November 2017

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 8 • Number 3

The Epicenter of Geophysical Excellence

TABLE of CONTENTS

MEETINGS

FEATURES

CHECK THIS OUT

LOOK INSIDE

On The Cover...

Seismic Surveying - Tunisia.

Photo Courtesy of WesternGeco.

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

Jan 2018 ..... **Nov 8**
Feb 2018 ..... **Dec 8**
Mar 2018 ..... **Jan 8**

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A Word from the Board

Attracting the Younger Generation

By Lillian Comegys, Secretary

Over the past several months that I have been on the GSH Board of Directors, a recurring topic has emerged in our monthly meetings: how can the GSH attract the younger generation of geophysicists to participate in the society? As the youngest member of the board I also have contemplated that question: what do my contemporaries want from a professional society membership? What do they need?

I created a short survey asking these very questions and sent it to several young geophysicists. A third of the respondents are not members of the GSH, and they all gave the same explanation, "I am a member of other societies and don't have enough time". From those that are members, almost everyone admitted to rarely participating in GSH events. There are several articles on the internet concerning millennials and professional organizations with much more intensive survey research. One article mentions that 58% of young professionals are members of a networking organization; however, the majority of those prefer those led by their peer group. What does this mean for the GSH? In order to attract the younger generation of geoscientists, we need to first enlist the ones already members of the GSH to become more active participants and take on roles of responsibility within the society.

The majority of my survey respondents reported they were members of these types of professional societies for continuing education opportunities. I believe that this is reflected in the overall success of the webinars. That being said, I think the importance of networking events should not be overlooked. Icebreakers, sporting clays and golf tournaments are a way to connect our community to serve in both good times and bad. These opportunities need to be promoted not only with the advertisements on the GSH website and monthly journal, but also from within each member's company. If you are a manager or a mentor, encourage your younger employees to attend the technical luncheons, breakfasts, or Special Interest Group presentations. Make sure they are informed of the online material on the GSH or SEG website, or the literature available at the Geoscience Center here in Houston. I have had the extreme good fortune to be surrounded by superiors that push me towards involvement in the GSH and SEG.

Lillian Comegys

In all honesty, several of the people that took the quiz skipped all but the first question (Are you a member of the GSH?). What does this say about my generation of geophysicists? That we don't have the time? Or that we simply don't care? This is the challenge that we are facing: as a society, we need to create a passion for geophysics and the geophysical community that extends beyond the normal working hours. I challenge every person reading this to think on this topic and provide feedback. How do we prove to the younger geoscientist community that the GSH is relevant to their career paths?

Dear GSH Journal reader,

Again, there is no letter to the editor this month, but that doesn't come as a surprise to me. Right now, I'm going to introduce you to a little time machine called the "Journal".

You might have already noticed that we are putting in a lot of time and effort to provide you with a great readership experience in the form of the GSH Journal. In order to compose a single issue, it usually requires at least 2 months of hard work from the authors, editors and publishers. (However most of the material comes from the regular educational and social events preparation/execution, done by outstanding GSH officers! These are the real heroes who provide us with great experiences and the material for the Journal.)

So here I am in September, slacking from my "real work" by writing this letter to you, while the great H-town is recovering from Harvey. There is no single person in Houston right now who hasn't been affected by this disaster. You have either been hit by it or are helping your friends and family who weren't that lucky. Maybe that's why you don't have time to write a silly letter to a lazy editor.

In this issue, we have a special article written by our president, Tommie Rape, sharing our experience of Harvey as a society. I also would like to highlight the Word from the Board section provided by Lillian Comegys. She raises some very important questions and I personally feel obligated to make changes in young people's perception of "old-fashioned" professional societies.

As always, I'm desperately waiting for your letters! Please, feel free to contact any of us with any and all questions or suggestions that you can come up with.

Sincerely,

Dmitry Kulakov

Living Legends Doodlebugger Quarterly Social Gathering

Thursday, November 9, 2017
9:00 A.M. – 12:00 NOON
At the GSH Geoscience Center

Our quarterly Doodlebugger event is coming soon!
Visit with colleagues and old friends and listen to tales of the oil patch.

Retired or nearly retired doodlebuggers, and their spouses are invited, as well as anyone who is interested in visiting our Geoscience Center.

Coffee, bottled water, soft drinks, and light snacks will be available.

This is a free event and no reservation needed.
Drop by for a short visit or stay for the whole morning and bring your friends!

We're located in west Houston, on Shadow Wood Drive, and you can get there by traveling about 1 mile NORTH from I-10 on the West Sam Houston Tollway North Service Road, past Westview, making a RIGHT TURN on to Shadow Wood at the Lone Star Breakfast and Grill and go 1/2 block. Look for the Geoscience Center signs and orange flagging. There is plenty of parking in front or behind the building.

If there are questions, contact Bill Gafford at geogaf@hal-pc.org

Technical Luncheons

Denoise and Residual-Signal Recovery

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Speaker(s): Stephen Chiu, Tao Jiang,
In-Depth Compressive Seismic, Inc.

Stephen Chiu, Ph. D

Tao Jiang, Ph. D

Westside

Tuesday, Nov. 14, 2017
11:00 a.m. – 1:00 p.m.

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

Downtown

Wednesday, Nov. 15, 2017
11:00 a.m. – 1:00 p.m.

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

Abstract:

Noise attenuations are imperative for extracting useful signal from unwanted noise. In this presentation, we examine two aspects of denoising: harmonic attenuation of sweep slips and recovery of residual-signal recovery using a pattern-based method.

There are various high efficient acquisition methods routinely applied in marine and land seismic survey, such as encoded source, HFVS, simultaneous shooting, slip sweep etc. We will focus on the slip sweep type of survey for land vibroseis. Traditionally slip sweep survey takes advantage of linear up sweep to separate second shot (the slip shot) from the main shot. The theory works well with synthetic, however in reality, the vibrator usually can't generate a clean linear sweep to the ground, but generate high-frequency harmonics of a different order from a fundamental sweep. As a result, the sweep cross-correlation/deconvolution will show high-frequency noise from the cross-talk between fundamental and harmonic sweeps. To get a harmonic noise free record before further processing, different methods are called for to handle the attenuation of harmonics. We will show our solution to attenuate this harmonic noise, which will work on both linear up or non-linear up sweep (cascaded sweep).

Biography:

Stephen Chiu received a BSc in Geophysics from University of Saskatchewan in 1980; MSc in Geophysics from University of Alberta in 1982; and a PhD in Geophysics from University of Alberta in 1985. He worked for several seismic service providers in Calgary as a research geophysicist from 1985 to 1997. From 1997 to 2015 he was employed by ConocoPhillips to further advance their seismic research. In 2016 he joined In-depth Geophysical, Inc. as the Principal Geophysicist. His research experiences spans all facets of geophysical software development and applications. His current research interests include bandwidth extension, migration, denoise, multiple-sourcing acquisition, and deblending algorithms. He has been a member of the SEG for over thirty years. He holds several patents and publishes over 47 publications.

Tao Jiang received BSc in Geophysics from Peking University, China in 2004; MSc in Geophysics from Chinese Academy of Sciences, Institute of Geology and Geophysics in 2008; and PhD in Geophysics from University of Houston in 2013. After graduation he worked as a geophysicist in Upstream Technology of BP America Inc. In 2016 he joined In-depth Geophysical, Inc. His research experiences and interests include seismic deblending and reconstruction, seismic modelling and migration, rock property characterization, seismic attribute inversion and effective medium theory. He is a member of GSH and SEG.

Technical Breakfasts

Processing Challenges in Unconventional Plays

Register for Tech Breakfast Northside

Register for Tech Breakfast Westside

Speaker(s): Mike Perz, TGS

Mike Perz

Northside

Tuesday, Nov. 14, 2017
7:00 – 8:30 a.m.

Sponsored by Anadarko Petroleum and Lumina Reservoir Inc.

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

Westside

Wednesday, Nov. 15, 2017
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

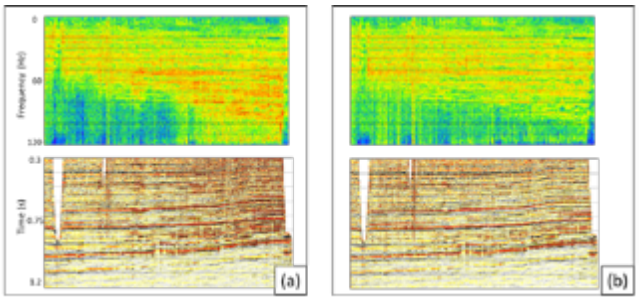
Fresh on the heels of the 2017 SEG workshop dedicated to the role of geophysics in unconventional plays, the present talk will consider a small, but important, subset of that workshop theme, namely seismic processing challenges which arise in unconventional reservoir development. While some of these challenges, for example the ubiquitous quest for higher frequencies, were earmarked as important topics long before the advent of the unconventional realm, others, such as azimuthal imaging and low-frequency preservation, have seen a relatively recent ascent to prominence correlating directly with the unconventional boom. Collectively these processing challenges have cast renewed focus on some existing tools and concepts (e.g., AVO-compliant processing, refraction statics, deconvolution and coherent noise suppression), while forcing rapid adoption of new technologies like 5D interpolation.

