January 2019

The Epicenter of Geophysical Excellence

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 9 • Number 5

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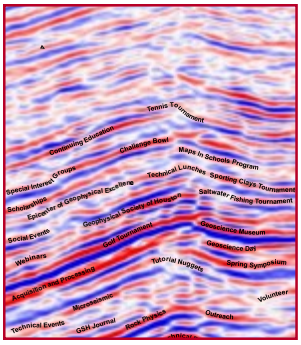
On The Cover...

Activities of the Geophysical Society of Houston.

Seismic image courtesy of Seismic Exchange, Inc.



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

Mar 2019	**Jan 11**
April 2019	**Feb 8**
May 2019	**Mar 8**

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A Word from the Board

Let's Be the Best GSH Members We Can Be!

By Gabriella Suarez, Treasurer

Professional associations, such as the Geophysical Society of Houston, are a vital part of our working scientific community. They give opportunities for continuous learning, knowledge sharing, and professional networking. These three factors have been the key to success for professional associations for many years, particularly when there is a willingness by professional individuals to join, volunteer, and serve within the organization. However, in an era where job security is uncertain, online resources and social media have been competing with professional associations, resulting in a decline in active membership, as well as, pushing down new membership, especially among younger professionals. As a result, our professional associations have had to evolve and adapt to the changing business environment and better understand our current membership from which our new leaders will emerge. They have had to offer tangible membership services that advance their member's professional networking and leadership opportunities at a reasonable cost-to-value ratio.

The Geophysical Society of Houston (GSH) was founded in 1947 and over the decades has actively participated in our city's professional development, as our Articles of Incorporation states: "… to advance … professional networking and leadership opportunities (and) to foster fellowship and cooperation among all persons interested in geophysics…". It offers multiple educational opportunities through technical breakfast and luncheons, Special Interest Groups, annual meetings and special talks, as well as social networking events such as golf, fishing, and sporting clays tournaments and ice breaker. The GSH is one of the more active geoscience professional associations in the city of Houston and among the top professional organizations in the United States.

I joined the GSH two years ago and I have come to appreciate the multiple opportunities that the organization has to offer. For me, what I enjoy most are the many networking and professional development opportunities I've experienced through the organization. My involvement with the GSH actually helped me during my "in-between-jobs period" through volunteering with the main office, where I made memorable personal and professional contacts, and I was exposed to the complexity of directing an active society with limited resources.

Gabriella Suarez

The continuation of our wonderful society requires active membership. Members who attend our technical and social/networking events are an indication to us of the level of interest you have in the fields of geophysics and geosciences and in the importance you place in our dear organization. Over the years, we have seen a decline of attendance to some of our events and we would like to think that is related to the industry downturn. Our existence and purpose depends on your participation as a member! We offer many opportunities in the greater Houston area, which cover many topics in geosciences so that there is a flavor for almost every taste. We are calling upon you, our dear members to work with us. Let us know what talks, functions, or events would make our society even more appealing to you and to potential new members. We all are the Geophysical Society of Houston and we would like to see its continued persistence and evolution. To accomplish this we need to work together and be more proactive and be the members that the GSH deserve: active and motivated.

I hope to see you at our next monthly event and please let your new colleagues know about the wonderful benefits and social opportunities that the GSH has to offer.

Dear GSH Journal reader,

Please, feel free to contact any of us with any and all questions or suggestions that you can come up with.

editor@gshtx.org

Sincerely,

Dmitry Kulakov, Editor

From the Other Side

By Lee Lawyer

There are two halves to "Geophysics". Geo is for earth but only the part of earth that contains oil/gas, sedimentary sediments. One could divide physics into a myriad of subjects. My recent trip to San Francisco proved that. The group I was with planned a visit to something called, the Exploratorium. This is a place where Physics has gone wild. They set up exhibits illustrating a variety of phenomenon. I liked the one that stored electricity using a large flywheel that provided enough current to turn on light bulbs. Another showed a "two-dot" problem with our two eyes. Waves were made with small particles in a flat box. If you get to San Francisco, put the Exploratorium on your list. Also, it is located "on the wharf" which is clearly a must in a visit to SF.

Les Denham sent me a letter he had from his brother. The described seismic survey activity was in Australia. I have done very little editing of the letter. It was hand written from the field. Les sets the background. Enjoy…

"My brother, John Denham, had worked as a computer on Austral GeoProspectors Party 6 since May 1962, with the base camp in the shearers' quarters at Fleetwood Station (latitude 22.2884 S, longitude 145.8174 E). I visited him there in October. They moved the basecamp about 40 miles to the north around the time of this letter. John probably wrote the letter from the new camp.

When he started with the company, John had taken his 1956 VW pickup to the field, but it had not proved to be ideal for the conditions, so after about three months he had traded it in on a 1956 Land Rover. Austral Geo Prospectors had no 4WD vehicles, so John's personal car was the most capable vehicle on the crew in the wet season. The letter follows:"

Dear Les,

Got back on 2nd – water only up to top of wheels. Only trouble – those plugs you got – pre-ignition. Had to replace at Condamine. Crew got back on 5th (w/o P.C.1 or P.Man2) the next day the P.M. (Tom Barnard) wrapped the s/wagon round a cow – wrecked it (both) coming out. Next we ran out of caps – road blocked nr. Charleville and Blackall and explosives truck could not get through. Got them last night on supply truck which met Seismic Supply3 truck at Barcaldine. Also, yesterday working with a box of caps brought back in Holden4, they twisted off tailshaft of the shooting truck. The mechanic has a 25-20 Winchester I may buy. We have just replaced the engine in the third ute – 8 months, (over 18,000 miles). Tell this to your Holden-in-Rover blokes.

We can only reach patches of the assignment. We can't get a dozer. The other computer just quit and the surveyor just found a 40' bust. The observer broke both cables today. It looks like rain, but then it has for weeks. Apart from the above everything is OK.

Yrs faithfully, John

P.S. That long locking bolt on the steering arm has torn the mudguard to bits.

P.P.S Winch cable works well – pulled water truck (180 IH5) out of bog on the way in – blokes in camp tried to get to telephone.

P.P.P.S. Please send me airmail a cord type 4-pin valve6 socket also cord type octal socket (for radio).

P.P.P.P.S. Where are you staying?

P x .S. 15th, The P.C. was to go to Longreach tomorrow to pick up the new computer (Tom Noel from P#5 nr Rolleston) but it just started raining – not much yet – BUT!

P x+1.S. 25th It did rain. Crew went on rain break on 19th – flew out, only way. On 21st I went to Longreach – stalled motor in water up to the ventilators below windscreen – air cleaner full of water. Wound out on starter – took about an hour to start it again – got water in both diffs, swivel cases, gearbox, transfer case, and winch, none in engine. The same day the Obs.7 and a driller drilled the rest of the line as far as Torrens Creek. On the 17th the Surveyor, Obs, Shooter went out in a Holden, bogged it six miles from the line, walked to the line and picked up a spread in 18" of water (we've found out those jugs aren't waterproof). They bogged the recorder as soon as they moved it. They walked 11 miles back to camp. I went out next day and pulled the Holden out – could not reach line. Next day I went out with Observer; reached line and brought recorder back – had to winch twice. Expect skeleton crew to go to work on Monday but it looks very like rain now. As well as plugs mentioned before could you please get me a ½ meg pot 9 with 12V 15A switch contacts – my car radio v.c.10 has packed up. Had a bit of other trouble with it – shorted H.T. line – didn't the vibrator sound strained!

All for now,
John

This letter clearly shows that both Les and his brother John, clearly fall into the category of "Living Legends". Most acquisition operations are fraught with problems. But the data gets acquired and the problems are managed. True doodlebuggers.

Technical Luncheons

3D Structure-preserving Frequency Broadening

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch North

Speaker(s): Stephen Chiu, In-Depth Geophysical

Stephen Chiu

Westside

Tuesday, Jan. 15, 2018
11:00 a.m. – 1:00 p.m.

Location: Norris Conference Center (City Centre)
816 Town & Country Blvd.
Houston, TX 77024
(Free parking garage)

Downtown

Wednesday, Jan. 16, 2018
11:00 a.m. – 1:00 p.m.

