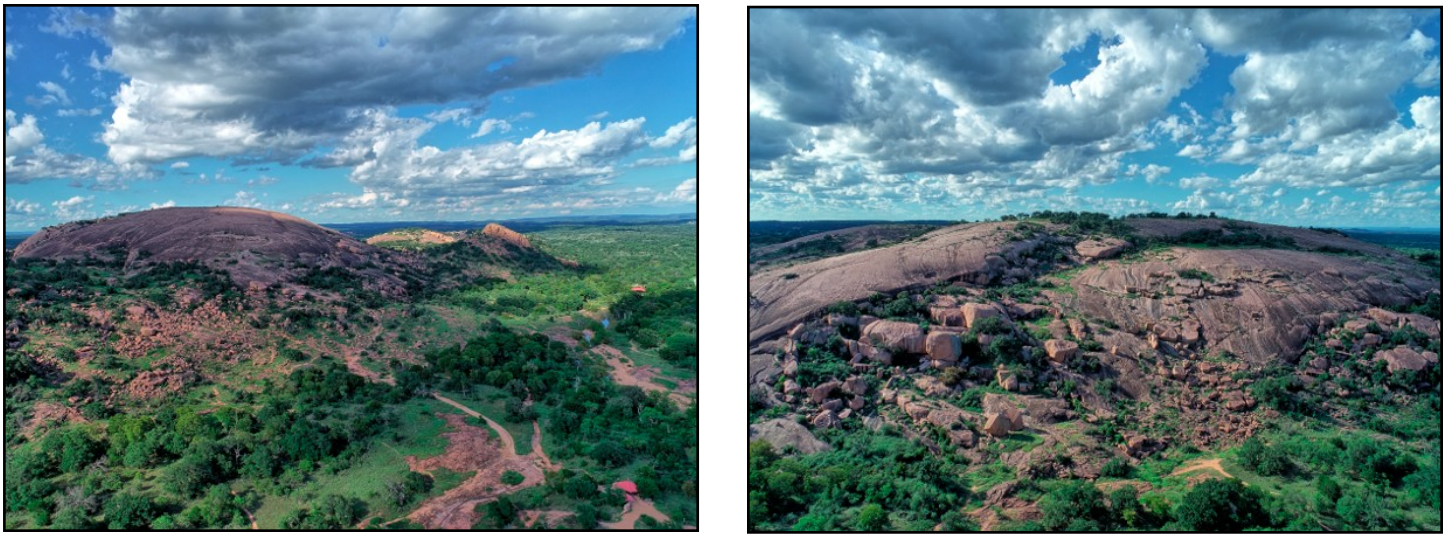


Figure 1. Aerial (drone) photographs of Enchanted Rock, west Texas. Exfoliation blocks are visible on the photos.

Enchanted Rock is an enigmatic and historic site in central Texas. It is an excellent spot for climbers (O'Grady, 2011), hikers (Williams, 2018), historians (Kennedy, 2010), and a geophysics field camp! The somewhat strange, bald, and rounded dome protrudes into the otherwise scrub terrain of central Texas Hill Country (Allred, 2019) which is itself embedded in the Edwards Plateau. "E-Rock's" Precambrian exposure, the Town Mountain pink granite (Hutchinson, 1956), is surrounded by a sea of Cretaceous limestone and Paleozoic sediments. E-Rock is thought to have been emplaced some 1 billion years ago (Ewing, 2016). The main dome (Figure 1), also called an inselberg or monadnock (island or isolated mountain), is part of the larger 160 sq. km. Enchanted Rock Batholith. The surface of Enchanted Rock is characterized by erosional pockets, towers, dikes, and broken rock sheets or exfoliation layers. Exfoliation domes may have formed on account of pressure reduction upon erosional exposure. These sheets or somewhat concentric "onion-skin" layers in the dome can be thinner toward the top of the dome.

As part of our annual University of Houston (UH) Geophysics Field Camp, we undertook surveys in the summers of 2018 and 2019 at Enchanted Rock. In these two years, some 40 students and 15 instructors conducted a wide range of geophysical surveys including gravity, magnetics, GPS, ground-penetrating radar, LIDAR, seismic, and multi-spectral scanning on the Rock. The surveys were undertaken for educational as well as research purposes.

The Enchanted Rock State Natural Area is part of the State of Texas Park system. We surveyed the main dome area with total station, GPS, and aerial drone (unmanned aerial vehicle – UAV) technologies. Our drone mapping, under supervision of the park rangers, was the first drone survey conducted over Enchanted Rock. Raptor Aerial Services, with UH

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assistance, designed and flew the surveys. GPS control points were first measured (Figure 2). We used a DJI Inspire 2 with a 20 Megapixel camera. Because the drones have a limited fly time, the survey was undertaken in four patches (Figure 3) over two days. Raptor processed the drone images into a digital elevation model with 1" ground sampling as shown in Figure 4. This astonishing resolution from drone photogrammetry is a major advancement in the surveying world, especially for sites such as Enchanted Rock which are both culturally and environmentally sensitive as well as physically hazardous (steep slopes, rocky terrain, and rattlesnakes). Enchanted Rock's base elevation is about 425 m (1400 ft) with the summit at 555 m (1825 ft).

We undertook several seismic test surveys as located on the image in Figure 5. This was demanding work as all of the equipment had to be hand carried up the Rock in summer temperatures (usually in the 90s F). We used 60 geophones with flat bases spaced at 3 m (Figure 6) in 2018 and 72 geophones spaced at 5 m in 2019. The bases did not provide the best coupling but due to the sensitive nature of the rock there could be no invasive or destructive aspect of the measurement. The conditions in 2018 were fairly calm. However, the 2019 survey was accompanied by strong winds (sometimes making

Figure 2. Raptor Aerial Services fixes a GPS location at the base of Enchanted Rock to calibrate the follow-on drone topography survey.