For example, the images below demonstrate the reinvigoration of an existing AVO-compliant processing algorithm known as surface-consistent (SC) amplitude scaling. Specifically, these images show the action of a novel type of SC scaling, essentially a frequency-dependent extension of the unbiased scaling approach of Nagarajappa and Cary (2015), applied to a dataset shot over the the Kansas Mississippian Trend. Figure (a) shows f-x amplitude spectra (top) and time-domain stack (bottom) before applying the scaling and Figure (b) shows the corresponding displays after scaling. Note the improved continuity in bandwidth and improved amplitude balancing on the stack in (b) after applying the new technique.

This talk will dissect a modern unconventional processing flow and examine key processing steps including the one shown in the above example. Real data examples will be shown throughout and the presentation will end with a candid overview of outstanding challenges.

Biography:

Mike Perz holds a BSc in Physics (University of Toronto) and an MSc in Geophysics (University of British Columbia). Upon graduating in 1993, he joined Pulsonic Geophysical as a seismic processing applications programmer, and four years later moved to Geo-X Systems Ltd. (later Divestco Inc.), first writing code then managing the processing R&D group. In 2010, Mike joined Arcis Corporation where he was employed as Vice President of Technology and Integration at the time that organization was purchased by TGS in 2012. He remains at TGS up to this day with a position of Director, Technology and Innovation, a role whose primary mandate is to demonstrate the value of seismic in unconventional resource development. Mike's research interests have historically spanned all elements of land processing, including deconvolution, refraction statics, interpolation, and azimuthal imaging. Mike served as Technical Chairman for the 2007 CSEG convention and has received several Best Paper, Best Presentation and Honorable Mention awards from both the CSEG and the SEG.



Data courtesy TGS

Data Processing & Acquisition SIG

A Novel Marine Exploration Method Offering True 4C 3D Full-Offset Full-Azimuth Full-Bandwidth Seismic Acquisition (FreeCableTM)

Register for Data Processing

Lionel Lhommet

Speaker(s): Lionel Lhommet, Kietta

Sponsored by Schlumberger

Tuesday, Nov. 7, 2017
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:

Traditional marine seismic acquisition methods (streamer, OBC) have reached some inherent limitations that are difficult to overcome. Some new methods such as nodes have been recently introduced but lead to a significant cost increase in opex due to their low productivity. The new patented method presented here combines the advantages of all techniques to offer excellent quality data in a very efficient manner. The presentation describes the method's background, its positioning compared to competing techniques, and presents the key advantages of this new concept.

Biography:

Lionel Lhommet received his formal education with a Master of Sciences degree in electronics and physics at Ecole Supérieure d'Electricité in Paris, as well as legal and finance at La Sorbonne University in Paris, completed in 2006 with a MBA at INSEAD-Cedep. He began his career in 1985 at CGG as Party Chief in Land acquisition seismic crews in Africa. In 1996 he has been appointed as Director of Petrosystems/Flagship, a subsidiary dedicated to G&G processing and interpretation. In 1999 he was appointed deputy Chief Operating Officer of Paradigm Geophysical. In 2003, he came back to CGG as R&D and Business Strategy Manager for Land and Shallow Water seismic data acquisition, and following the merger with Veritas he became head of EAME and APAC regions, managing 3200 staff with 1900 M$ annual Revenues with onshore & offshore seismic acquisition and 32 Data Processing centers. In 2010 he has been promoted to CGG Executive Committee as Director for all CGG/Sercel business worldwide. On April 2015 Lionel resigned from the Executive Committee to join Kietta, a start-up having developed a prototype of very innovative automated offshore seismic data acquisition technology: FreeCable.

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Potential Fields SIG

Residualization of Gravity Anomalies by Geodetic Harmonics

Register for Potential Fields

Speaker(s): E. Stephen Erck Ph.D., Consultant, Geordinates® Inc.

Thursday, Nov. 16, 2017
5:30 p.m. - 8:00 p.m.

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

Abstract:

A sequel to REGIONALIZATION OF GRAVITY ANOMALIES BY GEODETIC HARMONICS given by the same presenter March 17, 2016, the theory of geodetic (spherical and ellipsoidal) harmonic global geopotential models for determination of the regional (long wavelength) components of gravity anomalies is summarily reviewed.

The Multiquadric numerical solution to the (harmonic) Laplacian Equation in geodetic coordinates supplements this spectrum more locally to avoid computational limitations of the global models Legendre Functions. More applicably onshore, tests of Multiquadric fits of diagnostically-selected stations of total wavelength gravity anomaly data yield regionals and residuals more representitative (by 30% and 36%) of optimally-drill- derived data. Therefore all evaluations increase accuracy of such residual-based anomaly inversions to concur with the superior geophysical objectivity of geodetic harmonics over more subjective conventional methods.

E. Stephen Erck Ph.D.

Biography:

Steve has provided professional geoscientific operations, research and development for 37 years primarily as a geophysicist and geodesist. After a B.S. from Purdue University in 1981, he entered upstream oil and gas for Superior Oil and Mobil Oil Exploration and Producing Southeast Inc. Mostly defense navigation software development followed his 1989 M.S. from Iowa State University. After a Ph.D. from Texas A&M University in 2004, he then resumed prospect generation with Coastline Exploration Inc. before more potential fields work for Fugro Gravity and Magnetic Services until consulting starting 2011 for Geordinates.

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nmaitland@resolvegeo.com - 713-972-6209

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Sponsored Jointly by the SEG and GSH

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Azimuthal P-P for better Imaging, Fractures & Stress Analysis

Acquisition, Processing & Interpretation

Presented by Dr. Heloise Lynn

SEG
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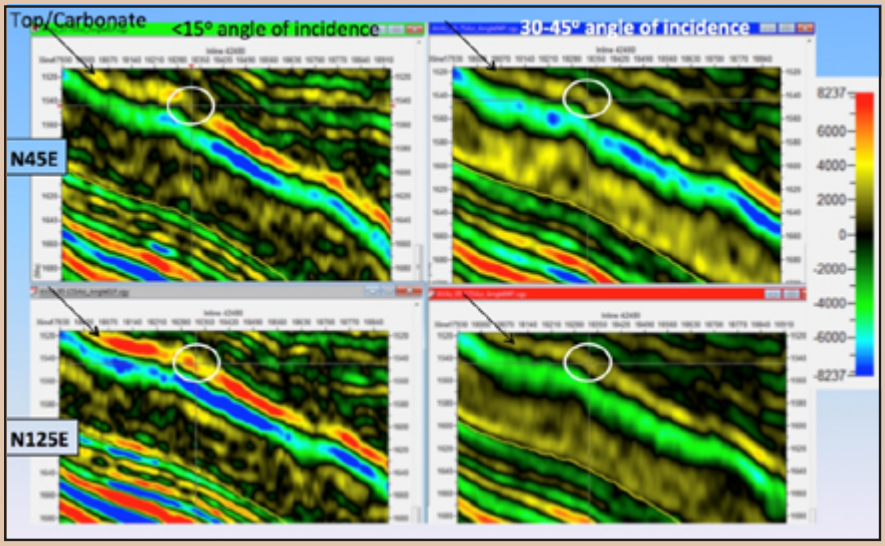
GEOPHYSICAL SOCIETY HOUSTON

Four Half-days (10 AM - 2 PM) December 6, 7, 13, 14, 2017



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6535 Dumfries Dr.

Validating 4D Seismic With Reservoir Surveillance Data: A Practical Example Offshore Equatorial Guinea, West Africa

By Chance Amos, Prabhdeep Singh Sekhon, Mosab Nasser, and Jaime Casasus-Bribian, Hess Corporation*

Summary

This case study describes the impact of integrating time-lapse (4D) seismic data with reservoir surveillance and production data for the Oveng field area of Okume Complex Field, located offshore Equatorial Guinea, West Africa. Aging assets on production decline can greatly benefit from 4D seismic to determine infill drilling locations as well as support reservoir management practices, but only when the seismic data has been validated against multiple other datasets to produce