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

Northside

Thursday, Jan. 17, 2018
11:00 a.m. – 1:00 p.m.

NEW LOCATION

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

Abstract:

Seismic data bandwidth controls the resolution of imaging subsurface geology. The broader the data bandwidth is, the better the resolving power to separate geological units. Unfortunately, the absorptive earth media attenuates frequencies during wave propagation, especially the higher frequencies. The loss of data bandwidth could reduce the resolution in mapping reservoirs accurately. The proposed 3D algorithm is one of the methods to broaden 3D data bandwidth. It simultaneously determines both unknown reflectivity series and source signature using a mixed L2 and sparse-spike inversion schemes. One of the keys of this method includes a constraint of a 3D structure-preserving filter in minimizing the presence of noise in the data. This constraint helps to produce a better estimation of the source signature and reflectivity series. In addition, it preserves the fidelity of the seismic data structures and maintains the same data phases before and after this process. The bandwidth broadening of both low and high frequencies, while preserving data structures, is critical in producing higher-resolution images in mapping reservoirs. We apply this proposed method to synthetic and three field data sets. The first data set, from Kansas, validates the well tie with data after the frequency broadening. The second data set, from Permian basin in Texas, increases the spatial resolution in mapping the areal extent of an upper Wolfcamp C limestone for optimal fracking operations. The third data set, from South Texas, broadens the frequency contents to better identifying faults and salt dome features. The synthetic and real data examples demonstrate that this proposed method is effective in broadening the data bandwidth of both low and high frequencies to improve the success in meeting exploration objectives.

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 seismic research in various exploration areas. In 2016, he joined In-depth Geophysical, Inc. as a principal geophysicist. His research experiences spans all facets of geophysical software development and applications. His current research interests include broadening data bandwidth, migration, denoise, data reconstruction, and multiple-sourcing algorithms. He has been a member of the SEG for over thirty years. He held several patents and published over 49 publications.

Technical Breakfasts

Seismic Reflection Imaging with DAS Data for Long Term Reservoir Surveillance

Register for Tech Breakfast North

Register for Tech Breakfast West

Brian Fuller

Speaker(s): Brian Fuller, Ph.D., Vice President Sterling Seismic & Reservoir Services

North

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

Sponsored by Anadarko Petroleum and Quantico Energy Solutions

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

West

Wednesday, Jan. 9, 2019
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

Fiber optic cables deployed on (or in) well casing are currently being used with surface seismic sources to record seismic data along the entire vertical and horizontal segments of wells. The common name for recording seismic data with a single fiber optic strand is "DAS", an acronym for Distributed Acoustic Sensing. In this presentation we describe a bit about DAS technology and then show a virtual source method that we developed as a way to efficiently process data recorded on the horizontal part of the DAS cable. The method results in seismic reflection images below (and sometimes above) the entire length of the horizontal part of the DAS fiber. Our primary goal in developing this data processing technology was to provide a complete pathway to low-cost time lapse seismic reflection imaging in horizontal wells for reservoir surveillance. The idea is that production-induced changes in rock properties (velocity, stress field, etc.) could be detected via time lapse seismic imaging from the DAS data and rock mechanics analysis could provide estimates of the amount of fluid and/or gas produced along the horizontal borehole. At the time of this writing we can only show results from processing synthetic DAS data but we can say that the results from synthetic data are similar to the results we see in real data. We hope to have presentation rights for one or more real DAS datasets by the time this talk is presented.

Biography:

Brian holds a Bachelor of Science degree from Western Washington University, a Master of Science degree from the University of Wyoming, and a Doctorate degree from the University of Wyoming, and degrees in Geophysics. He has over 30 years' experience in the oil and gas industry including successful oil exploration, software and technology development, and service company work. He has a long term professional interest in borehole seismology and is currently focused on development and application of reflection seismic imaging using horizontal DAS cables. Along with numerous co-authors, Brian has been part of two SEG Best Paper awards, both of which were related to microseismic technology. He currently holds the position of Vice President of Reservoir Geoscience at Sterling Seismic & Reservoir Services in Littleton, Colorado and lives in the Denver area.

Data Processing & Acquisition SIG

Using Models of Attenuation in the Prediction of Boundary-related Internal Multiples

Register for Data Processing

Speaker(s): James Wu, Senior Software Geophysicist. Schlumberger

Co-authors: Zhiming James Wu, Jing Wu, Frederico Xavier de Melo, Clement Kostov, Schlumberger

Sponsored by Schlumberger

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

James Wu

Tuesday, Jan. 8, 2019
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

Abstract:

We consider methods that predict internal multiples by combining events in the data through convolutions and correlations. It is well established that such methods predict traveltimes of internal multiples accurately. However, the use of correlations in the prediction leads to amplitudes of the predicted internal multiples that contain systematic errors related to scattering or absorptive losses.

Building on previous analysis of prediction of internal multiples in absorptive media (Wu and Weglein, 2014), we present a modified method for prediction of boundary-related internal multiples (Verschuur, 2006; Wu et al., 2011) that uses models of attenuation in the subsurface.

Taking the attenuation factors into account improves the amplitudes of the predicted internal multiples, making the task of adaptive subtraction easier. We'll discuss various scenarios depending on availability of attenuation models that extend to the acquisition surface, or alternatively, cover only some part of the subsurface.

We illustrate our method with synthetic and 2D marine field data, as in Melo et al. (SEG 2018).

Biography:

James Wu has been working as a Geophysical Software Developer since 1999, with Western Geophysical and then Schlumberger. James's applications expertise ranges from signal enhancement and noise suppression to various domain transformations, as well as surface and internal multiples prediction and attenuation. James is also involved in providing technical support for the software.

James received Physics BS and MSc degrees from Suzhou University in 1990. He came to the U.S. in 1995 and obtained a Computer Science MSc degree from University of North Texas in 1998. In 1997, James qualified to be a PhD candidate in Physics at Toulouse Graduate School, University of North Texas.

Microseismic SIG

High-resolution Microseismic Source Locations and Moment Tensor Solutions From the Permian Basin

Register for Microseismic

Jim Rutledge

Speaker(s): Jim Rutledge, Schlumberger

Co-authors: Scott Leaney, Schlumberger, John Best, Michael Craven, and Laura Swafford, Chevon

Sponsored by MicroSeismic

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

Thursday, Jan. 10, 2019
11:30 a.m. - 1:00 p.m.

Abstract:

A detailed microseismic survey was carried out in the Spraberry Field of Midland County, Texas. A vertical pilot well was completed in eight separate stages and was monitored from four surrounding wells within 300 m of the completion well. Each monitor well was equipped with a 20-level 3C geophone array spanning the completion zones, thus providing symmetric and full receiver coverage. A velocity model was built from dipole sonic and calibrated for vertical transverse isotropy (VTI) parameters using perforation shots, sonic-derived anisotropy, and crosswell seismic time picks. The microseismic locations reveal simple vertical planar clouds only a few meters wide and oriented along maximum horizontal stress direction. Moment tensor solutions show a mix of strike-slip and dip-slip shear mechanisms along failure planes aligned with the hydraulic fracture orientation. The common interpretation of stimulation microseismicity representing a discrete fracture network via connection and activation of natural fractures is not generally applicable in this case. Formation microimager (FMI) data indicate that natural fractures play little role in generating the microseismicity or steering fracture growth. Instead, the observations indicate that the microseismic shearing is directly associated with the development of vertical hydraulic fractures. The dip-slip events are mostly associated with upward growth in the Spraberry formation and are most abundant over depths where potential weak beds or weak interfaces occur, as identified on the FMI data.

Biography:

Jim Rutledge has been employed with Schlumberger's Microseismic Services since October, 2012. He spent most of his career, from 1984 to 2012, asa staff seismologist at Los Alamos National Lab. From 2004 to 2012 he also worked as a consultant for Schlumberger Cambridge Research and MEQ Geo, Inc. He received a BS in Geology from Pennsylvania State University and an MS in Geophysics from the University of Arizona. Starting in 1989, Jim has led and participated in several studies that demonstrated the uses of microseismic monitoring in oil, gas and geothermal fields for various applications including: hydraulic fracture monitoring, EOR monitoring, production-induced seismicity, subsidence and well-failure problems, gas storage, as well as subsurface CO2 sequestration.