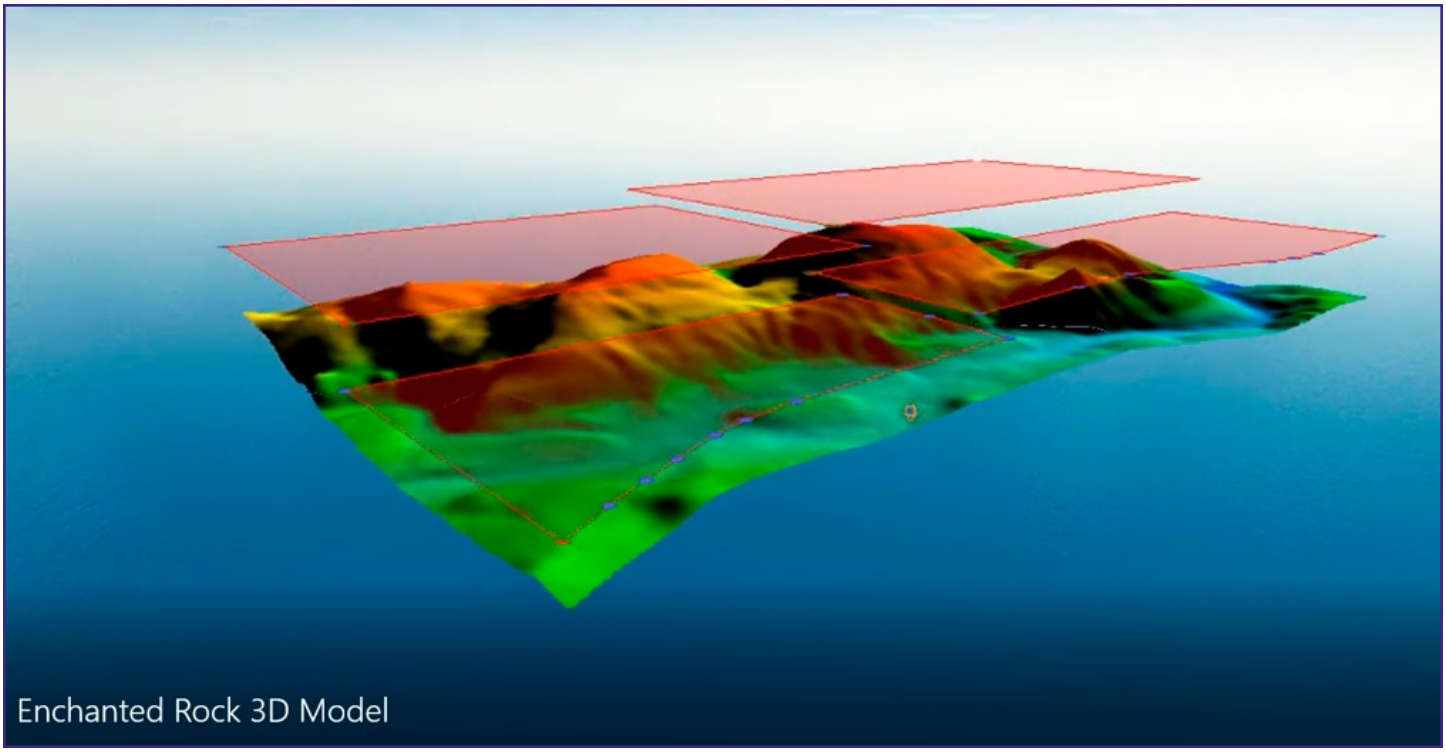

Figure 3. Design patches for the drone topographic survey over Enchanted Rock.

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Figure 4. Geo-referenced topographic map (digital elevation model) derived from the aerial drone survey and registered using GPS locations with photographic overlay.

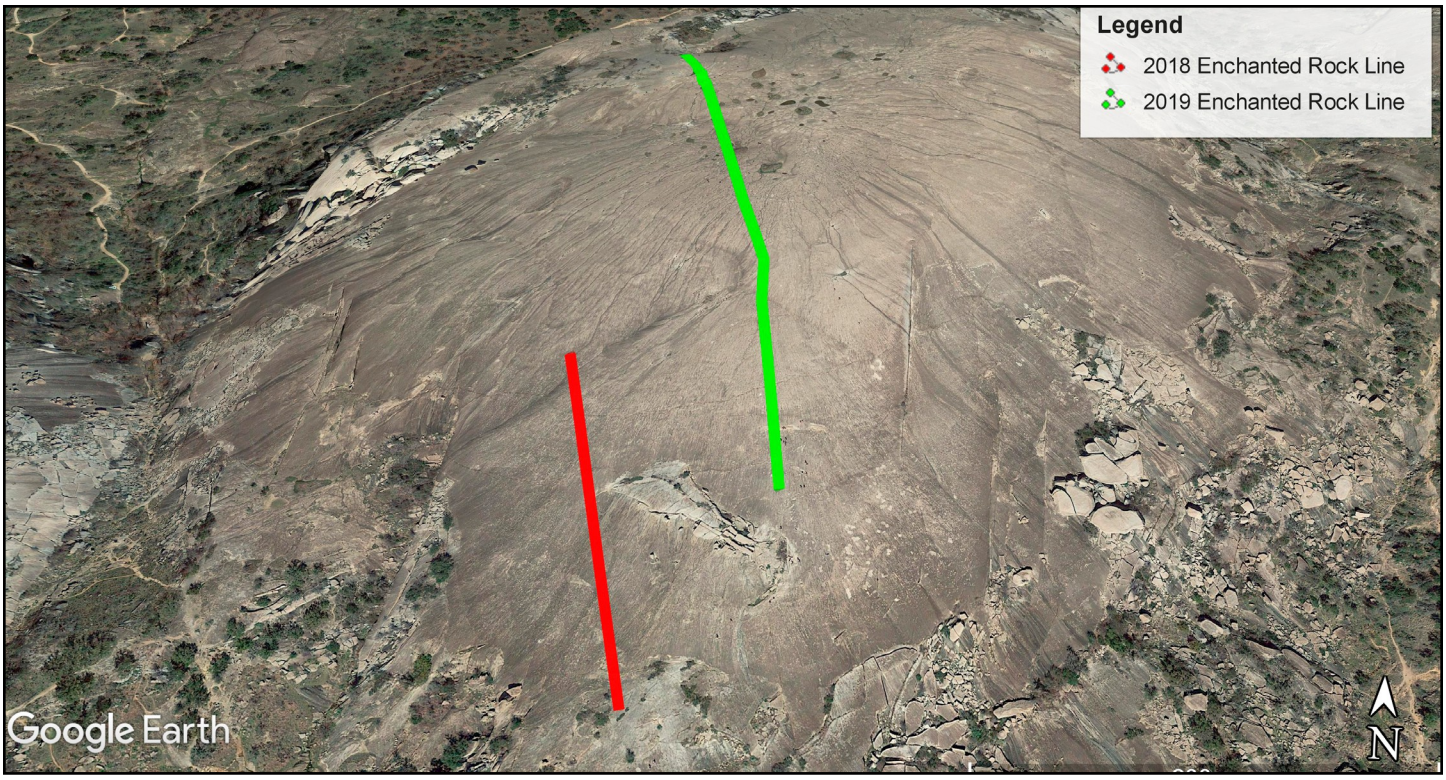

Figure 5. Aerial photo of Enchanted Rock with seismic lines annotated (2018 in red, 2019 in solid green)

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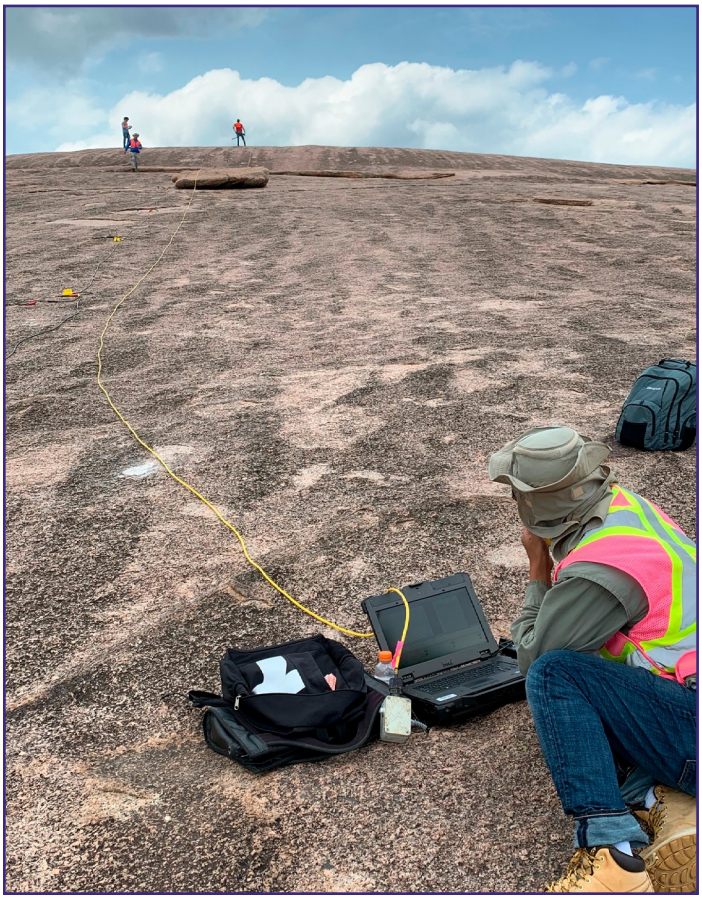

Figure 6. Photographs of the seismic line looking toward the summit of Enchanted Rock (photograph from 2018 on the left and 2019 on the right).

it difficult to stand) with corresponding noise levels. Other groups on the dome (Figure 7) expressed considerable interest (and noise) in the surveys. We employed a 12 lb. sledgehammer and single tap on the rock to provide a vibration at each source point.