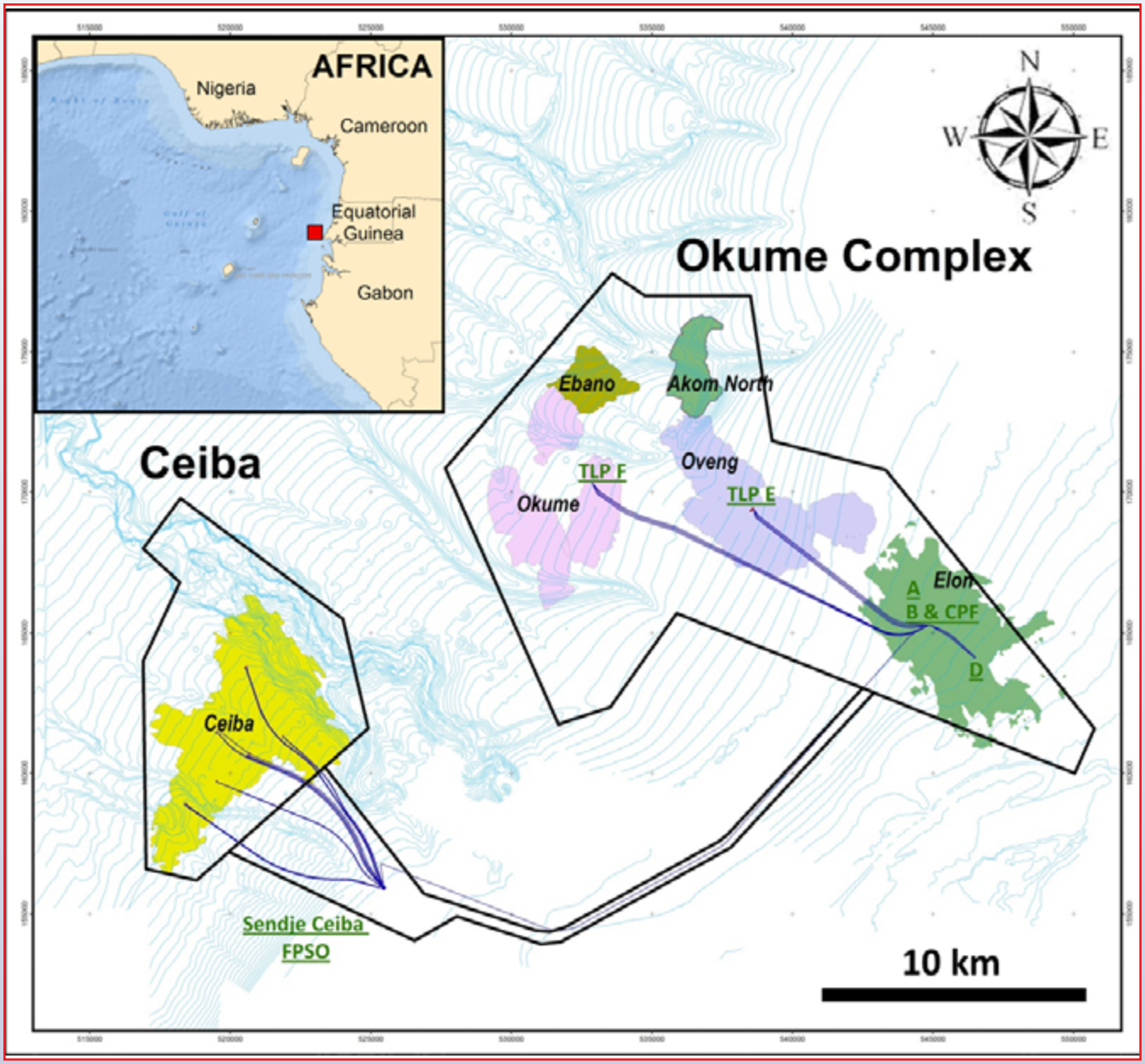

Figure 1: Location of Okume Complex, offshore Equatorial Guinea

Technical Article continued on page 14.

Technical Article continued from page 13.

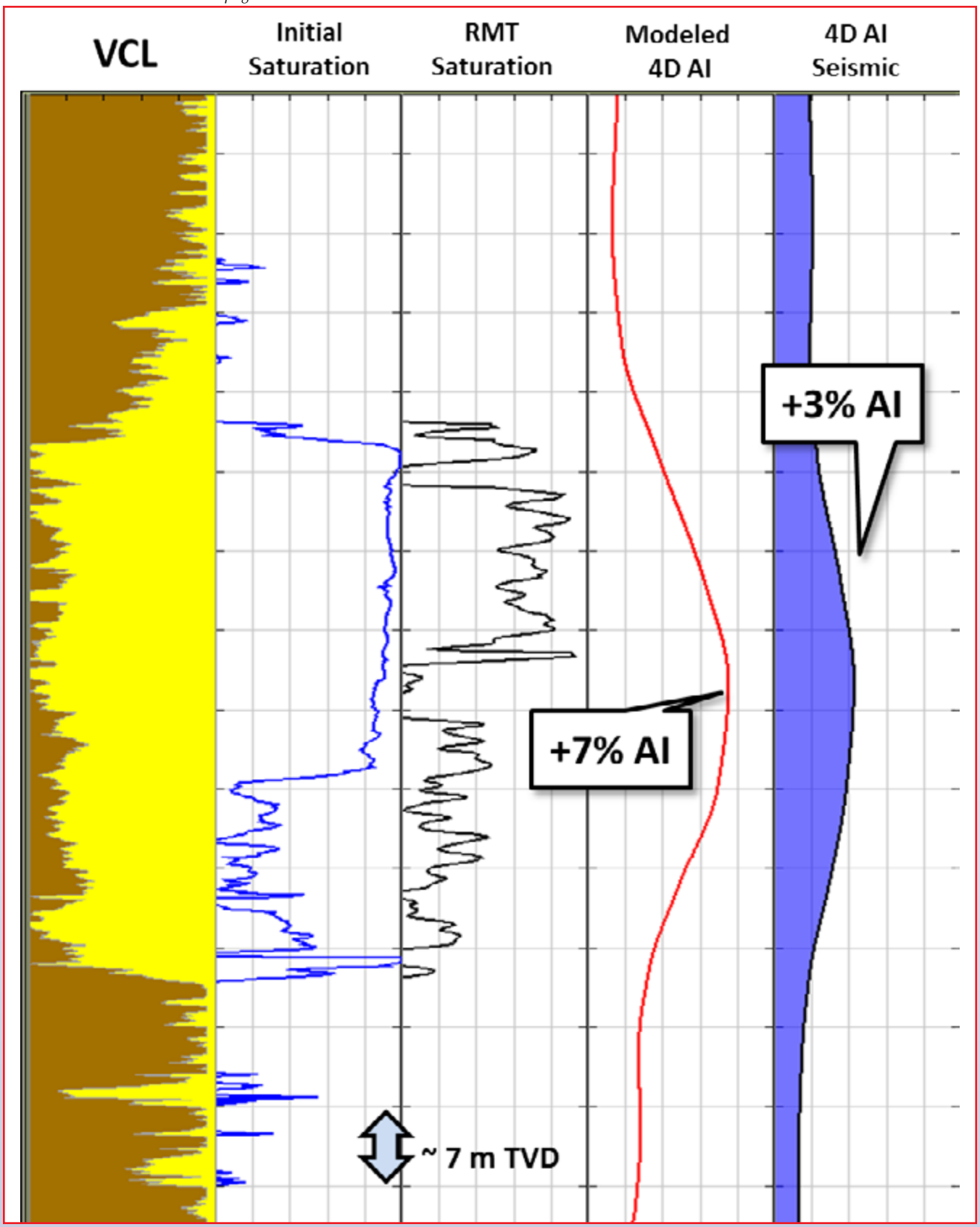

Figure 2: Forward modeling example showing volume of clay, initial logged water saturation, RMT water saturation, the modeled change in acoustic impedance based on the change from initial to RMT water saturation, and the change in acoustic impedance from seismic inversion. Note the 4% difference between the modeled response and seismic response.

Technical Article continued on page 15.

Technical Article continued from page 14

a robust interpretation. This case study describes a multi-disciplinary, collaborative effort towards validating 4D seismic with historical production data along with field surveillance data such as repeat saturation logs, and highlights examples of providing new information for building a more accurate geomodel as well as influencing infill well planning and drilling. The key message is that once all data have been screened and integrated, informed decisions can be made to optimize the value of the asset.

Introduction

Time-lapse seismic data has proven effective in reservoir management and future production planning (Huang et al., 2011; Gainski et al., 2010; Ebaid et al., 2009; Mitchell et al., 2009; Gonzalez-Carballo et al., 2006). It has also proven to be a critical piece of data at the Okume Complex, located approximately 30 km offshore Equatorial Guinea, West Africa, (*Figure 1*). The producing interval consists of very high-quality, quartz-rich Campanian-aged sandstone deposited within slope-channels in a moderate to weakly confined submarine canyon setting. The complex nature of the deposition coupled with syn-depositional faulting has created a very intricate network of dynamic connections as well as barriers and baffles throughout the reservoir. It has been noted that understanding the baffles and barriers within the reservoir is a prime component in accurately modeling dynamic flow behavior (Beaubouef et al., 2011). The goal of 4D seismic data is to enhance this understanding throughout a producing field by observing pressure- and saturation-induced changes to the recorded seismic signal, however the 4D seismic signal alone can produce non-unique interpretations. By working across disciplines and integrating multiple datasets, a robust interpretation of baffles, barriers, and overall internal dynamic behavior can be achieved with the goal of identifying infill drilling opportunities and enhancing our reservoir management practices.

Data

Eight exploration and appraisal wells were drilled and logged in the Oveng field area and one conventional core was acquired. This was followed by seven producing wells and five injection wells over two phases of production drilling.