New Special Interest Group - Unconventional SIG

This new SIG aims to provide a forum for discussion of any technology or workflow or case study having to do with unconventional oil and gas exploration, exploitation, and production, with an emphasis on geophysics and how it can be integrated with other disciplines such as geology and engineering.

For information, contact Scott Singleton,
scott.singleton@comcast.net

Potential Fields SIG

Early South Atlantic Break-up: Review and Discussion

Register for Potential Fields

Speaker(s): D. E. Bird, Bird Geophysical and Department of Earth and Atmospheric Sciences, University of Houston

Co-authors: S. A. Hall, Department of Earth and Atmospheric Sciences, University of Houston

Thursday, Jan. 17, 2019
5:30 p.m. - 8:00 p.m.

Sponsored by CGG

NEW LOCATION:

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

Dale Bird

Abstract:

Recent identification of M-series marine magnetic anomalies over the Santos and Campos Basins of Brazil (Chrons M4 to M0), and over the Orange and Cape Basins of South Africa (Chrons M11 to M0), indicate that seafloor spreading between South America and Africa initiated in the southernmost part of the ocean basin at ~135 Ma, and progressed northward where Brazil separated from Angola at ~131 Ma. The ~44 mm/a initial spreading rate decreased to ~29 mm/a when the spreading center reached this approximate mid-point between the two plates. Total reconstruction poles, from early break-up to present day, also progressed northward: approximately 39° N to 72° N. Understanding the nature of continental crust deformation, prior to these rigid plate motions, along the conjugate margins is essential to understanding the early evolution of the South Atlantic Ocean Basin. Permo-Triassic basins and foldbelts, which formed along the Panthalassan margin of Gondwana in austral South America and South Africa, may provide key insights for this understanding.

Biography:

Dale Bird established Bird Geophysical in 1997. Prior to this he worked for Aerodat, World Geoscience, Marathon Oil Company, Digicon, and Aero Service. Dale earned B.S., M.S. and Ph.D. degrees in geophysics from the University of Houston where he currently serves as a Research Associate Professor. Dale is an active member of AGU, AAPG, GSA, GSH, HGS and SEG, and he is an avid chess player.

Multi-Source Towed Streamer Acquisition Techniques

Marc Rocke, Edward Hager, Philip Fontana, Polarcus

Summary

The use of more than two sources for acquisition of narrow azimuth marine towed streamer data has been shown to increase overall 3D survey efficiency and / or significantly increase overall trace density and image resolution.

The use of sources in place of streamers also helps reduce overall survey costs, operational risks, and crew HSE exposure.

Introduction

The primary advantage of using multiple sources and smaller inline source intervals in towed streamer acquisition is to produce greater trace density per square km of 3D survey area in the most cost and operationally efficient manner.

This approach has been successfully demonstrated and generally accepted on land where overlapping, and simultaneous sweeps (blended data), continuous recording systems, and data de-blending processing techniques have dramatically increased trace density, improved data quality, and lowered overall acquisition costs in terms of money and time.

The technology tools used in towed streamer marine to accomplish similar results are very efficient source arrays, digital source controllers, continuous recording systems, acoustically quiet streamers, 24 bit electronics, and interfering source noise removal processing routines (i.e., de-blending).

Method

In real terms, all seismic reflection profiling recordings are "blended" in the sense that they contain energy from the previous source (residual source noise), the current source, and succeeding source. Traditional sequential recording of towed streamer data was aimed at maximizing the recording length while avoiding direct interference from the succeeding source. This

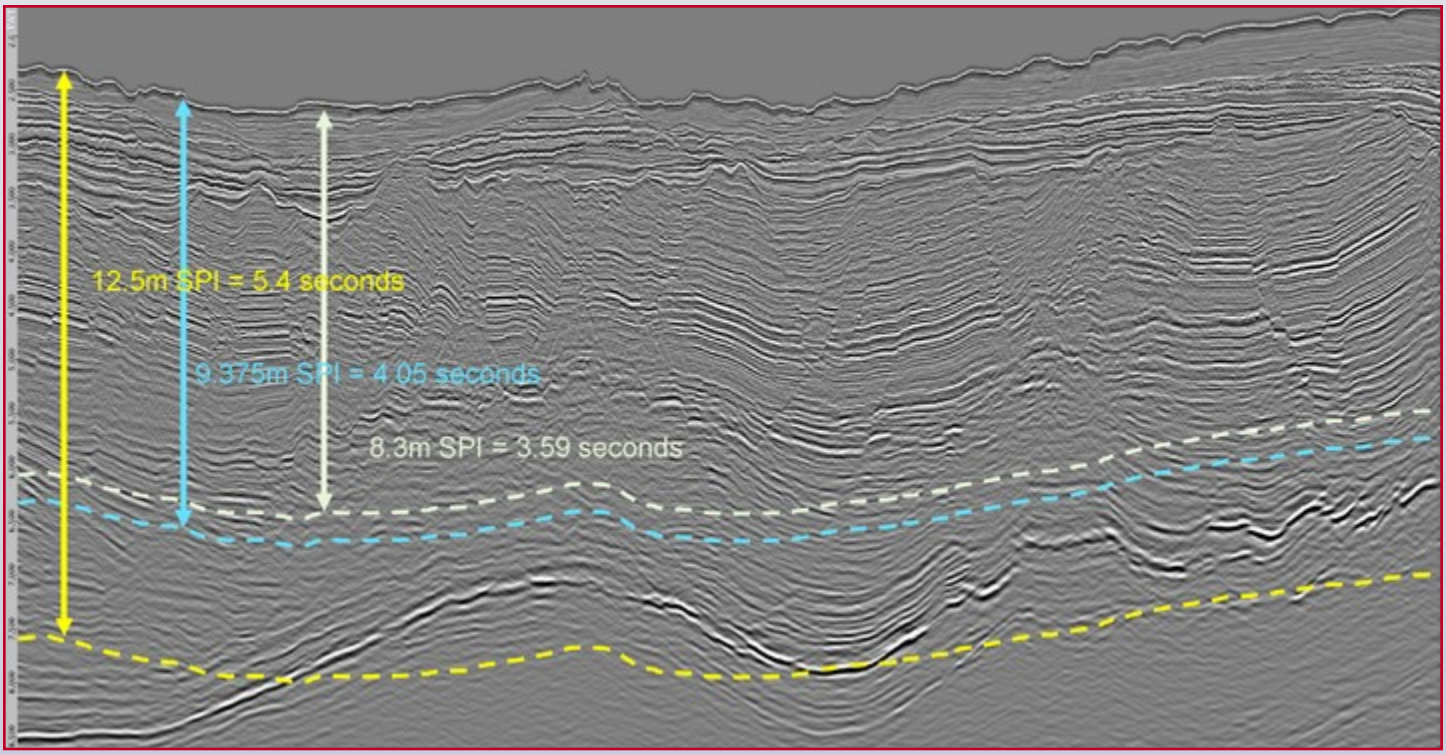

Figure 1: Shot interference times are relative to the sea-floor reflection, as traced by the dotted lines.

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

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constraint put boundaries on in-line source intervals and vessel speed, i.e. successive shots could not be acquired until the full fixed recording time was completed.

With continuous recording, those constraints can be relaxed with a balance between minimum inline source distance, vessel speed, and the arrival time of interference from the next source. The time of the arrival of the sea-floor reflection between adjacent source locations, the first instance of reflection energy interference, is simply the time it takes the vessel to move from one source location to the next. The interference zone is then relative to the sea-floor reflection time along the seismic line. *Figure 1* illustrates the time of the transition zone between "unblended" and "blended" data for a range of inline source point intervals.

So, for the time above the interference zone, the data is the same "unblended" as that recorded with a conventional sequential fixed record length.

The times below the transition zone will require a de-blending technique to remove the energy from the succeeding shot. In the case of overlapping sources, the de-blending is basically an adaptive noise removal process since natural time variations between source firing times due to small variations in vessel speed produce a natural "dither" in the coherence of energy from each source relative to the time base of the other sources. In spatial domains such as constant offset, CMP, etc., the interfering energy appears as random noise. *Figures 2 and 3* show the before and after de-blending of a constant offset section.