We processed the data through a flow which included deconvolution, geometric spreading, velocity analysis, and a newly derived NMO equation for a curved recording surface and internal geometry (Stewart et al., 2019). From refraction and reflection analysis, we find rock velocities of about 2800 m/s - 4000 m/s. The processed seismic data from both years indicate an intriguingly strong and dipping reflector at about 60 ms or 80 m depth (Figures 8 and 9). This could be indicative of a fault, the base of an exfoliation sheet or perhaps a dike. We are excited to undertake more extensive seismic surveying in the future to help resolve this feature.

Figure 7. Seismic line on Enchanted Rock with UH personnel as well as a visiting school group.

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Summary

Enchanted Rock is a fascinating locale for hiking, history, and geoscience investigations. University of Houston has undertaken geophysical field camps in this area in 2018-19. We also conducted the first airborne drone survey to provide a detailed digital elevation map of the main dome region. In addition, we undertook the first seismic surveys on the Rock to determine its elastic properties as well as explore its internal structure. We found an intriguing interface at about 80 m depth which might be an exfoliation surface, fault, or dike. Future camps and surveys will continue to assist with student training, technology testing, and understanding of this remarkable geologic area.

Acknowledgements

We thank the drone and seismic team members, especially Michael McClimans, plus students of the 2018 and 2019 UH Geophysical Field Camps. We are grateful to the SEG Foundation for providing much needed support for the Camp. We would also like to recognize UH's Earth and Atmospheric Sciences administrative staff members, in particular Jim Parker and Laura Bell, for their assistance with registration and contracts. We are especially appreciative to the staff at the Enchanted Rock State Natural Area for granting us survey access and providing logistical support.

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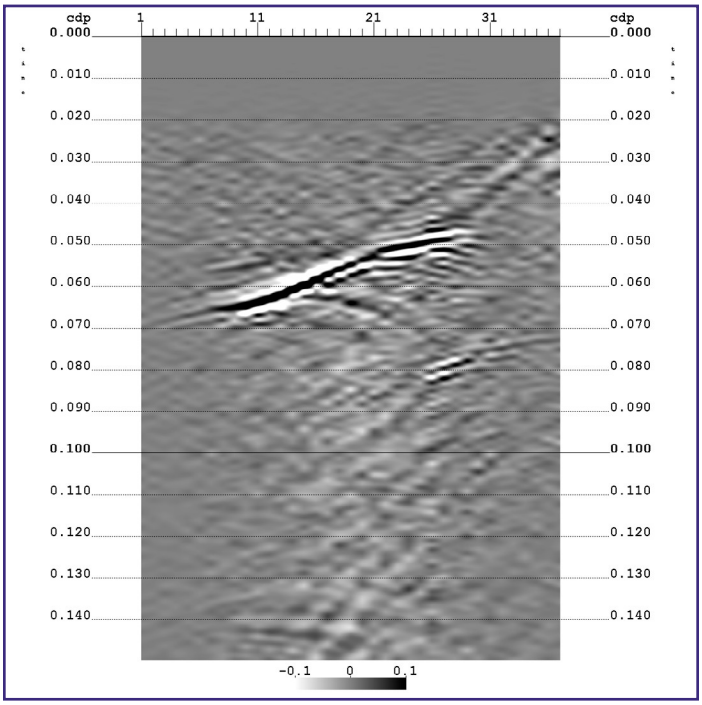

Figure 8. Seismic line, toward the summit from left to right, in 2018 shows a strong reflector at 0.07 s to 0.05 s.

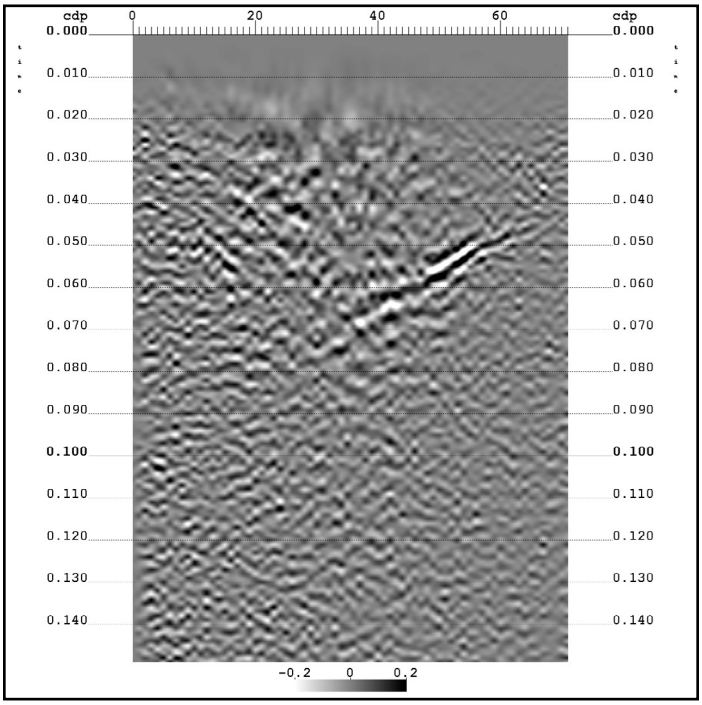

Figure 9. Seismic line acquired in 2019 under windy conditions (from left to right toward the summit), again indicates a strong reflector at about 60 ms or 80 m depth.