Three seismic surveys were used in this study: A pre-production Western Q-marine survey acquired in 2003 followed by two monitor surveys acquired in 2010 and 2014. Excellent repeatability was obtained throughout both monitor surveys in areas not affected by infrastructure. Moreover, the absence of a geophysically complex overburden coupled with the relatively shallow depth of the reservoir aid in yielding excellent data quality. In addition to careful data acquisition, high-quality seismic processing is paramount for detailed time-lapse interpretation.

A 3D/4D rock physics inversion was performed on the seismic data with excellent results. Elastic properties were mapped into reservoir properties such as clay volume, porosity, and hydrocarbon saturation, and these inversion products were used to successfully characterize the reservoir at a neighboring field (Marler et al., 2014). The accuracy of these inversion products is calculated at 82%, an 11% increase compared to other methods of seismic pay identification (Nicholls et al., 2014). While inversion has proved very successful at predicting static reservoir conditions, this study aims at validating the time-lapse seismic inversion products with non-seismic related reservoir surveillance data to better understand dynamic reservoir behavior.

Geological complexity has been apparent throughout the development and production phases of the Okume Complex, leading to several uncertainties regarding well connectivity. To address these uncertainties, the subsurface team has employed several well surveillance techniques including production trend analysis, pressure interference tests, tracer analysis, capacitance resistance modeling (Parekh et al., 2011), and reservoir saturation logging. This reservoir saturation logging occurred at approximately the same time as the 2014 4D monitor seismic survey, leading to a natural integration opportunity.

Methodology

Initial steps included a multi-disciplinary data screening for accuracy and reliability. Some of the data challenges faced by this study included co-mingled zonal production and infrastructure-related 4D seismic data gaps. This screening ensured that the extensive production, pressure, logging and seismic data for the field was integrated to provide a high quality dataset for further study.

Various models were utilized to relate reservoir surveillance information to the seismic data. Changes in elastic properties of the reservoir due to fluid saturation changes can be confidently modeled using Gassmann's equation (Gassmann, 1951) or modified variants thereof. Additionally, methods are available to model the effect of changing pore pressure on the rock frame and subsequent seismic response (Macbeth, 2002; Smith et al., 2004). A qualitative compendium can be developed to relate the observed 4D seismic signal to reservoir changes due to production (i.e. saturation and pressure changes), however these basic models are non-unique. For example, an observed softening (decreased impedance) could be caused by a decrease in pore pressure below bubble point such that gas comes out of solution, or could be caused by an increase in pore pressure such that the rock frame becomes more compressible due to weakening grain contacts. Thorough calibration and data integration is the basic methodology used in this study, and is required to move past a qualitative model and make an impactful interpretation of time-lapse seismic data.

To calibrate the 4D seismic signal, a detailed quantitative modeling exercise has described the expected elastic response to production and injection at the wellbore. *Figure 2* illustrates

Technical Article continued on page 16.

Technical Article continued from page 15.

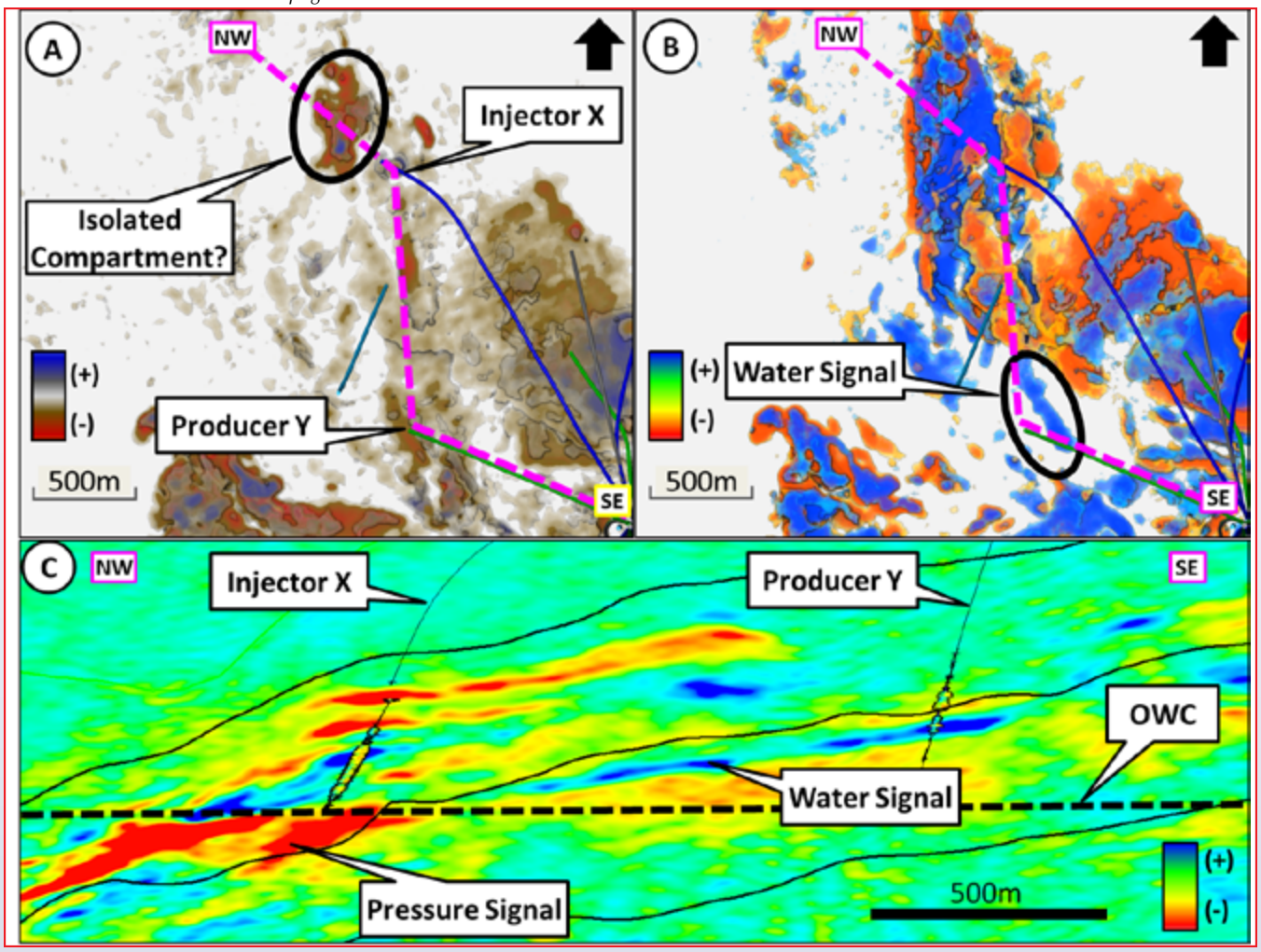

Figure 3: Opacity rendered map view of A) full stack 4D seismic response and B) acoustic impedance 4D response in the reservoir section. Note the increased impedance (blue) feature leading towards Producer Y. Line C displays the 4D acoustic impedance response between Injector X and Producer Y. Note the softening (red) below Injector X and the hardening (blue) observed near Producer Y.

forward modeling the change in logged reservoir saturation from repeat logging as well as the change in reservoir pressure into a change in acoustic impedance (AI). Forward modeling was conducted at several well locations and compared to the change in seismic AI. This difference in AI change was used to provide a calibration point for quantitative interpretation of the observed 4D seismic. This data was then coupled with additional reservoir surveillance data such as pressure trend, salinity, and tracer analysis to develop a more robust interpretation of dynamic reservoir behavior.

Analysis and Discussion

The following example highlights the use of calibrated 4D seismic in reservoir management. The X injector in *Figure 3* was completed in 2010 intending to support updip production wells. However, injection water tracer has not been observed at the producers, and a pressure connection was not obvious with existing data. An initial look at the 4D full stack seismic data displayed a large signal outboard of the injector and isolated from the production wells (*Figure 3A*). This observation was interpreted as injection into an isolated compartment. The 4D signal also highlighted several faults in the area which appear to be baffles or barriers to fluid flow, information which was then used in dynamic reservoir modeling. Once the 3D/4D rock physics inversion was completed and the elastic responses calibrated to production information, a more quantitative interpretation of the 4D signal was possible.

While both increasing and decreasing AI signals were observed in the vicinity of the injector, increasing AI interpreted as water replacing oil above the oil-water contact (OWC) and decreasing AI interpreted as increased pore pressure below the OWC, a narrow channelized feature displaying a water-replacing-oil signal was observed leading in the direction of producer Y (*Figure 3B*).

Through the aforementioned calibration, the increase in AI corresponds to ~40% increase in water saturation. The confinement of water flood coupled with the placement and

Technical Article continued on page 17.

Technical Article continued from page 16.

interpreted transmissibility of faults were updated within the reservoir model, leading to a more accurate representation of the subsurface. However, further data integration was needed to fully explain this injector-producer pair.