This is quite different from the de-blending techniques required to separate energy from the interference of sources fired in "simultaneous" mode. In either case, almost all contractors and major oil companies have active R&D programs aimed at the development of processing schemes to optimize de-blending of overlapping and/or simultaneous source energy.

The second attraction of using multiple sources is that we can set up the source receiver geometries to either increase the density of cross-line 3D sampling and/or increase separations between streamers to increase overall operational efficiency.

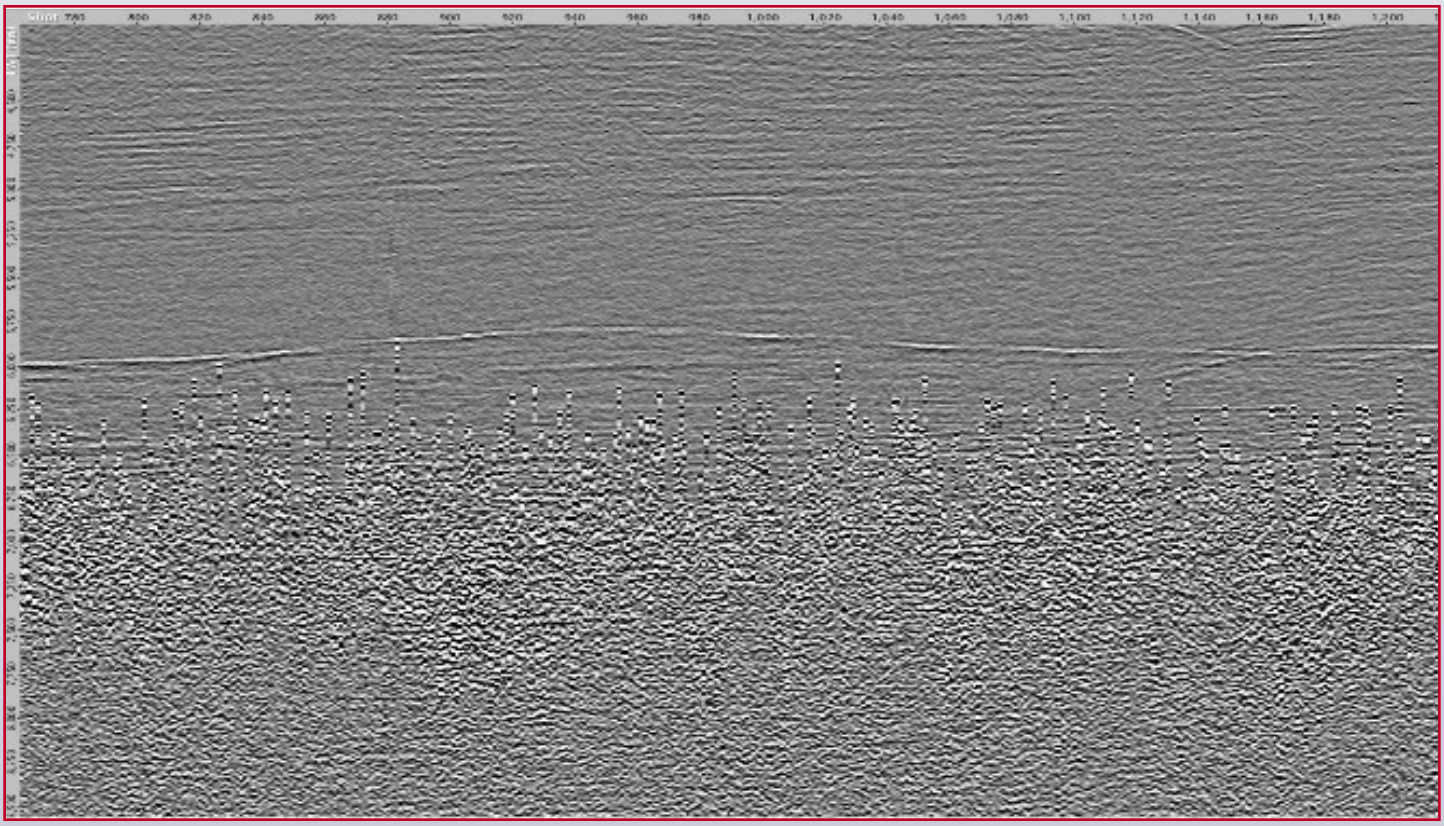

Figure 2: Common-offset panel shows shots fired on constant distance show a natural time dither of about 200-300ms

Technical Article continued on page 14.

Technical Article continued from page 13.

Figure 3: Common-offset panel after deblending of shots in Fig. 2

Take for example a survey designed to sample the 3D wavefield at 12.5m cross-line intervals. An example of conventional dual source acquisition with 12 streamers would result in a geometry of 50m streamer separation and 25m source separation. That configuration produces 24x12.5m cross-line samples and requires a 300m sail-line interval to sample the sub-surface adequately. With a triple source approach with the same number of streamers, the streamer separation can be opened to 75m with 25m between sources. This configuration produces 36 x 12.5m crossline samples and requires a sail-line interval of 450m. The difference is a *33% reduction* in the number of sail-lines.

The simple plot in *Figure 4* shows how the use of triple sources instead of dual can greatly impact the overall efficiency, cost, and safety of a towed streamer survey. For example, 25m cross-line sampling on a 900m

Streamer Spread	Number of Sources	Source Separation	Cross-line CMP spacing	Shot Interval	Source Interval (m)	Nominal Bin Fold	Shot Overlap Time (s)**	Sail-line Interval (m)	Trace Density (traces/sq. km)
Dual Source									
14x100	2	50	25	25	50	81	10.8	700	518400
16x100	2	50	25	25	50	81	10.8	800	518400
Triple Source									
10x150	3	50	25	12.5	37.5	108	5	750	691200
10x150	3	50	25	9.37	28.13	144	4.05	750	921600
10x150	3	50	25	8.3	24.9	163	3.59	750	1040964

Table 1: Example of dual and triple source geometries. With deblending trace densities are significantly increased.

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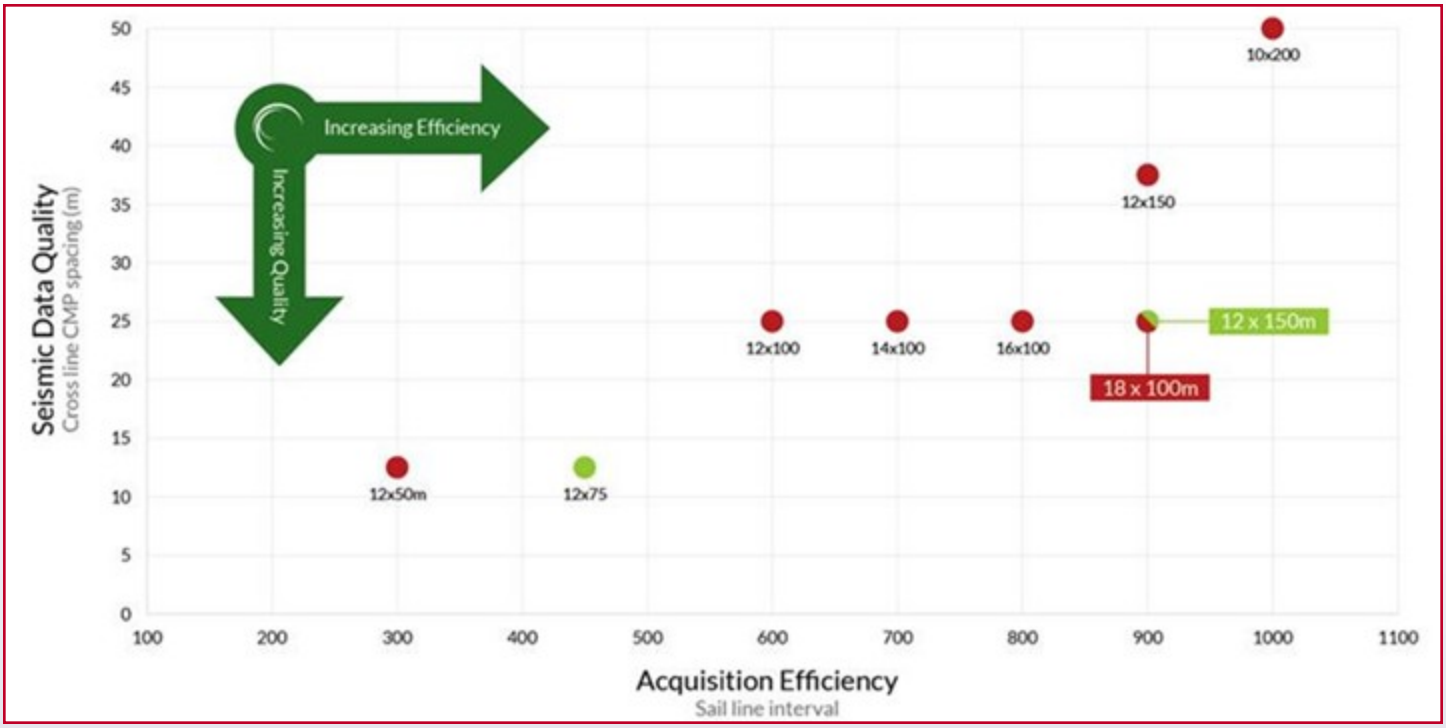