GSH GEOSCIENCE CENTER CHALLENGE

Match donations by Scott Petty. Jr., Lee Lawyer, Tom Smith, and Dick Baile

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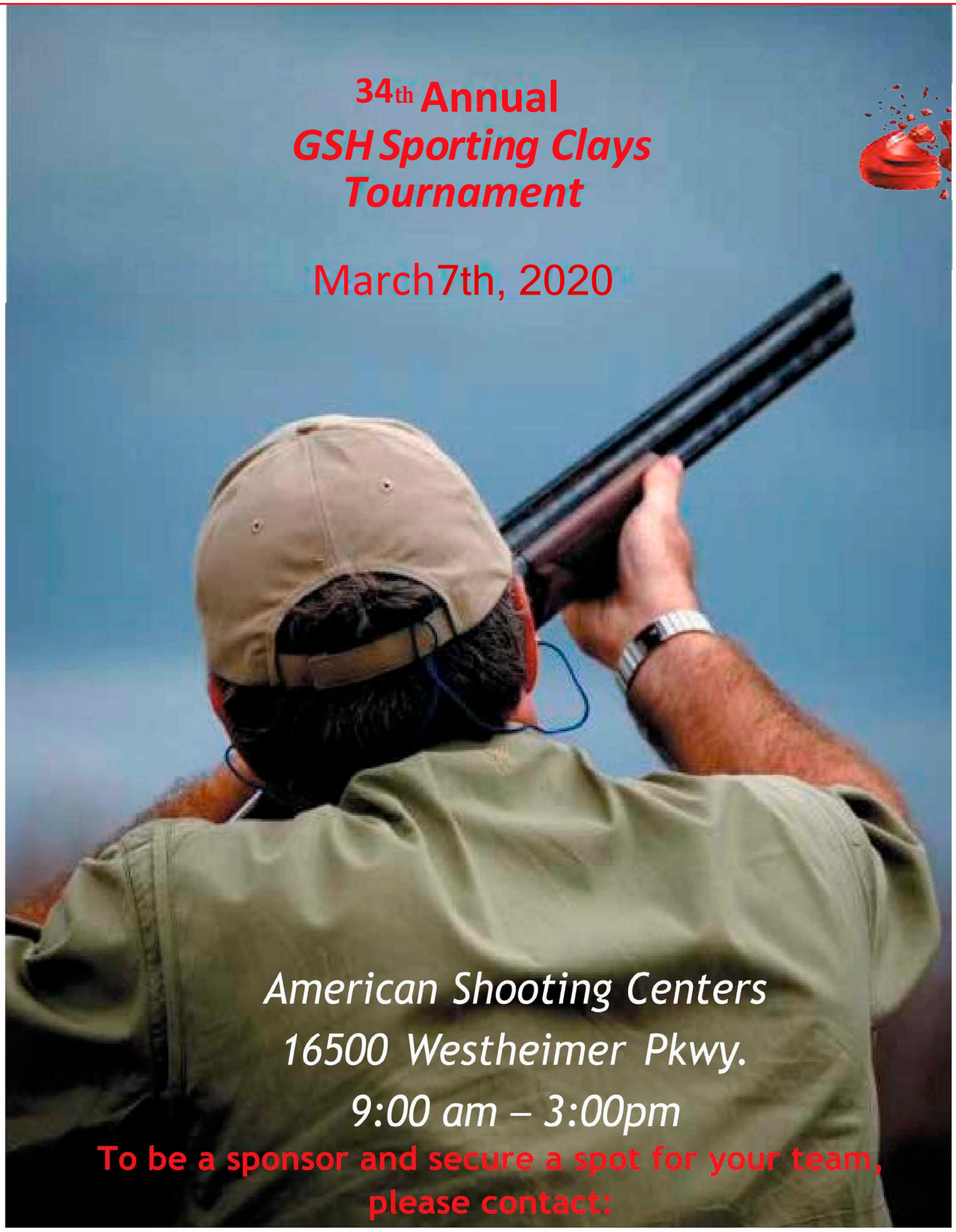
Donations recieved support Programs and Activities of the GSH Geoscience including: Geoscience Artifact Cataloging and Storage, Loans to Colleges and Universities for Display, Bob Sheriff Library, Meeting and Seminar space, and Living Legends. The GSH is a 501(c)3organization.



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

Geoscience Center

The History of Geophysics *By Bill Gafford*

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

The GSH Geoscience Center Museum inventory is now included as a **virtual museum** in the SEG Wiki with over 1300 searchable items included. There are pictures of most of the items and some descriptions are included. Everyone is invited to add information or corrections to the descriptions including links to additional information. This project has taken quite some time and I want to thank Andrew Geary at the SEG and Ed Lengel, Karl Schleicher, Gene Womack, Les Denham, Frank Dumanoir, and Chuck Meeder at the Geoscience Center for help providing suggestions and input during the last year. This will be an ongoing project as items are added to our inventory and information about existing items is researched. Please go to the SEG Wiki and browse through the museum artifacts. Suggestions for improving the Wiki are always welcome. A screenshot of a typical page is included with this article.

Amplifier Standard Unit

Item	Amplifier Standard Unit
Item code	
Description	Refract/Reflect
Manufacturer	Petty Geophysical
Circa	1933
Model	
Donor	Petty Collection
Location	The University of Texas at Austin
Serial number	
Taxonomy	GSHP024

Reflection - refraction seismic amplifier. This was Petty's standard until automatic volume control came into use. The unit was designed primarily for reflections but its characteristics were very flexible and it was equally suitable for refractions. (1933)

Amplifier Standard Unit - SEG Wiki

Donations of books, training manuals, and periodicals continue to be received. As our Bob Sheriff Library has continued to expand, some of our donated materials are duplicates and many of these duplicates are passed along to the AAPG Publications Pipeline where they are eventually shipped to university science libraries overseas. The items in our library, which include SEG and AAPG publications, various company training manuals, regional studies, and other reference books are available to be checked out. We also have a bookcase of duplicate books and other publications such as training manuals, CDs and DVDs that are **free** to anyone who visits the Geoscience Center. There are subjects that would appeal to everyone's interest.

Our next Living Legends Doodlebugger social event will be on Wednesday February 12th. Everyone is welcome and registration is not necessary. There will be coffee, water, soft drinks and light snacks. □

The Geoscience Center is open on Wednesday mornings from 9:00 am to 12:00 pm or by appointment, and visitors are always welcome.

Please contact me at:
geogaf@hal-pc.org or by phone at: 281-370-3264 for more information.

Recognizing Outstanding GSH Volunteers...

Frank Dumanoir By Tommie Rape

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

Frank Dumanoir had an early introduction to the petroleum industry, as he was born in Maracaibo, Venezuela while his French father was working there for Schlumberger. Frank grew up in Italy, Connecticut, New York City, and Paris, as his father worked around the world. Frank earned a Baccalaureate degree in Math and Physics from Louis le Grand College in Paris. He then joined his family in Houston, at which time Frank entered Rice University. Frank received a Masters in Electrical Engineering from Rice in 1974.

After graduating from Rice, Frank continued the tradition of his father by joining the petroleum industry. He spent 7 ½ years with Exxon, where he designed seismic systems/equipment and later was the Field Supervisor of Geophysical Operations. He then joined CGG where he soon moved into the area of seismic data processing. It was in this position that he began the growth of his business network, including me. Frank spent 17 years with CGG where he rose to the level of Vice President of their North American Data Processing Services. After CGG, Frank has worked with several companies, including Paradigm, TGS, and PGS. Through these years he transitioned from managing data processing and other services to more of a business development role. He currently operates his own consultancy, Effdee consulting. His current client is Z-Terra, where he works part time identifying and developing new business. Frank's extensive experience in the industry has provided him with excellent technical expertise and a network of industry personnel matched by few in the petroleum industry.

During his professional career Frank expanded his "professional" associations when he married his wife, Mariam, who is also a geophysicist, having spent most of her career with Gulf/Chevron in seismic data processing and then financial analysis. They have two daughters, who are not in the petroleum industry.

Frank further expanded his early professional associations when he joined the SEG and GSH in 1979. Like most GSH members, his activity with the society was attendance at technical presentations. Frank says that he highly valued the technical education provided by the seminars and presentations and was a regular attendee at many of the GSH technical presentations. In 2002 he initiated his volunteer activities with the GSH when he was asked to join, participate in, and then run the Data Processing Special Interest Group (SIG). He not only organized and planned speakers, he sat at the registration table and welcomed attendees and made sure that registration fees were paid and collected. This was an early sign of Frank's concern and engagement in the preservation and active promotion of the

Volunteers continued on page 36.

Interview continued from page 35.

GSH and its provision of technical education for our local professional colleagues. His capabilities and dedication were recognized by the GSH membership, and he was elected Treasurer of the GSH in 2002. Frank's service grew when he was elected President Elect in 2007 and then served as President in 2008. As with many of our best volunteers, his service did not end after his term as President. Frank worked with our Spring Symposium Committees in the planning and execution of the annual Spring Symposium. In this role he made use of an affection for electronics that he developed in his younger days; i.e. Frank oversaw the setup and running of electronics during the Symposium and other events. Frank also started attending weekly meetings and social events at the GSH Geoscience Center, and here he made further use of his affection for electronics; he helped in the organizing and documenting of electronic equipment collected by the Center. Frank also leveraged his networking and financial skills as he proved to be a valuable fundraiser for the Geoscience Center and other events. His fundraising for GSH is contagious, as several of his employers have proven to be valuable sponsors of the GSH, and that certainly is due in no small part to him. Making further use of his organization and networking skills, Frank volunteered for the Webinar Committee. Over the last several years the GSH Webinars have proven to be an invaluable source of technical education for geoscientists around the world and an important source of funding for the GSH. His GSH service does not end here. Frank attends most of the GSH Board Meetings, providing valuable experience and expert advice to new board members, thus ensuring the continued success of the organization. His valuable presence also makes him available to occasionally sit in as the host of Tech lunches. For the last several years Frank has also arranged the speaker's gifts that are provided to our technical presenters. And last, but certainly not least, Frank has assumed the role as Chair of the GSH Office Committee, where he helps with the coordination between the GSH office and the volunteers and other members of the GSH. This is certainly an impressive list of volunteer activities with the GSH.