A water signal was observed on the 4D AI leading from the vicinity of injector X towards producer Y, yet an injection water tracer connection has not been established. Produced water salinity data from producer Y shows a higher salinity value than other producers in the field area being supported by injection. A closer inspection of the 4D AI data shows that the water signal observed at producer Y does not connect directly to injector X, but appears to connect to the softening (interpreted as increased pore pressure) which occurs below injector X in the water-leg. This is interpreted as injector X supporting producer Y via an aquifer connection, which agrees with the salinity data. To further understand connectivity, the team initiated a pressure interference study by shutting in injector X. The test confirmed a pressure connection and validated the team's interpretation. With this in mind, injector X was returned to injection to continue to support producer Y.

Continued time-lapse seismic acquisition has also proven useful in evaluating future infill drilling opportunities. A location of interest was identified after the 2010 monitor survey indicated an apparent isolated compartment (*Figure 4A and 4B*). A minor 4D AI softening was observed, but was near background amplitude level and considered insignificant. This compartment was interpreted to be stratigraphically sealed from the adjacent producing interval, and lies between an injector-producer pair. However, the 2014 monitor survey displayed greater 4D signal at the location of interest, and compartment connectivity was called into question (*Figure 4C*).

The 4D rock physics inversion products coupled with reservoir surveillance data were instrumental in describing this dynamic behavior. Two plausible interpretations could explain the observed 4D signal in the prospective area; depletion from a nearby producer causing gas out of solution and reservoir compaction or increased pore pressure overlying a water signal due to nearby injection. Reservoir surveillance data shows a pressure as well as tracer connection between the straddling injector-producer pair, and confirms that no significant amount of gas has been produced. Based on this integration, the prospective area is interpreted to be experiencing basal sweep as well as increased pore pressure due to injection. Based on our modeling, this increase in AI corresponds to a ~30% water saturation increase. The decrease in AI observed in the updip portion of the prospective area corresponds to 400 psi increase based on modeling, which directionally agrees with reservoir pressure information from the nearby injector.

Conclusions

Time-lapse seismic data has proven very successful in aiding interpretation of reservoir behavior under producing conditions. Careful acquisition and processing of 4D seismic coupled with calibration to production and surveillance data is paramount for making an informed, quantitative interpretation of the time-lapse data. This study showed the successful integration of seismic, reservoir saturation logging, salinity data, pressure trends, and tracer analysis to develop a robust dynamic reservoir interpretation. By understanding and integrating multiple datasets, impactful decisions can be made with respect to reservoir management as well as infill drilling.

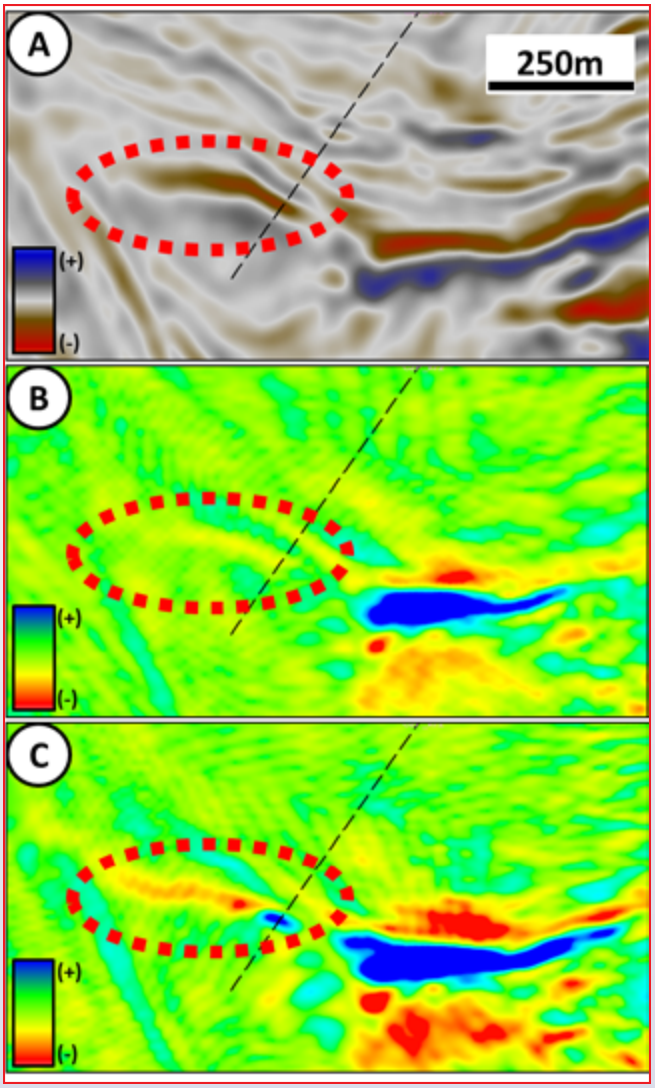

Figure 4: Cross section view through infill well location of A) full stack seismic data, B) time-lapse acoustic impedance of 2010 monitor survey, and C) time-lapse acoustic impedance of 2014 monitor survey.

Acknowledgements

The authors would like to thank the Equatorial Guinean Ministry of Mines, Industry and Energy (MMIE), Hess Corporation, GE Petrol, and Tullow Oil for permission to publish this study. Additionally, Qeye Labs for their RPI products and many of our colleagues for their hard work and insightful comments that made this project successful.

Technical Article continued on page 18.

Technical Article continued from page 17.

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Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 32.

U of H Wavelets

SEG Wavelets and AAPG Wildcatter's Summer Intern Panel Reflection

By Claire Ong

On September 15th, SEG Wavelets and AAPG Wildcatters hosted an intern panel to discuss the experiences and tips that six graduate students had to offer regarding their summer internships this past summer. Every speaker had a small five to ten-minute presentation that included a brief description of their main tasks, challenges, and recommendations.

Challenges faced during internships

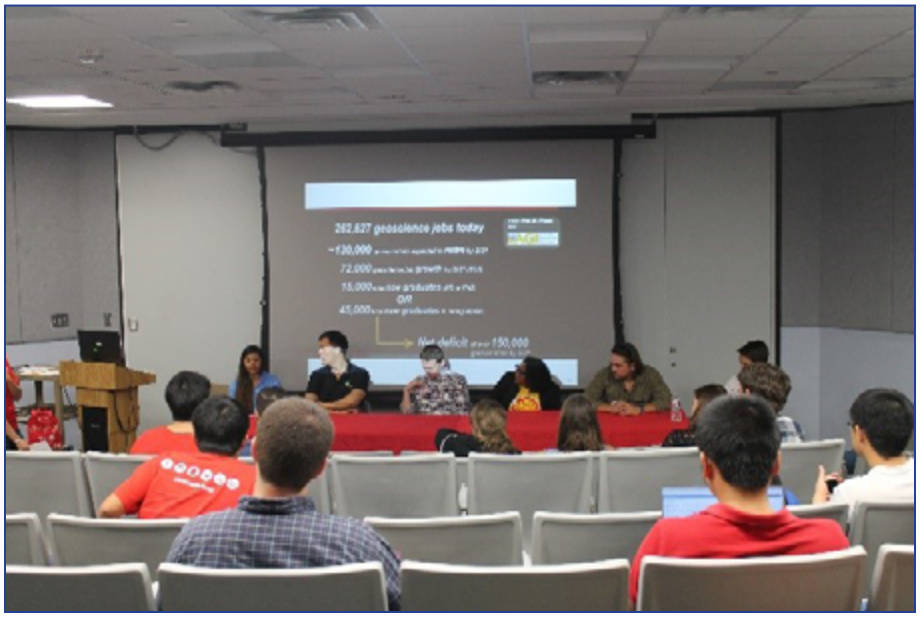
Each speaker had different challenges that ranged from struggling to simultaneously intern and do graduate research and to being able to communicate and understand information shared by completely different disciplines.

The companies interned for were Kosmos Energy, BP, Total, Shell, Geokinetics, and Southwestern Energy. While the tasks and challenges the speakers were given differed from each other, there was an overall agreement that their goals were to communicate and network with other people, be well-rounded in other connected fields, and develop and improve technical abilities.

Reflections

At the end of all the presentations, the speakers sat at a table in the front of the room and answered questions from the audience in a way that compared and contrasted their experiences.

One of the audience members asked, "Is it better to work in a large company or a small company?" Walter Reed, a Master's student in geophysics, responded explaining that it depends on what one is looking for. Smaller companies tend to not be as strict as larger companies. Naila Dowla, a geology PhD student, spoke of her own experiences in her company and the allowances that she might not have gotten in a larger company. She also explained aspects that one can experience more in a larger company rather than in a smaller one.



The audience of the intern panel ranged from undergraduate to PhD students. They were able to learn from the experiences of the six speakers, and take that information to build an understanding of what types of challenges can occur when interning, and how to accomplish what needs to be done without any setbacks.

GSH Education and Development for Unemployed Professionals

By Whitney H. Blanchard, Chair

To help our members pursue personal and educational development during the current downturn, GSH hosted its third event focused on unemployed professionals. The target audiences for this event were those looking to gain knowledge in geophysical and personal development areas for upcoming career opportunities. This event was hosted at the GSH Geoscience Center at 1790 W. Sam Houston Parkway North, in northwest Houston. Several members were impressed with the venue, and excited to see the wealth of knowledge and history GSH has to offer at this location. Guest speakers for this event were Peter Wang (left) from Paradigm, and Klaas Koster (right) from Occidental Oil and Gas (Oxy).