Figure 4: shows the relationship between cross-line sampling intervals and sail-line intervals for a variety of dual-source (red dots) and triple-source (green dots) towed streamer configurations.

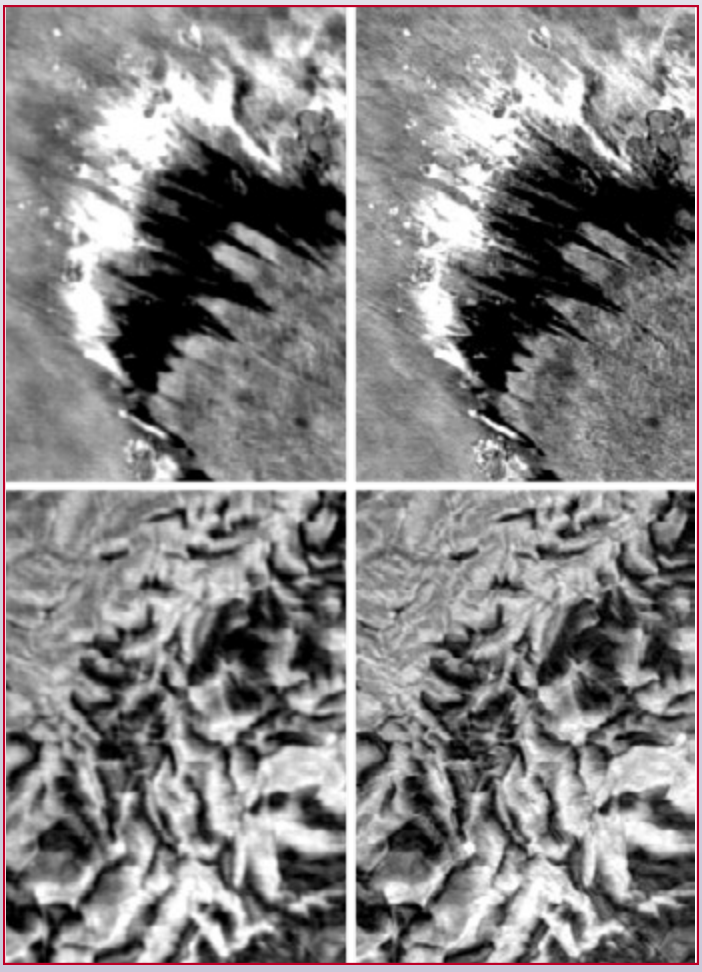

Figure 5: PSDM Timeslices with dual source left, penta source right. Top comparison through a mass transport event and bottom through polygonal faulting. Slices are about 1500m across

sail-line interval can be achieved with 18 streamers spaced at 100m and dual sources spaced at 50m. Or, the same cross-line sampling and sail-line interval can also be achieved with 12 streamers spaced at 150m and triple sources spaced at 50m. The reduction of the number of streamers from 18 to 12 has a significant impact on the cost base of the survey vessel, the operational risk during the course of the survey, and crew HSE exposure hours as fewer streamers and shorter surveys have less back deck and small boat operations.

Table 1 shows the comparison of survey efficiency and overall trace density between 14x100m and 16x100m streamer configurations with dual sources on 25m flip/flop shot intervals and a 10x150m streamer configuration with triple source on 12.5, 9.375, and 8.33m flip/flop/flap shot intervals. Leveraging the de-blending of overlapping shots allows shorter shot intervals with resulting significant increases in overall trace density per sq.km of the 3D survey area.

Technical Article continued on page 16.

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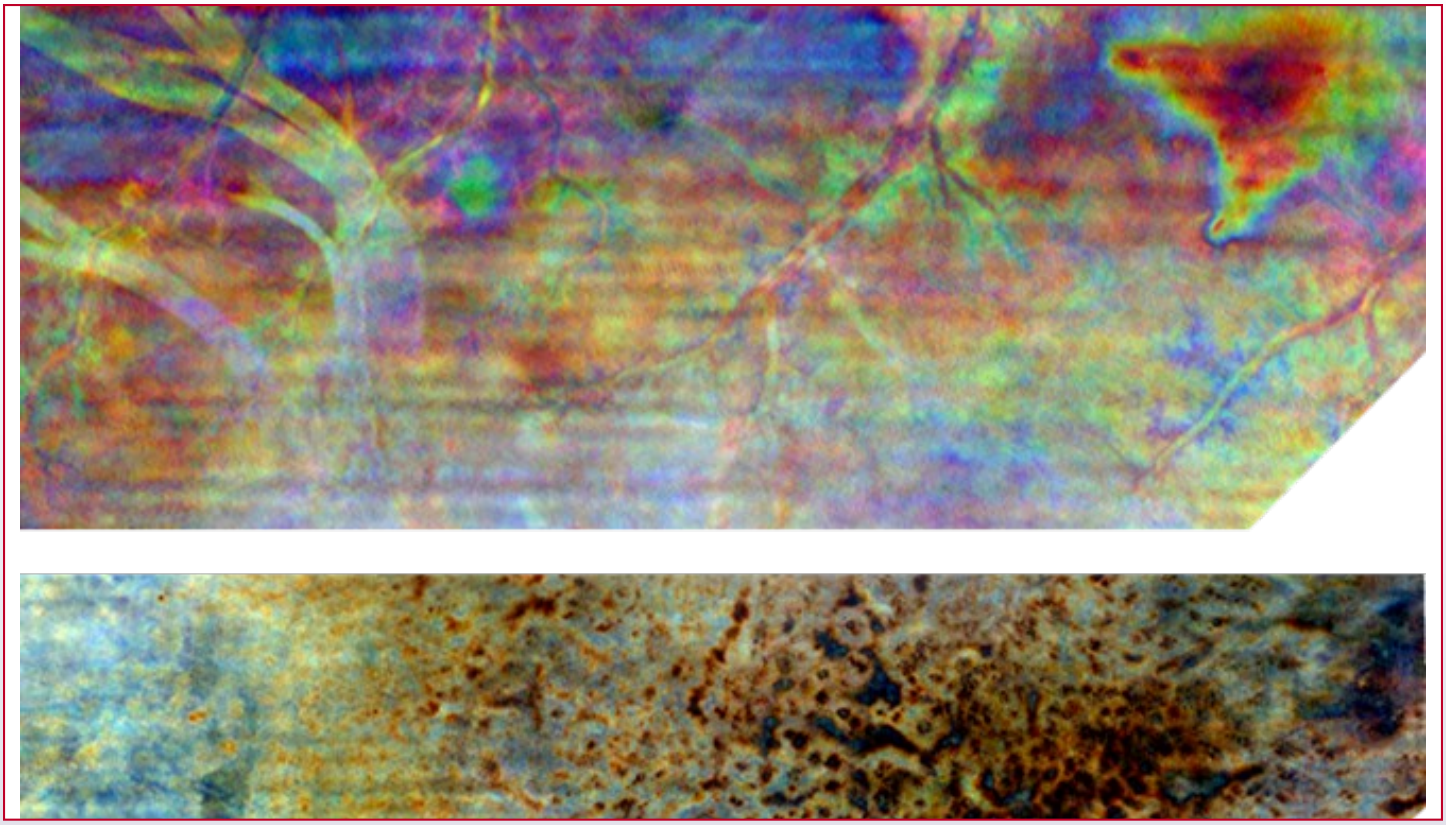

Figure 6: RGB enhanced time slices from a shallow water penta source acquisition after fast-track onboard PSTM. Top slice at 200 m below the seabed shows channel systems, and below, at 290 m below seabed, circular dissolution features. The slices are ~9km across.