Frank says his long involvement with the GSH has been an integral part of his career. The Data Processing and other SIG's have meshed with his job. The technical education provided by the GSH has been very important. Also, the connections he has made have proven invaluable to his business. When the petroleum industry has gone through its repeated ups and downs, his networking has provided his employers with continued business. He also says he is very lucky to have sat many times with the

Volunteers continued on page 37.

Interview continued from page 36.

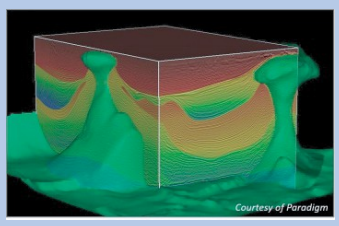
luminaries of our profession. Frank is glad that he also has benefitted personally with his GSH involvement. Many of his personal friends were met through the GSH. According to Frank, the GSH events are not work – they are fun; he enjoys being with other people of the same profession, and the meetings and events give him something to look forward to.

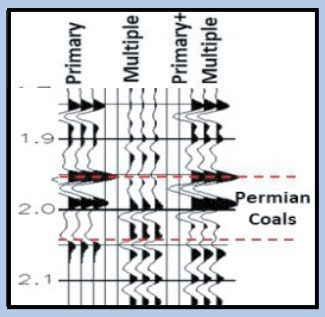
When asked how to get new people involved in the GSH, Frank says that we first must just make them aware of the opportunities that the GSH provides. Having seen these opportunities, they should recognize the benefit to themselves. In their own self-interest, their involvement in the GSH should rise. Volunteering for the GSH will provide additional benefits to the volunteers. He says that volunteering has given him exposure and experience in how to handle different situations that don't always show up in the work environment. Non-profit organizations are a different way of life. But perhaps one of the most valuable benefits of volunteering is in meeting new people and growing your network, both professional and personal. Frank says he has gained so much from being able to discuss ideas with individuals from his network that he might not have been able to discuss otherwise. Frank also highly promotes encouraging the greater involvement of educational institutions, e.g. Rice University, University of Houston, and others.

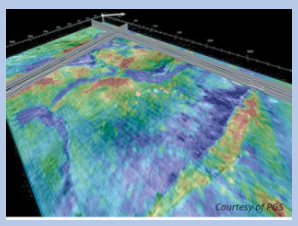
The GSH is very lucky to have Frank involved in our activities. Both Frank and the GSH have benefitted from this cooperation. The next time you see Frank at a GSH or other activity, be sure to tell him thanks for all he has done for the GSH. And, if you really want to get his attention, tell him that you have an old piece of electronics or a Corvette Stingray that he should look at. Thanks, Frank!!!! □

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.







Title	Presenter
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
EverythingYou Always Wanted to Know about Microseismic Monitoring	Peter Duncan
Full-Wave Seismic Exploration: Acquisition, Analysis, & Applications	Rob Stewart
Introduction to Applied Depth Imaging	Ruben D. Martinez
The Interpreter's Guide to Depth Imaging	Scott MacKay
Machine Learning Essentials for Seismic Interpretation	Tom Smith

View more details & access the recordings by visiting
seg.org/Education/SEG-on-Demand
then click on GSH/SEG Webinar Recordings on the right

Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 45

A Conversation With... *Andrew Munoz*

By Hailey Byers

Firstly, I want to thank Andrew Munoz for accepting this offer to be interviewed by the GSH. Andrew is a Sr. Geophysicist at Ensign Natural Resources, which is a private equity-backed exploration and production company focused on acquiring, developing and producing US unconventional resources. He has an insatiable thirst for knowledge and leaving the world in a better place than he found it. I believe that his interview will be helpful for many people, but mostly for mid-entry level folks who many seek guidance from someone who is at a more relatable point in their career. Let's get started.

Hailey: I see that you went to the following schools: Langham Creek, UT Arlington, Texas A&M, Colorado School of Mines. That's interesting to me because I am also from Cypress, and I went to Texas A&M for my undergrad. How was your experience going from a large and competitive high school district to college and then on to increasingly challenging universities thereafter? Can you comment on the quality of education that you received at each institution, and how you navigated to where you are today?

Andrew: I was fortunate to live and graduate from a high school that gave me multiple opportunities for diverse activities. I was active in theater, which gave me strong communications and public speaking skills early on. I also heavily participated in National Ocean Sciences Bowl and went to the national competition every year. This is where my passion for geoscience started. Out of high school, I went to UT Arlington, which is a small college. I went in as a physics major with a geology minor and I intended to eventually double major. The small class sizes and honors-level science and math courses allowed me to build a strong background in my fundamentals. After two years I transferred to Texas A&M so that I could major in Geophysics and take geophysics-specific coursework, which I could not do at UTA. At A&M, I was given many opportunities to succeed in geophysics and I was able to get internships with Devon and Newfield in the summer since they visited campus. I was attracted to Colorado

Andrew Munoz

School of Mines for graduate school because of the Center for Wave Phenomena consortium. This consortium provided access to top notch professors and brilliant students from around the world and gave me the opportunity to build a very strong technical background. At Mines, I worked with Dave Hale who taught me important skills in programming and critical thinking. During my geophysics programs, I was able to build a large network of friends, colleagues, and mentors; this network has been invaluable throughout my career.

Hailey: This may tie into the previous question, but of the geosciences. What drew you to geophysics and did you set any ambitious goals that you are hoping to accomplish in your career?

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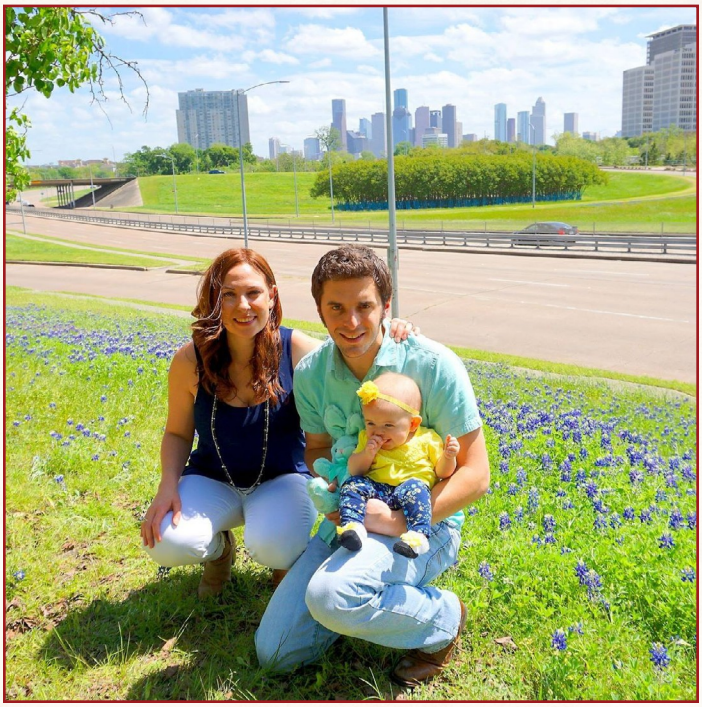
Andrew: My first exposure to applied geophysics was at the Summer of Applied Geophysics Experience (SAGE) program that I attended in 2008. This was held in Santa Fe, NM and provided the opportunity for hands-on learning in geophysics through field acquisition, processing, and interpretation for multiple types of remote sensing methods. We acquired magnetic, electromagnetic, gravity, seismic, ground penetrating radar, and magnetotelluric surveys and then learned how to process them and interpret the results. I enjoyed potential fields and EM geophysics the most from this experience and my undergraduate experience, however, when I started interning in oil and gas, I knew that industry was where I wanted to have a career. My goals have shifted as I have witnessed the industry dramatically changing over the past 5 years. The primary focus of my career has been to make seismic data a primary tool for unconventional resource development wherever I'm working. I am currently living a dream of mine to build a geophysics program from scratch for an oil and gas operator and help guide it to success.