The first talk, presented by Peter Wang, focused on machine learning for geophysicists and trend following for portfolio risk management. Peter started by outlining predictive modeling techniques and the evolution of geophysical exploration methods over the past two decades. He then concluded with risk management tips for personal investments during a downturn. Peter has published his work in his latest book "Financial Survival for Oil & Gas Workers," currently available online.

The second speaker to present was Klaas Koster. His talk highlighted what his company would look for in a potential candidate for hire. He also pointed attendees to valuable SEG online resources. Klaas advised on which journals, training classes, free datasets, software and online code repositories they should be considering when pursuing personal development between jobs.

Essentially, both speakers discussed the opportunities that exist for industry professionals between jobs. Their key takeaway was that those interested in industry must stay current with the latest geophysical advancements and take advantage of existing opportunities for educational development. These creative and innovative endeavors demonstrate the drive and ambition that many companies are looking for in today's industry.

Overall, the event was con sidered a success and several attendees were thankful for the talks and guidance our speakers provided. We appreciate the sponsorship of Oxy for this event and ask that members look for our next event in November.

Occidental Petroleum

GSH vs Harvey

by Tommie Rape

The Gulf Coast and Houston recently suffered some traumatic experiences under the barrage of Hurricane Harvey. Having lived in Houston for over 30 years, I have experienced hurricanes before and have seen numerous flood events, but I have never seen a weather event of this scale in the Texas Gulf Coast. I and my household escaped with relatively minor damage, but many, many people suffered to various extremes, including loss of life. I certainly do not want revive the distress possibly felt by many of you, but I do want to report on how the GSH fared during and after the storm. The GSH certainly did not suffer to the extent that many others did, but certainly it was negatively impacted by Hurricane Harvey and its aftermath.

A number of GSH members had their house and property flooded by Harvey. I do not want to name names because, with limited communications, I would miss many of you that have suffered. Some were flooded during the initial period of severe rainfall and associated flooding. A number of others that lived in western Houston survived the initial flooding, but were flooded several days later after the enlarged release of water from the Barker and Addicks Reservoirs. Numerous GSH members actually had to be evacuated by boat from their homes. Some members survived the flooding in Houston with no damage, but had property along the Texas coast where the initial impact of Hurricane Harvey caused massive destruction. These members that suffered flood damage went through varying degrees of clean up and are currently involved in different level of reconstruction activities. Many members also had their offices impacted by the flooding, some of which will take months to repair.

In addition to the domiciles of our members, the GSH office was impacted by the storm. Our office building survived the initial storm, but was caught in the rising waters from the release from the reservoirs. The first floor of our office building is a parking garage that is half submerged below ground level. The garage had seven to eight feet of water in it, and the surrounding streets and outdoor parking for the building had several feet of flood water, making the building inaccessible. Only a week and a half later the water outside the building had receded to a level where it could be pumped from the parking garage. However, there was no power in the building, and some minor clean up was needed on the two upper office floors. Only on the second day of the third week we were finally allowed to reoccupy our office, but there was still no air conditioning on our side of the building. The Houston heat obviously does not make for pleasant working conditions. Finally on the next day the air conditioning was repaired. Unfortunately the building elevator is going to be out of commission for at least a month or two. On the third day back in the office the electrical power in half of our office space went out again. It was repaired that evening, but at the time of this writing, we are still keeping our fingers crossed that we have seen the last of the building problems.

While we were excluded from the office, our office staff of Karen Blakeman and Kathy Sanvido, managed to conduct much of their normal work from their computers at home. But

GSH vs Harvey continued on page 22.

GSH vs Harvey continued from page 21.

some records were available only on the computers in the office, and for almost two and one half weeks these papers and our office phones were inaccessible. This certainly had a negative impact on our communications with members, but we think this missed communication was minimized by the fact that most people seemed preoccupied with other matters. At the end of the second week we had to move our scheduled Board Meeting to our Geoscience Center. We were lucky with the timing of the storm in that we have few events scheduled during the first and last weeks of the month. The GSH only had to cancel two technical events during that period, which was due to the general chaos in the city. We also had to postpone and reschedule the Sporting Clays event and the Education & Career Development for Unemployed Professionals event.

I am sure that everyone has been very impressed with efforts of so many volunteers helping the many people in need. I know of several GSH members that helped other members in the mucking and cleaning out of their flooded properties. I am not surprised by this, because, after all, we are an organization of volunteers. While our members were helping other members and other flooded victims, the GSH, through its members and as an organization, was helping the SEG in its final preparations for the SEG Convention.

The GSH wishes everyone the best in their continued recovery efforts. We are moving forward in an effort to help our industry and profession return to normal.

32nd Annual GSH Sporting Clays Tournament

RAIN OUT DATE January 27th, 2018

American Shooting Centers
16500 Westheimer Pkwy.

Ryan Marshall (713) 962-9414

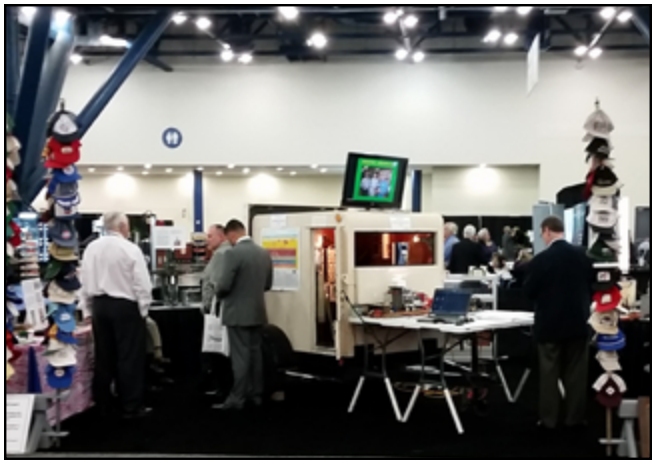
ryan.marshall@dawson3d.com

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

Geoscience Center News

By Bill Gafford

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



The Geoscience Center did not have any storm or flooding damage other than a small leak in the roof. We were glad to be able to host the September GSH Board meeting since the GSH office was inaccessible due to the flooding. A picture of the BOD meeting is shown below. We also hosted the ***Education & Career Development for Unemployed Professionals event on September 20 after it was rescheduled from an earlier date due to Hurricane Harvey flooding.***

The Geoscience Center is available for other meetings also.

Much of our effort in the last few months has been involved with preparation for our booth at the SEG Annual Meeting. I hope you had a chance to come by, visit and see some of the items from our Museum Collection. I think we had something of interest for just about everyone. Some of the older attendees enjoyed seeing instruments that they had used in their early careers and the younger visitors of our booth were interested to see items that were new to them. The centerpiece of the booth was the 1950's era doghouse. A picture of our booth is shown below. The raffle drawing we had for a registration to the SEG Annual meeting was won by Russ Andress. Shown below is Beth Jones of the Bergen Companies, our landlord, drawing the winning ticket, and Russ is seen in another picture visiting our booth.

Our next Living Legends Doodlebugger Social Event will be on Thursday morning, November 9. As usual, everyone is invited, it is free, and no registration is needed. We expect a number of new visitors who have recently found out about these events. There will be light snacks, coffee, water and soft drinks. Bring a friend.

We would welcome any volunteers who might have a few hours to come by and help with a variety of projects we are working on. It could involve working with our ever expanding library, helping research some of our unusual artifacts, or helping to refurbish some of the items in our collection. And financial support is always needed and welcomed.

If you would like to visit the Geoscience Center and see some of the Mystery Items from the GSH Journal or previously mentioned in the Geoscience Center News, volunteer to help with some of our projects, please contact me at geogaf@hal-pc.org or at 281-370-3264.

GSH/SEG Early Icebreaker

The Beer Hall at the St Arnolds Brewery was the scene of the first social event of the GSH 2017-2018 season. The Saturday night joint GSH/SEG Early Icebreaker on Sept 23rd was at capacity for over 300 people in attendance. Thanks to the staff of St Arnolds and Lupe Tortilla for keeping everyone fortified with cold refreshments and Tex Mex food. Special thanks to the staff of the GSH, Karen Blakeman, Karen Sanvido and GSH volunteers. The level of support placed by event sponsors shows great appreciation from the community. Thank you sponsors and attendees for your commitment to the GSH.

TITANIUM SPONSORS	PLATINUM SPONSOR	GOLD SPONSOR	SILVER SPONSORS	BRONZE SPONSOR
IN-DEPTH GEOPHYSICAL	RPS	RESERVOIR IMAGING	fairfieldnodal	DAWSON Dawson Geophysical Company
SHEARWATER			Fracture ID	
			Resolve GeoSciences, Inc.	
			SEITEL THE Onshore Seismic Data Company	
			Spectrum MULTI-CLIENT • SEISMIC IMAGING	

GeoStatistical Inversion

And Stuff You Need to Know

Something New

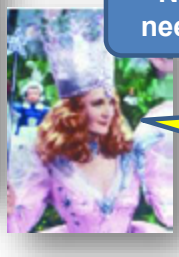
The frequency of papers dealing with this general topic has been increasing rapidly in recent years.