With same source and streamer equipment, a set of five sources (penta) has been configured to sample the 3D wavefield on a 6.25m x 6.25m grid (Hager et al. 2015 and 2016). This represents a significant uplift in sampling resolution not only for the primary signal but for coherent noise modes. We see this as having potential value in areas with complex overburden and/or shallow targets where the high-density sampling can significantly aid in coherent noise removal and overall increased resolution of the primary targets. For example, In *Figure 5* we can compare penta source and dual source acquisitions as the processing effort has been "normalised" by regularising to, and migrating on, a 6.25m square grid.

Figure 6 shows RGB-enhanced timeslices for a shallow water survey. The data were processed onboard through to pre-stack time migration, without regularization, within 5 weeks of last shot. The lack of regularization does leave some residual footprint in the data, however these timeslices are shallow at 200m and 290m below the sea-bed, or ~300ms TWT, so not unexpected.

Conclusions

With modern acquisition and processing capabilities, the use of multiple source configurations for towed streamer acquisition has been demonstrated to increase overall survey efficiencies, 3D cross-line sampling, and overall trace densities per sq km of the survey area. The demonstrated uplift in overall data quality from increased trace density and the overall savings in time and cost due to more efficient in-field operations, with a complementary reduction in HSE exposure, are being recognized and requested by many mainstream E&P companies.

Acknowledgments

We thank the managements of Polarcus and DownUnder GeoSolutions for encouraging the development of the acquisition and processing techniques and providing vessel and processing resources to demonstrate the viability of the techniques.

Permalink: https://doi.org/10.1190/segam2017-17750447.1

GSH Outreach

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

Energy Day 2018,
Huw James, Robert Stewart, Lisa Buckner & Mac Hooton

Energy Day 2018, Lisa Buckner

Saturday, October 20 was the 8th Annual Energy Day organized by Consumer Energy Alliance. This family-friendly free downtown festival was held in partnership with the City of Houston in Sam Houston Park. It is intended to educate K-12 students and the general public about all forms of energy. Attendees were educated by 60 interactive exhibits highlighting a wide range of energy sources and technologies that help shape our everyday lives and the Houston economy. An estimated 25,000 people attended including 54 school groups from 9 Houston area school districts who were bused from their campuses to the event. Please visit the Energy Day website at http://energydayfestival.org/ for more information, event photos and video. The GSH had a tented booth with the Ocean Drilling Activity, an ION interpreted Gulf of Mexico section, P & S wave motion demo using a large colorful coiled toy spring, cutaway geophone, first oil and rock samples. SEG President Dr. Robert Stewart stopped by to visit the GSH booth as well as the UH booth where some of his geophysics students were volunteering. A huge "Thank You" goes out to our tireless volunteers Mac Hooton and Huw James who worked alongside me for 5 hours talking with a steady stream of eager students in spite of the light scattered rain showers.

On **Monday, October 22**, I gave a 40 minute presentation on Plate Tectonics to 80 eighth grade science magnet students at **Seabrook Intermediate School** who were covering the subject in class. The presentation was created by Marc Sbar, a former

Energy Day 2018, Mac Hooton & Huw James

GSH member and outreach volunteer, who retired from the industry and is now an Adjunct Professor in the Department of Geosciences at The University of Arizona. He has given this presentation to middle school students in Arizona. It was well received by the Seabrook students who asked some good questions afterwards. Each student was given an "Earth is calling … Will you answer?" brochure and a GSH logo coiled toy spring. I also gave their science teacher a plate tectonics evolution of the Earth poster printed by SDI which I brought back from the SEG Annual Meeting and the USGS Tapestry of Time and Terrain map and accompanying pamphlet (Maps in Schools Project).

Outreach continued on page 18.

Outreach continued from page 17.

Lisa Buckner, Seabrook Intermediate School

The Women's Energy Network held their annual **Young Women Energized** event on **Tuesday evening, November 13 at Houston Baptist University**. I volunteered as a table host and spoke with 11th & 12th grade girls about careers as a geophysicist in the oil and gas industry. Each student that I spoke with was given an "Earth is calling … Will you answer?" brochure.

North Shore Middle School held a career day on **Friday, November 16**. I was one of 20-25 presenters from a wide variety of different fields. I repeated a 15 minute geophysical careers classroom presentation 10 times to a total of 300 students. Since this was the first time to visit the school, I gave their science department a USGS Tapestry of Time and Terrain map and accompanying pamphlet (Maps in Schools Project).

UPCOMING EVENTS – Volunteers Needed

Friday, January 18, 2019 - First Colony Middle School Career Day (Sugar Land)
– Career Booth

Saturday, January 19, 2019 - The Educator Event @HMNS
– Talk to K-12 teachers

Thursday, January 24, 2019 - Morales Elementary School Science Night (Pasadena)
– Science Booth

Saturday, January 26, 2019 - Aldine ISD High School Science Fair
– Judges Needed

Saturday, February 16, 2019 - Girls Exploring Math and Science (GEMS) @HMNS
– Science Booth

Saturday, February 23, 2019 - AAUW Expanding Your Horizons in Science & Mathematics (Houston)
– Hands-on activity workshops for middle school girls

Saturday, February 23, 2019 - Science & Engineering Fair of Houston (GRB Convention Center)
- Judges Needed

Saturday, April 6, 2019 – Scout Fair (NRG Arena)
- Science Booth

Saturday, April 13, 2019 - HISD When I Grow Up Career Expo (Houston)
– Science Booth

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

A Live Webinar

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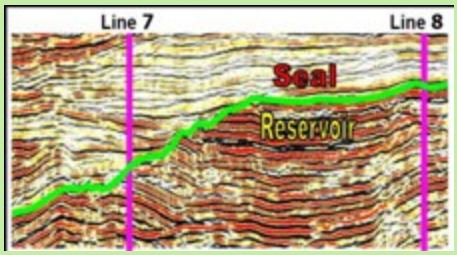
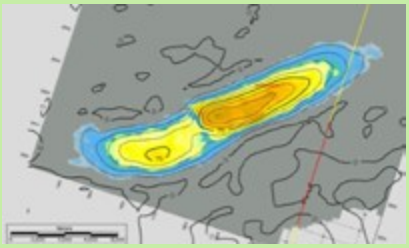
SOCIETY OF EXPLORATION GEOPHYSICISTS

Seismic Applied throughout the Exploration Life Cycle

This is Part 3 of Webinars on Seismic Interpretation





Four Half-days (10 AM – 2 PM)
Feb 5-8, 2019

Presented by
Fred W Schroeder

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

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

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

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

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

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

This **16 hour course** can be taken in the comfort of **your office** or even **your own home**. It works on PC's, iPads, or iPhones. No travel costs. The **Course Fee: $390**, with major discounts for Groups and Students. 1.6 CEU's are awarded.

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Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 22.

GSH OUTREACH is looking for volunteers for:

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

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- Social gathering on Tuesday evening
- Banquet toasting and roasting the honorees during lunch Wednesday
- Great opportunities for knowledge sharing and networking
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2019 Honorees
Dan Hampson and Brian Russell

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

The Mystery Item on page 20 is a blaster from 1948.

U of H Wavelets

SEG Wavelets Receive Summit Award at the 2018 Annual SEG Meeting and Participate in Earth Science Week at the Houston Museum of Natural Science *By Matthew Sexton*

A member of SEG Wavelets is giving a demonstration on our seismic acquisition set-up at the Earth Science Week Celebration.