Hailey: How did you decide to go get your masters and once you did how'd you decide where you wanted to obtain the degree from? Did you make that decision based on location, the merit of the school, the reputation of a certain college at a university, friends/mentors attend a particular university, etc.?

Andrew: In oil and gas, a master's degree is a minimum requirement to work as an exploration or development geophysicist directly out of school. I applied to multiple geophysics programs around the country, and ultimately my wife and I decided to move to Colorado where I could attend Colorado School of Mines and she could attend law school at University of Denver. I visited Mines before choosing a school and met my advisor (a practice I highly recommend). This also made a positive impact on their decision to accept me as well. The idea of moving from Texas to beautiful Colorado as well as going to a great program at Mines made the decision easy.

Hailey: I see from your CV that you have spanned many areas of geophysics in a short period. These disciplines include seismic inversion, AVO, geomechanics, microseismic, and induced seismicity. These are all disciplines in which you can spend your career specializing in. Can you comment on how to find the balance between knowing the theory with great depth and understanding the knowledge needed for practical application?



Family in Bluebonnets

Andrew: I have benefited greatly from access to top notch mentors who have given me time and training in most of these areas of study. I naturally have a desire to learn new subject areas and hone my skillsets, so I'm constantly seeking out new knowledge. I love learning. Sometimes I get so entrained in a subject I don't know the line between useful application and pure theory, so having someone around with a great deal of experience makes for a much faster learning process as their experience has taught them where to draw that line. I also have a desire to make an impact on business decisions, so I often ask myself, will what I'm doing or studying ultimately make an economic difference or at the very least, substantially reduce our risk profile.

Hailey: You have experienced significant changes in the way geophysical issues are approached. From the deterministic (model-based approaches)

Interview continued on page 44.

Interview continued from page 43.

in which geophysics is considered a science where there's always a unique solution, to the statistic in which the techniques used (AI and big data) aren't always based on physical models and the result can be a range of possibilities. I'm curious on how this shift in practice has been perceived by the young generations. Can you comment?

Andrew: While I am strongly in favor of using statistical methods for solving a wide berth of problems, I have a great appreciation for underlying physics and deterministic solutions. I often worry that many younger geophysicists are losing touch, or never get enough exposure, to the model-based deterministic approaches that carried the field for so long. We need to train geophysicists to approach problems using simple physics-based models so they have an physical understanding to their solutions. Physical models allow us to extrapolate, but machine learning only reliably interpolates. As geophysicists, we love new technology and using the best models, so sometimes we jump to the most complex solution without considering the simplest option may be the best and most cost-effective option. I also see applications of machine learning being overused and overstated in technical conferences due to a lack understanding of the statistical limits of these algorithms. Machine learning has the potential to solve many complex multivariate problems in geophysics, but as a community, we must be more discerning of what is useful and what is incorrect or exaggerated.

Hailey: You are said to be a skilled and creative geoscientist. Can you comment on the role that these qualities play in advancing a career, or on how these can be best combined?

Andrew: Being knowledgeable in your field helps earn the respect and trust of your colleagues as well as gives you the ability to take on more important projects in your career. Skill comes with practice, and creativity is more of a result of restlessness with the status quo. Most of my skill is just a result of putting many hours into my own personal development and learning subject areas that seem to be impactful in geophysics. If someone else can learn or do something, then with the right tenacity, I believe I can too. If I run into a problem that I cannot solve using conventional software, I create my own. I developed my programming skills early-on, which allows me to create custom solutions to some of the complex problems I encounter. I would encourage young geophysicists to not only question the norm, but to do something about it.

Christmas 2018

Hailey: You have been working in the industry for five years and you are now a Sr. Geoscientist. What are your expectations for the future? How would you like your career to progress?

Andrew: I just completed my first major career move coming to Ensign, so my near-term goal is to help grow this company to its highest potential. I hope to continue to expand my knowledge, especially on the business side of the industry, but also continue to utilize geophysics in our exploration and development programs in new and exciting ways.

Interview continued on page 45

Interview continued from page 44.

Hailey: You have worked in several companies. What do you look for in a company?

Andrew: I like working at a company that is small enough that my decisions make an impact on the success and failure of the company. I also really enjoy working with smart and creative people that are never complacent. I think a culture of constant improvement is required in oil and gas for a company to be successful. I really enjoy being given creative flexibility and having the trust of my colleagues.

Hailey: Building on the last question: so far in your career you have worked for more than just one company, how/when did you know when it was time to move on from one to the next?

Andrew: Since I've worked for one company for most of my career, my latest career move is really my first voluntary change. I spent much of the early part of my career developing my experience in geophysics, geology, engineering, and business and being at a larger company gave me the resources to build on those skills. While I was happy in my position, I was given the opportunity to work at a small, privately backed company where my influence would be much more substantial. I saw great potential in the people at Ensign and felt I could meet the challenge to help build a successful oil and gas operator.

Hailey: Are there any major trends that you have seen in the industry so far? If so, have any of them been things that you expected, or have you learned things that you weren't anticipating?

Andrew: In geophysics specifically, I have seen a surprising drop in the use of seismic data, but fortunately there are still many creative young geophysicists pushing the field forward in unconventional resource exploration and development. Every year I seem to pick up a different skill I did not expect to develop in order to solve new problems.

Hailey: You started you career at a very rocky period in the industry. How did you handle those challenges and what did you do to stay motivated?

Andrew: I was fortunate to have a job before I graduated, so I was able to start on better footing than many of my colleagues. My first 5 years contained a lot of change. I had to relocate my family several times, and I was lucky have a very supportive wife who uprooted her career multiple times and stuck out those tough moves with me. These moves not only ensured that I kept a job, but also allowed me to work at offices that provided opportunity for active hands-on experience and career growth. I tried to ensure that I had mentors who were invested in my growth and who kept me motivated. I also kept myself well-versed in the most relevant issues of the time by attending conferences and networking. I had to ensure that I was never complacent and was always learning and growing. Having good friends and colleagues to turn to is extremely important; they can be great resources for help or guidance. Most importantly, I try to stay grounded with my life outside of work and spend plenty of time with family and friends.

Hailey: Wow! You are a busy guy with a lot on your plate, so again we greatly appreciate your time and efforts put forth for this interview. I enjoyed the conversation, and I think many folks will appreciate your unwavering passion for your career and optimistic outlook on life. We all wish you the best of luck in your life and career. □

The Mystery Item
on page 41
is a
Gravity meter cut-a-way
from 1939,
made by
Lacoste and Romberg.