A quick search, using key words such as **Inversion, AVO, or Bayesian** produces nearly **600** papers. A Whitman's Sampler is shown above.

Dick, Jane, Spot, & Rocky
Thirsting for Knowledge

How can we get in on the fun – and understand what they're talking about?

No problem, my Lovelies; first we need fatten you up a little, so that …



Easy, Wicked One, there will be no fattening up around here. The only thing these miniature budding geophysicists need is a little grounding in these topics:

Impedance

This is our old buddy from the acoustics era, but now we're ready for the elastic truth that was first revealed in the 20th Century by Patrick Connolly.
Where Acoustic Impedance, I = ρVp, Elastic Impedance (EI) yields estimates of ρ, Vp, and Vs. In turn, these quantities pretty much define the lithology in the layer between boundary reflections.

Inversion

The process of transforming the reflectivity at the rock boundaries, which measures the contrast in rock properties, to the actual

Tutorial Nuggets continued on page 26.

Tutorial Nuggets continued from page 25.

Inversion (continued)

the values of Vs, Vp, and ρ, and, if desired, to related rock properties such as Porosity, Clay volume, and Water Saturation.

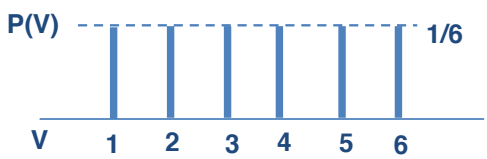
AVO

It is the Rpp(θ), expressed as angle stacks which will be inverted. These are the guys that contain information of the contrasts Δρ, Δ Vp, and ΔVs. Later, we will introduce the possible use of Rsp(θ) to augment and improve our estimates of the parameters to be inverted.

Probability And Uncertainty

NB: Both well logs and seismic data are fraught with embarrassing errors, miscalculations, and slop. We do the best we can, but there will always be noise, and as a consequence, uncertainty in our estimations and predictions. If we can quantify this ugly aspect of interpretation, we will be showered in the accolades by our friends, neighbors, and clients. This is where we throw ourselves onto to the Statistical Altar of the Merciful Gods of Probability: Luck, Chance, and No Way. May they bestow Insight upon us.

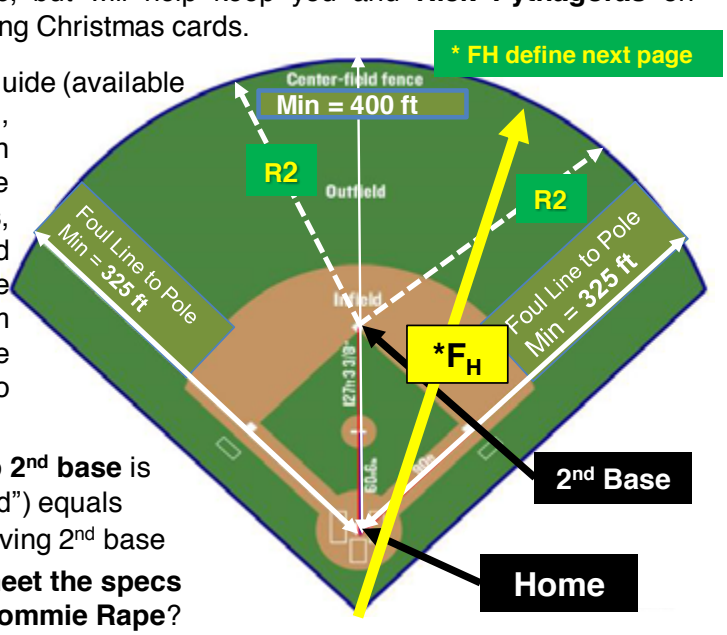
As an advance glance at some of the useful principles that will eventually lead to a bluffing acquaintance with such topics as the ***Bayes Theorem***, let's look at the statistics of **dice** (Six faces on each cube, with 1 through 6 dots, respectively). When rolling a single die, it is equally probable that any one of the faces will show on top: P(V): **P(1) = P(2) = … = P(6) = 1/6.** This is called a "Uniform" Probability Distribution Function (PDF), often depicted graphically as shown below.



There are no surprises here. Now, suppose we **roll both dice:** what is the probability of any particular **sum** of the two faces? Not so obvious. You can brute force calculate it, but a clever approach is to remember the words of the Guru: "***Practically everything is a Convolution."*** Try it.

The **October Puzzle** honored *The Boys of October* with **a Geometric Baseball Problem**. This one doesn't have any baffling logic, but will help keep you and **Nick Pythagoras** on speaking terms and maybe even exchanging Christmas cards.

Following the MLB Official Dimensioning Guide (available at GSH International Headquarters), **Dmitry Kulakov**, world renown geophysicist, editorial genius, and part-time grounds keeper for the Houston Astros, came up with a blinding brainstorm to build the outfield fence on the arc of a semi circle whose radius, **R2**, was the distance from **2nd base** to center field honoring the minimum distance from home plate to straight away center of **400 feet**.

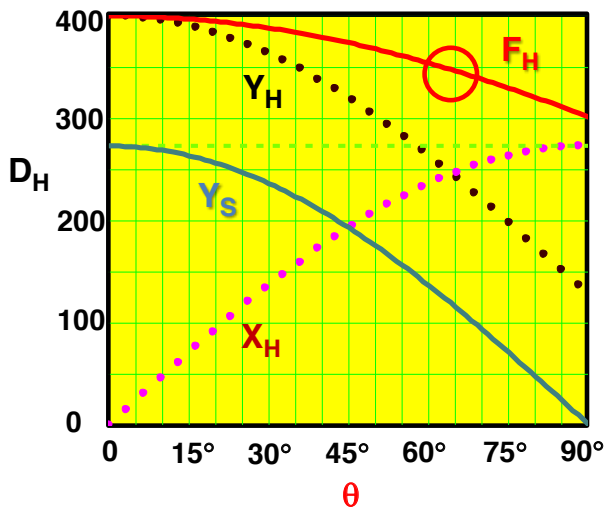


Given that the distance from home plate to **2nd base** is the diagonal of a 90 ft square (the "diamond") equals some **127.28 ft**, **will Dmitry's dream** of having 2nd base the center of symmetric baseball utopia, **meet the specs** imposed by the Baseball Czar (2017-18) **Tommie Rape**?

Tutorial Nuggets continued on page 27.

Tutorial Nuggets continued from page 26.

Tommie is especially concerned about the right field foul pole being no less than the prescribed **325 ft from Home.** Does Tommie worry too much?



Of the **3** answers received, which addressed the puzzle*, this amusing, graphical, and somewhat compelling answer from the bleachers, appears at the left.

Notation: θ = Angle of radius, **R2,** of **circle** centered at **2nd Base**. (0° points at center field).

D_H = distance measured from Home plate;

Y_H = Y-axis distance to fence measured from **H**ome; **X_H** = distance to fence from Home; **Y_S** = distance to fence from 2nd Base; and the all important distance, **F_H**, measured from **home** to the fence.

The distance along the foul line, where **Y_H = X_H** (45° from Y-axis): **F_H** ≈ 347 ft (red circle) well above 325 ft

All is well, Tommie. [* Incidentally, most answers simply said, "Tommie worries too much."]

November Puzzles: Honoring Probability

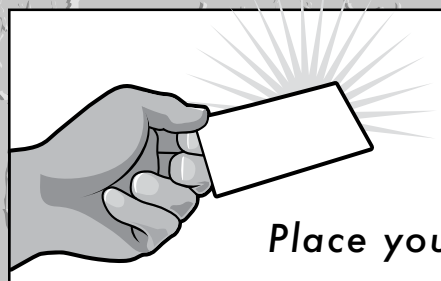
Because **Probability** and **Statistics** are such a big part of modern **Inversion**, let's use some principles to solve these Level 1 brain teasers and have some fun, too, while we're at it.

(1) Look out for Hidden Danger in the *Sea of Assumptions.* This puzzle identifies a couple of probability principles.

Haynie Lee, a crafty gambler with a heart of stainless steel, offers Mother Superior Katherine Pitman, a weekend High Roller, an opportunity for a killing: If she rolls a fair die, and if a "1" shows, she wins. If not, Haynie wins. "But that's not fair! The chances of rolling a 1 are only 1/6!" she responds. **T**he crafty one counters, "Of course my dear, that's why we'll give you 3 rolls to get a 1. That's 1/6 three times for 3/6! It's clearly a fair bet." Should the Good Mother take the "fair" bet?

(2) Lee Stringer, Haynie's equally crafty partner, steps out of the darkness and offers you the following wager using **2 fair dice**. You roll both dice; if the highest number on the pair is a **1, 2, 3, or 4**, you win the bet. If the highest number on either is a **5 or 6**, Lee wins.

Clearly, the chances of **rolling a 1,2,3,4** on a die are **4/6 = 2/3**, but does the presence of the 2nd die alter your thing? Should you make the bet with the smiling stranger?