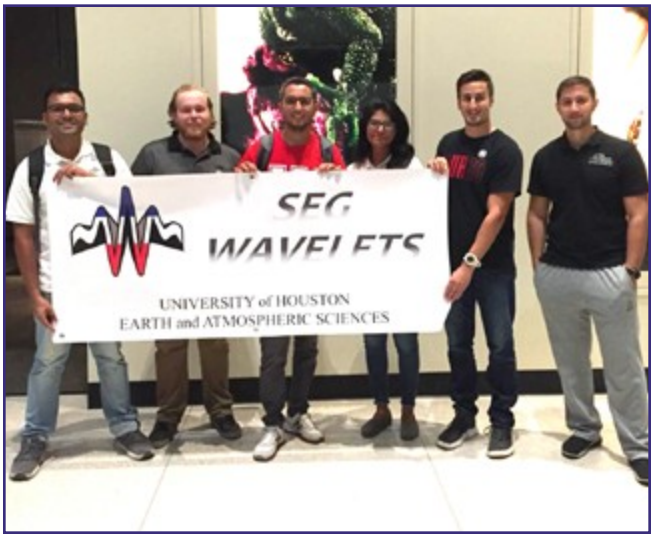
Our current president, Jackson Zerr (left), and our former president, Lian Jiang (right), holding the Summit award presented to them at the 2018 SEG meeting in Anaheim, California.

During the 2018 Annual SEG meeting in Anaheim, California that took place on October 14-19th, SEG Wavelets, a UH Student Chapter, was presented with the Summit level award for meeting the highest standards of excellence and achievement set forth by SEG. We are honored to receive this award that only 10 SEG student chapters are presented with out of the 300 chapters worldwide. In addition, our student chapter ranked 3rd in the world and 1st in the USA. We would like to thank our many sponsors and team members who helped us create, organize, and participate in events that promote the field of exploration geophysics.

On October 3rd, SEG Wavelets proudly participated in the Earth Science Week Celebration presented by the Houston Geological Society. The event was held at the Houston Museum of Natural Science and gave an opportunity for our chapter to get our local community interested about earth science by providing some fascinating insight into the field of geophysics. The SEG Wavelets had multiple booths set up in the Glassell Hall that displayed a few of the geophysical tools and instruments that geophysicists utilize such as seismic, GPR, and LiDAR analysis. Many of the participants who came to our booth were engaged with the instruments which made the whole experience an educational and enjoyable one. Our largest set-up demonstrated seismic acquisition and included 8 receivers which recorded waves generated by a hammer/plate exchange with the resulting seismograms displayed on a monitor. We then gave an explanation on how geophysicists use seismic data to image the structure of the earth in the pursuit of oil and gas. As a fun keepsake for the participants, the seismograms were

Wavelets continued on page 24.

Wavelets continued from page 23.



A photo featuring members and officers of the SEG Wavelets UH Chapter that participated in the Earth Science Week Celebration.

printed out for them to take back home. The SEG Wavelets are happy to have been a part of this wonderful and educational event.

Looking for more ways to participate in the Geophysical Society of Houston?

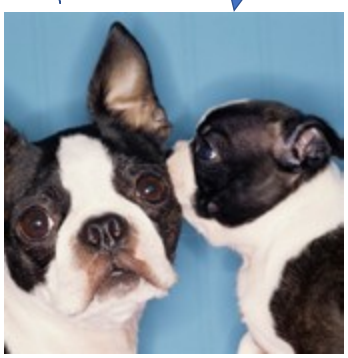
Consider how you can make a difference by volunteering at one of our events!

Contact Nicola Maitland to learn more about this excellent networking opportunity:

nmaitland@resolvegeo.com - 713-972-6209

What's new?

Reduced pricing for the Journal ads and Bundling options with other GSH ads & sponsorship!



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

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

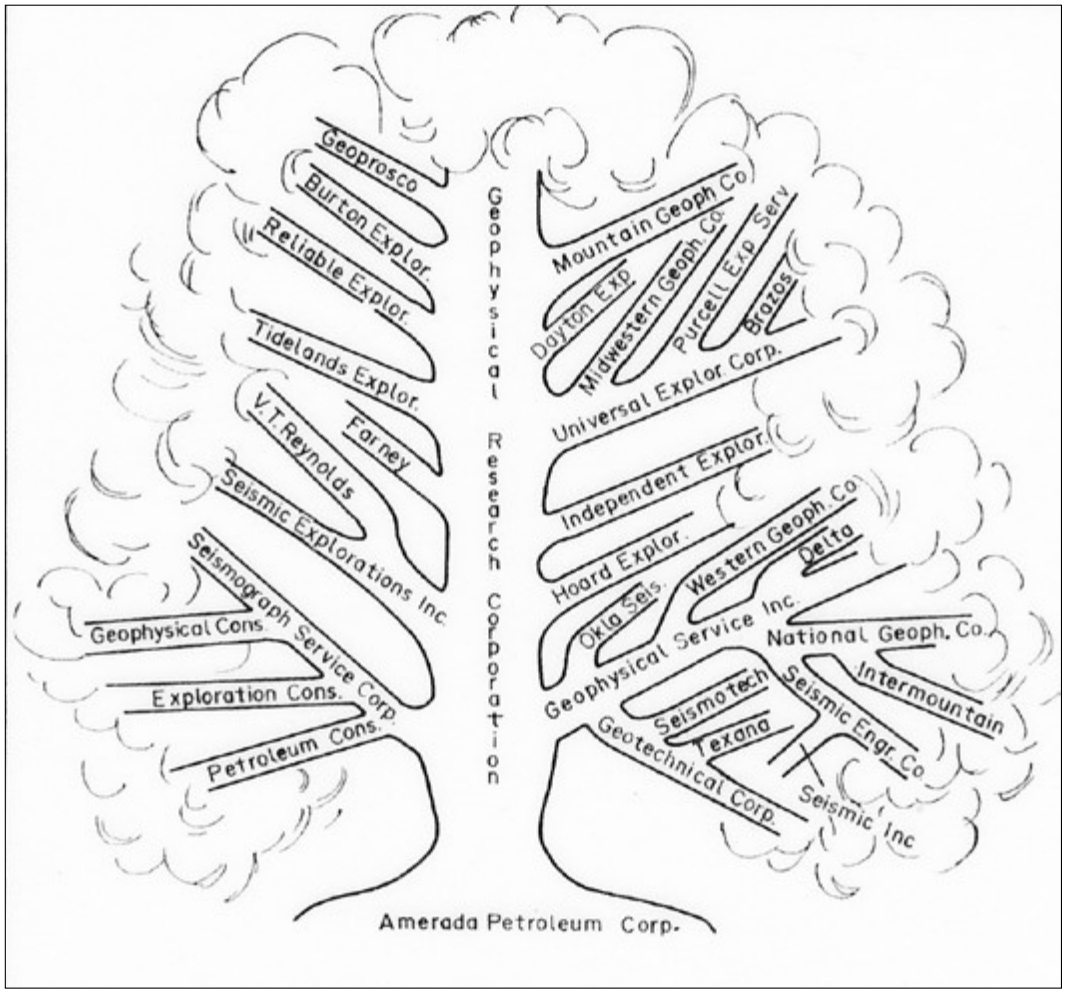
GSH Office ‣ (281) 741-1624 karen@gshtx.com

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

Geoscience Center News

By Bill Gafford

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



We recently renewed our lease on the space for the Geoscience Center and we hope to continue our efforts to preserve geoscience history with our museum collection of artifacts and publications from the 1920's forward, and to use these items to educate the public. We are still in need of financial support to keep this project moving forward. Donations from companies or individuals are welcome and donors will be recognized at our entrance.

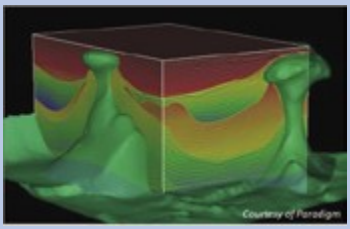
We have been working with Karl Schleicher, who is the SEG "Wiki "champion, to input some of the items from our inventory into the SEG Wiki. This is a long term project but should allow people to add information to the brief descriptions we have on some of our older artifacts. Volunteers for this project are welcome.