Join us at the Geoscience Center for:

2019 Inaugural **GSH FALL FORUM**
The Business of UNCONVENTIONALS

On **Friday, November 1**, the GSH held the first inaugural **Fall Forum on Unconventionals** at the Norris Center. This event resembled a mini-URTeC, which was by design given the success URTeC has had representing the unconventional industry and promoting the philosophy that integration among primary oil and gas professions is the only way we will make headway in that play. Thus we put together a high quality group of experts whose primary task was to address two fundamental questions about unconventional plays:

1. Are unconventionals economically sustainable? If they are, how does geophysics play a role?

2. What techniques and technologies do we teach early career professionals and college students who wish to go into this play?

Both of these topics were in hot debate at the 2019 URTeC held in Denver on July 22-24, so we felt it would also be of great interest to the Houston oil and gas community. To address these topics from

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Fall Forum continued on page 48

Fall Forum continued from page 47.

a strategic level rather than a technical level, we collected a team of speakers that consisted of a President and CEO, an EVP, a VP, three Directors, a Manager, and an Engineering Advisor from an operator, several service companies, two academic institutions, the Bureau of Economic Geology and an engineering firm.

Rob Stewart, U of H professor, Director of Allied Geophysical Lab, and SEG Past President, led off with a discussion about the state of geophysics in academia which as one would imagine is in dire straits due to the recent oil and gas downturn, and what must be done to salvage student programs (namely, internships and other forms of support by oil and gas companies as well as professional societies such as the GSH). Georgina Scorer, Director of Unconventional Reservoir Excellence at ConocoPhillips, described Conoco's philosophy that earth sciences are required to understand the subsurface and that unconventional plays would not be successful without their integration with engineering disciplines. Ge Jin, Co-Director of the Reservoir Characterization Project at the Colorado School of Mines, reviewed the various technologies CSM is teaching students in the earth sciences to prepare them for professional life in the industry, including compressive sensing, fiber-optic sensing, and machine learning techniques. Emery Goodman, Manager of the Tight Oil Resource Assessment Project with the Bureau of Economic Geology, described the TORA project and its main findings, which involve resource assessments of the main unconventional basins in Texas. For instance, this

Fall Forum continued on page 49

Fall Forum continued from page 48.

project is updating the technically recoverable resource estimate for the Midland Basin Wolfcamp A and B to be between 35 and 52 BBO. Seems these estimates keep growing every time another study gets published.

After lunch was a packed afternoon. One of the highlights of the day was Bernadette Johnson, VP of Strategic Analytics at Drilling Info, Inc., who dazzled everyone with a slide deck packed with statistics, trends, political assessments, and predictions for the future of energy production and consumption around the world. Following her post-lunch talk was a panel discussion involving the relationship of geophysics and engineering. Each of the three panelists first gave a 15 minute talk on their main points followed by a moderated panel discussion. George King, well known engineering advisor with Viking Engineering, issued the dire warning that engineering of lateral fact that microseismic is a key technology needed to help quantify this problem as well as providing intelligent ways to solve it. Katja Akentieva, EVP of Onshore Seismic and Well Data Products at TGS, reviewed the new business models of multi-client data and how these can be of use to make high-quality seismic data available to more operators in a cost-efficient manner, which by its very nature would help resolve some of the unknowns for operators who otherwise would not be able to afford seismic data.

I would like to thank my planning committee, without whom this event would not have taken place. That committee consisted of Erkan Ay, Whitney Blanchard, Karen Blakeman and Kathy Sanvido. We look forward to bringing you another Fall Forum on Unconventionals should the GSH membership desire us to do so. □

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Doodlebugger Diary

GSI Widens Its Horizon in Offshore Tests

By Roger Tickner, GSI, 1982

Recounted by Scott Singleton

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. During the last two years I've been recounting my own experiences but last June I shifted to publishing three episodes of SEG Past-President Nancy House's experience in the Peruvian jungles. Last fall I started reprinting a series of early 1980's articles from the GSI Shotpoints. These newsletters are among many archived GSI publications maintained by Bill Boettcher at http://gsinet.us/.

It is GSI's policy to remain at the forefront of technology in the seismic data collection, processing and interpretation field, which implies an active role in research and development.

As a part of this role, a group of Dallas-based engineers and geophysicists recently captured the M/V Ross Seal and made it the focus of their attention for a series of sea tests in the Gulf of Mexico.

The vessel spent several days at dockside in Galveston whilst modifications were made to the airgun array handling facilities to improve the wide tow capability. Also, some instruments in the doghouse were "rearranged" to make way for LeBarron Kinard's new TIGER II airgun controllers, our airgun pulse measuring equipment, and additional recording and plotting devices.

An experimental airgun array, the appearance of which raised everybody's eyebrows, replaced the standard 4075-cu-in. array, and a brand new 120-trace streamer was reeled on board.

The whole master plan was put together very efficiently by Carl Smothers, who produced and distributed a well-documented manual of instructions nearly half an inch thick. It became the best-read book on board over the next few days. Dockside modifications were supervised by D. J. Whitman, with the back deck in the care of Bill Kennedy and the doghouse watched over by yours truly.

Fig 1: Let wide tow broaden your horizons. The M/V Ross Seal with outriggers on the stern to allow airgun arrays to be towed some distance from each other.

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If you would like to add stories to the Doodlebugger Diary, send them to: Scott Singleton at scott.singleton@comcast.net ***or mail them to Box 441449, Houston, TX 77244-1449***

Doodlebugger continued from page 51.

Expeditions of this nature are always something of an adventure, as new ideas are tried, tested and analyzed. Close cooperation is necessary between the ship's crew, the regular seismic crew and the experimental party. The vessel undergoes a variety of unusual maneuvers, which the mate, Ric Smith, enjoyed, whilst engine loading and fuel consumption under the new conditions is checked out so the impact of converting the whole fleet may be computed. This brought the chief engineer, Robert Roberts, and his second, George Hutchins, into conversations they don't normally have.

It was a credit to the personalities on board that excellent coordination was obtained at all times. Paul Johnson organized the navigation and ran the night shift for us when we got through those chores for which we did not need daylight.

Two pulse tests took place involving three separate array concepts. Willie Karhu, George Blair and Eric Fye had their work cut out keeping the complex systems in working order and changing systems over efficiently so valuable time was not wasted.

Boyce Taylor came back out of retirement to run the pulse test equipment, which was also more complex than usual, as we were comparing two separate systems. Mick Stormonth, a pulse tester par excellence, also lent a hand.

Bob George rode with us and brought with him Harry Harrison's newest airgun. This was tested in action, but Bob insisted on a second line being attached to the gun when it was deployed at depth, for if it had been lost, he would have dreaded the return to Dallas with the news! However, we all took great care that no such disaster should occur.

Safety was an important aspect of the trip. Experimental rigs are generally more delicate than proven production versions, and because some equipment is being deployed for the first time, there

Fig 2: A steel dolphin leads an airgun string. These floats were used to guide the arrays and to provide for their added visibility.

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Doodlebugger continued from page 52.

remains the unthinkable risk of a miscalculation somewhere leading to a serious accident. Appropriate safety meetings were held and each day's activities discussed. By a process of careful planning, using experienced people and taking each new step cautiously and with vigilance, a 100% safety record was maintained.

Fig 3: Carl Smothers, Bill Kennedy, D.J. Whitman and Willie Karhu confer on the boat during testing.