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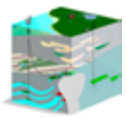

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Doodlebugger Diary

The Hunt For Refraction Data Interpreter

By Ed Davin

Ed Davin is an editor/indexer with GeoRef, the AGI's global data base. His encounters with J.R. Schander are of interest. In 1925, J.R. Schander was appointed vice president and manager of NAMEX. Ludgar Mintrop sent him to the United States to visit and supervise the NAMEX torsion-balance and the SEISMOS refraction crews. The voyage took place in August 1925. On shipboard Schander married his charming wife. The photos are taken from an album of pictures taken by Schander during his trips through Texas and Louisiana.

This Doddlebugger Diary by Sam Evans first appeared in the March, 2011 issue of the Journal.

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

Dr. Rikard Schander and wife, 1928.

Brazos River Bridge. Schander at the wheel.

Richmond Road, Schander standing.

I was working as a geophysicist for Chevron in Venezuela. All of the major companies had sponsored a seismic reflection survey of the Gulf of Venezuela north of and contiguous with Lake Maracaibo and also the Gulf of Paria, located between eastern Venezuela and Trinidad. Since there was no well control, the reflection horizons mapped were designated with such names as the "Jones reflection" or the "Kitch reflection." To give more substance to the interpretation, the companies decided to run a refraction survey covering the same areas, another group-shoot. This was duly done, and each major company had its own database. Alas, no one in any major company, as far as I know, knew how to interpret refraction data, so the Chevron affiliate contacted an affiliate in Houston asking, "Know anybody who can handle refraction data?"

The answer was Johannes Rikard Schander. I was assigned to work with him in our Maracaibo office. We lived in the Hotel del Lago in Maracaibo and were driven each morning to the Chevron office just south of the city, which is still in operation. At the end of the day we were driven back to the hotel and had a leisurely dinner. During the many hours that we spent together, Dr. Schander and I got to know each other pretty well. He told me lots of stories. Sometimes another colleague with worldly knowledge would join us and we would pump him for more. I'll tell you what I remember. Schander had two doctorates, one from the Charles University in Prague and the other from the University of Freiburg in Briesgau (although after all these years it could have been the other Freiburg in East Germany). He told me about coming to the Gulf Coast to sell torsion balances. When the Depression hit in the

Doddlebugger continued on page 32.

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 31.

late '20s, business fell off, but back in Germany Hitler was rising, and Hitler needed all the oil that he could get in Germany. Indeed, his first move was into Romania.

Schander joined the German Geological Survey and started to explore for oil throughout Germany and Austria. He did a lot of work in the North German Salt Basin. When the Germans moved into the Netherlands, he was behind them with his seismic crew. I remember him saying: "The pride of my life – I found oil on the Baataschaft that is Shell's doorstep. Shell explored for oil all over the world – Venezuela, Canada, etc. – and it never occurred to them that they were sitting on one of the world's giant fields."

When WWII was over, Schander contacted some friends in Houston with connections, and he returned to the US. I don't know what consulting company he was working with when Chevron contacted him. More intriguing was where he picked up the refraction technique that was all graphics and mechanical drawing. He also seemed to have a sixth sense when the refracted layer emerged on our plotted section. He called the geological age and formation name.

(Editor: When the oil crisis occurred in the Middle East, Ed changed jobs. He joined Creole (SONJ). Later he was transferred to Tulsa as Senior Research Geophysicist.)

In time, the VP of Exploration made an agreement with Shell to look for oil on the North Sea. Word came down from Rockefeller Plaza, then headquarters of SONJ: 'Put Davin to work on the North Sea!!' I knew nothing about the North Sea except maybe where it was situated. But I knew Johannes Rikard Schander, who lived in Houston. I phoned him and told him that I had some seismic data that he would find interesting. I would like to come by. He was happy to hear from me. Such a move was against all company policy. SONJ were neurotic about security. There were even screens on my office windows in Houston. I just told my colleagues that I had to go on an errand. I spread several seismic sections out in Schander's office. He smiled. His face lit up!! Pointing to the reflection horizons, he called out, "There is the Dogger, the Bunter, the Zechstein, etc. etc." I carefully made a lot of notes, thanked him very much and returned to the Exxon Research Center on Buffalo Speedway.

At my first meeting before Research Management I said that I had a working hypothesis on the stratigraphy of the North Sea, but Management objected. "Shell is there on the spot," they said. "You are doing just a back-up!!"

"Call them horizon 'A' or horizon 'B'," I answered. "That would be boring."

"Okay, but you will make a fool of yourself when we get together with Shell." I was willing to run that risk.

Exxon had a study group in Geneva working on the geology of Western Europe. I would visit them every few months. They would critically review my interpretation from a geological perspective. In time a meeting was set up in The Hague. Walker Johnson, VP of Exploration, led the Exxon Group plus others who would be in the operation. Shell brought three groups: one that worked only in Western Europe, one in Eastern Europe, and a third International. They had a lot to say, but Schander had reassured me that they didn't know a damn thing about the North Sea. I could tell that although they talked a lot, they just didn't get it.

Finally, Walker spoke up: "Well, Ed here has been working on this project. He has some ideas that he would like to share with you." The VP/Shell nodded approval, so I took the floor!! As I wound up my presentation, the VP/Shell got quite agitated!! "You are from Houston!! HOW IN THE HELL would you know so much about the North Sea??" Well, I could not tell him that I got my information from a German. The Dutch hated the Germans. I told him about the Geneva group. It was the classic geology of Western Europe. But Walker came to my rescue!! "I'll tell you the answer to that question!!! You put the right man on the job, and you get the job done!! Now let's get on with this meeting."

When I got back to Houston I met with Schander and told him all that had happened. "I am sorry that I could not tell them the real story. You know how the Dutch feel about the Germans." Schander laughed. He understood perfectly. No need to apologize.

Mystery Item

The Mystery Item for the November GSHJ is a map measuring tool from the 1950's.

Mystery Item on page 18.

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Interpretation pitfalls

All practitioners of subsurface interpretation, regardless of their primary discipline or specialty, know about pitfalls, the hidden or unrecognized dangers or difficulties which abound not only in subsurface data but also in interpretation workflows. We learn through experience how to identify pitfalls, to create or modify workflows to handle them, and especially to be vigilant in looking for them not only in technology and conventional practices but also in individual work habits and approaches to problem-solving. The purpose of this special section is for interpreters to share their experiences, both good and bad, with pitfalls as they've encountered and dealt with them in their project work. In this sense, no pitfall is either too simple or too complicated that it can't be thoroughly scrutinized and documented, because in the case of each and every pitfall that has ever entrapped an interpreter, doubtless there are other unsuspecting interpreters who in learning about that pitfall can avoid falling prey to it.

The editors of *Interpretation* (http://www.seg.org/interpretation) invite papers on the topic **Interpretation pitfalls** for publication in the November 2018 special section to supplement the journal's regular technical papers on various subject areas.

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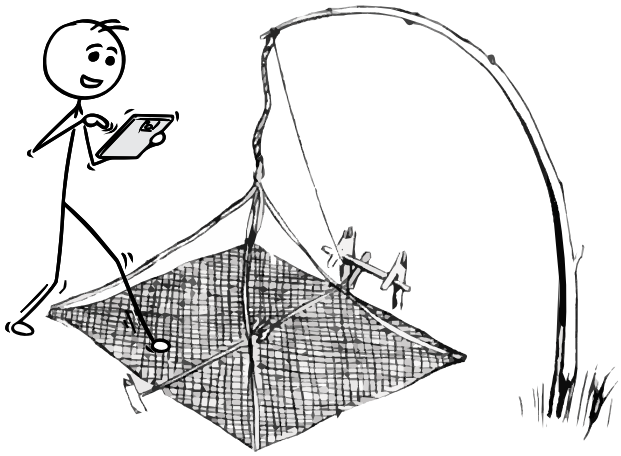

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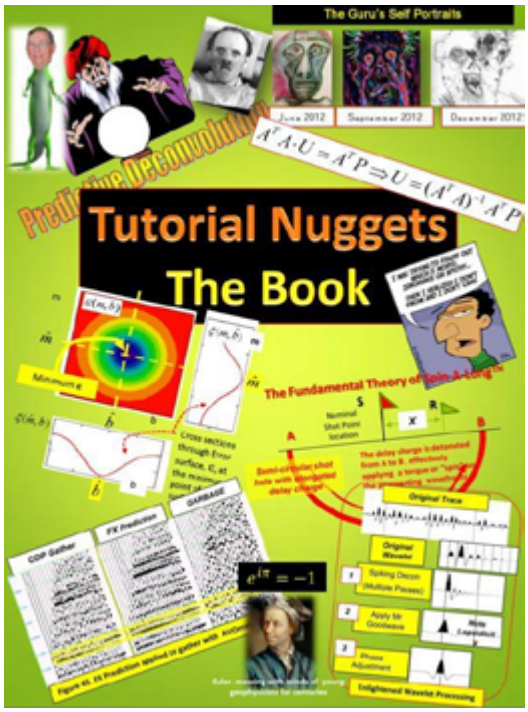

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