Things did go wrong, of course. With a complex experiment, something always does. But at no time was hand or heart put at risk. It was refreshing and encouraging to watch a heavy equipment deployment, which on the first attempt looked hazardous, appear routine and safe after a few practice runs to give the experts the opportunity to work out the methodology. We all are looking forward to fleet deployment of this state of the art equipment which undoubtedly will lead to our continuing reputation in the industry as the leader in acquisition technology. □

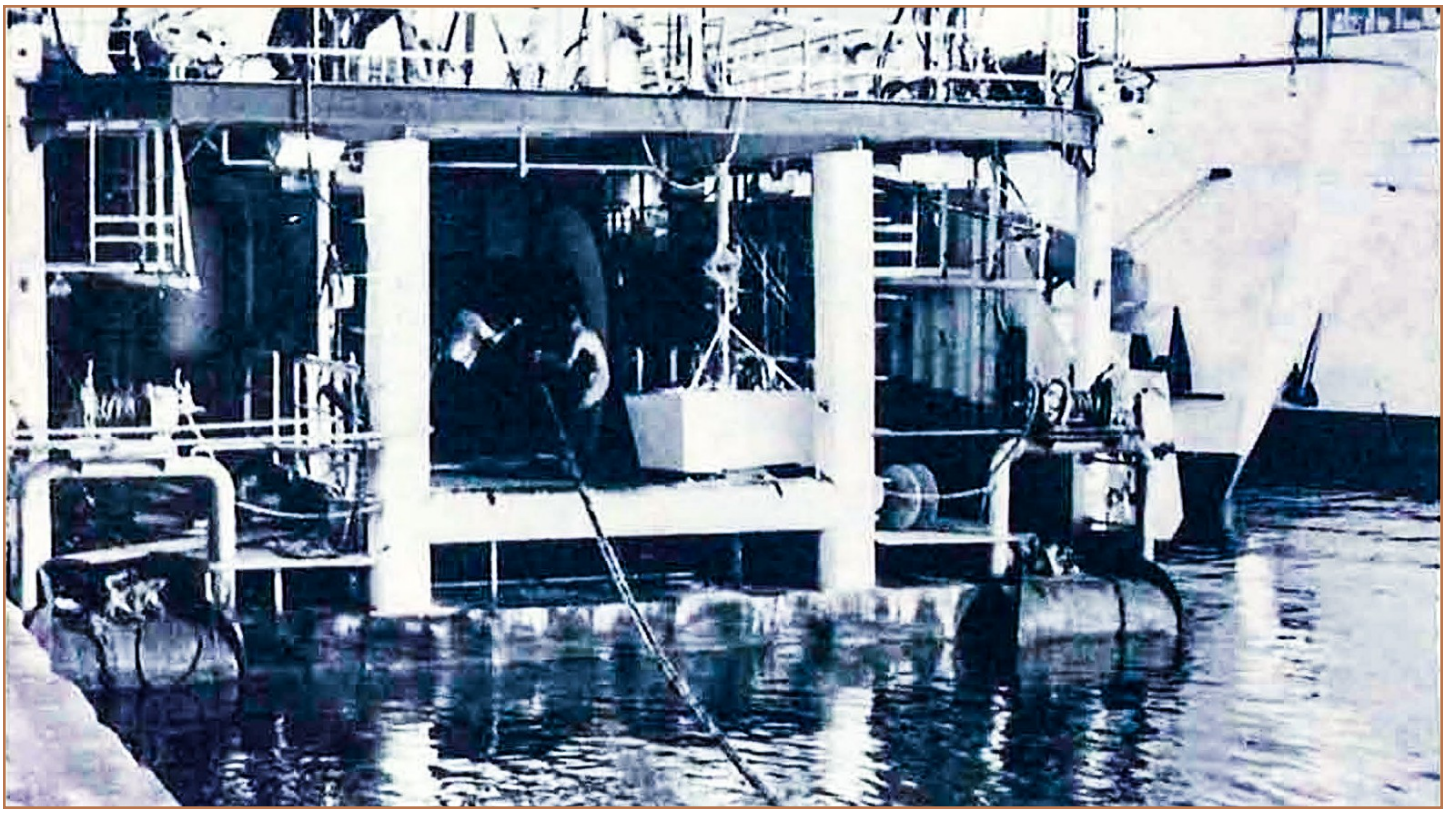

Fig 4: Loading the new dish-phone 120-trace streamer through the back deck of the M/V Ross Seal in Galveston.

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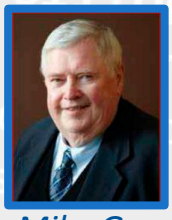

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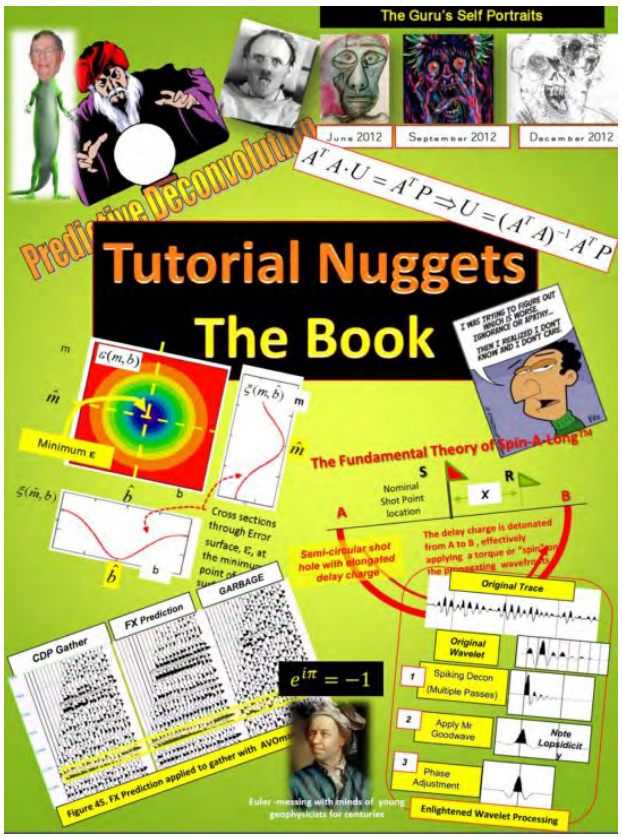

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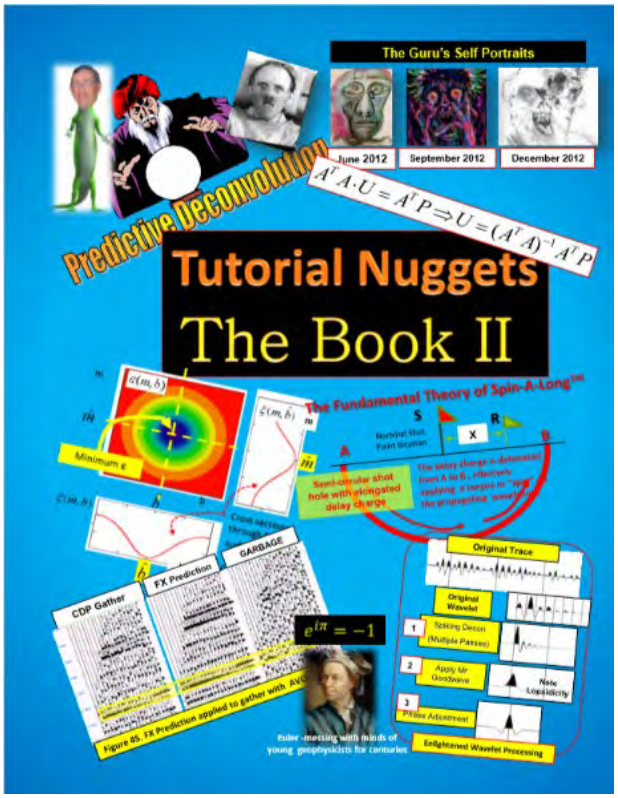

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