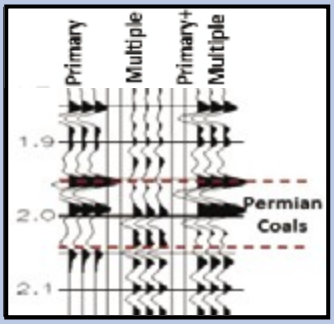
Our inventory also includes over 100 items that were donated by the Geophysical Research Corporation, or GRC, when the GSH Museum Committee started the collection in 1960. Unfortunately, our records do not include much detailed information about these items which included geophones, amplifiers, blasters, tuning forks, and torsion balances. We have been searching for descriptions and documentation for these instruments for the last few years with little success. The GRC was formed as a subsidiary of Amerada Petroleum Corporation in 1925, with Everette De Golyer as President and John Clarence Karcher as Vice President. The company began building instruments for seismic refraction surveys and discovered a number of salt domes with this equipment. Seismic reflection surveys followed and GRC proved the value of seismic exploration by discovering more salt domes and related petroleum discoveries. This success led to the formation by personnel who had worked for GRC of many geophysical companies, including GSI and Seismograph Service Corporation. This is shown, along with the many other companies in the picture below which is called the "Amerada Tree", with GRC being the main trunk of the tree, and Amerada at the base. We are hoping that some of our members may have worked for some of these companies and may have documents or company histories that would be useful in our research of the GRC instruments.

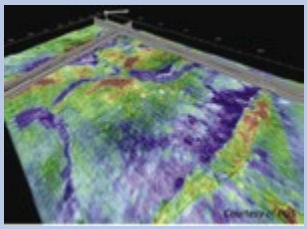
Visitors are welcome at the Geoscience Center on Wednesday mornings from 9:00 until noon or by appointment. Please contact me at geogaf@hal-pc.org or at 281-370-3264 for more information.

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 A. Hardage
Simplifying and Lowering the Cost of S-Wave Reflection Seismology	Bob Hardage
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
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
Everything You 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

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SOCIETY OF EXPLORATION GEOPHYSICISTS

Recognizing Outstanding GSH Volunteers...

Karen Blakeman

by Tommie Rape

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

Karen Blakeman was born and raised in Midland, Texas. She grew up in a home associated with the petroleum industry, as her father was a petrophysicist for The Superior Oil Co. and then for Mobil after the merger. The family moved to Houston, the heart of the US petroleum industry, when her dad was transferred here. Karen remembers that most of the family vacations when she was growing up were geological field trips. Her sister, Janie Schuelke, is a geologist and a member of the HGS. Her brother-in-law, Jim Schuelke, is a past president of the GSH. Though she started out in a different work environment, it seems that it was inevitable that she would eventually end up working in association with our industry.

Karen was one the earliest women to attend Texas A&M, where she obtained a Bachelors of Environmental Design (B.E.D.) and a Masters in Architecture with an emphasis in interior space design. Karen worked in interior architectural design in Austin for 13 years; part of that time she had her own business where she designed the interiors of numerous hospitals and medical clinics. She gained her architectural registration and interior design certification and was very active in AIA Austin and the Institute of Business Designers (Central Texas Chapter.) As the GSH was later to find out, Karen helped make things happen that seemed to have little chance of occurrence. For instance, in one medical building that she was designing, the planned art work was removed from the budget due to economic restraints; Karen found someone to donate money for the art to ensure that the building achieved the aesthetics desired. Family duties called her back to Houston where she continued her architectural design work, which included work on well-known establishments such as the Houston Chronical and Hobby Airport. While raising three daughters in Houston, Karen also taught at the University of Houston for a while. In Houston, she earned LEED Accredited Professional designation and Construction Document Technologist.

Karen's involvement with the GSH began in 2012 when the GSH moved into its own office that had previously been shared and staffed with the Houston Geological Society. Available due to a downturn in the building industry, Karen was a great fit for the position due to her vast experience with volunteer organizations and volunteer work and to her having run her own business. Karen fitted out the office utilizing her

Volunteers continued on page 29.

Volunteers continued from page 28.

design experience. She acquired the furniture very economically; she actually owns some of the furniture and art work. The office was described as "looking like a frat house before Karen fixed it up". Karen then organized and developed the business workings of the organization, which had previously been handled by the HGS. It took quite an effort to identify and overcome the "hairballs" (issues that had to be addressed to make the office functional). During this initial period, she frequently worked late into the night. Once, she even celebrated her birthday with others in the GSH office with a puzzle and Chinese food. Assuming the role of Office Director, Karen organized the financial records (with the existing Treasurer, Barry Rava) and still maintains them. She handles most of the GSH banking interactions, invoicing, outgoing checks, credit card operations, etc. Her list of responsibilities for the GSH far exceeds what can be covered in this article. To name a few: Karen acquires most of the advertising and some of the sponsorship for the GSH; she works with most of the event chair persons in the preparation for social and technical events; she is the first line of communication with most of the contractors/contracts for the GSH; in the world of continuously changing people in officer positions and committee chairs, Karen developed and provides guidelines to help ensure that events run smoothly from year to year; she oversees and maintains the office space, equipment, and supplies; partially due to her interest and skills in graphics, Karen prepares many of the ads and announcements for various media; and many other things. She is probably most visible to most of you when she attends and handles check-ins at various social and technical events; at these events she is very capable in recruiting new members and advertising. Or you may have talked to her on the phone at the GSH office, where she endeavors to help members who call in for assistance.

But Karen's efforts for the GSH go beyond these normal duties. As you can imagine, an organization as large as the GSH that conducts almost 100 events a year requires considerable effort from

Volunteers continued on page 30.

Interview continued from page 29.

many people. Karen works many hours at night and on weekends to ensure that these events occur as smoothly as possible. Karen enjoys graphics, and she works at night creating flyers for GSH events and the Journal. She also comes in on many of her days off to take care of pending business for the GSH.

Karen "wants to make a difference in the world", and she does this by volunteering for many organizations in addition to the GSH. Karen learned from her Dad that "If you want anything done right, do it yourself". Being limited to how much you can do by yourself, she has joined organizations that further her effect. Karen is also dedicated to the Rotary Club, where she has not missed a weekly meeting in 31 years. She has received several awards from the Rotary Club recognizing her service. Karen has participated in several professional architectural and design organizations and has held numerous leadership positions in these organizations. She has worked with several children organizations. Karen has also exhibited a strong dedication to helping Landmark Forum, a training and development company that provides personal and professional growth. She also volunteers for the Sharpstown Rotary Literacy Project which partnered with First Book Team Houston, Cycle Houston, Channel 13 ABC and the Jack Valenti School of Communication at the University of Houston providing Disney books to help kids learn to read, so that they can read to adults and help them learn English.

Karen gets a great deal of satisfaction helping the GSH improve. Membership and activities have increased during Karen's involvement with the GSH, and she is grateful to have had a part in that. She has immensely enjoyed the relationships that the GSH has provided. Karen encourages GSH members to come forward and also volunteer to help the GSH. Karen suggests that you check in with her or Kathy in the office, or with Nicola Maitland (the GSH Volunteer Coordinator), and find ways to volunteer that you will enjoy and benefit from. Getting to know other geophysicists, including many of the leaders of our profession, can be helpful to your future career, and it might even surprise you how fun they can be. If you are between jobs, spend some of that extra time helping the GSH, and you might even meet key people that will open future opportunities. Volunteering to work with a GSH committee will also help you gain experience that will facilitate your being a future leader of the GSH.

It is obvious to many that Karen wants to do a good job, and that she strives to make the GSH the best organization that it can be. Her vast experience in volunteering has been beneficial to the GSH and has helped us make the GSH a better professional society for its members. If you know Karen, you know that she is full of ideas to help make things happen. If you see Karen, please thank her for her work and volunteer efforts, and then share with her some of your ideas that will make the GSH even better than it is.

GSH Annual Golf Tournament 2019

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

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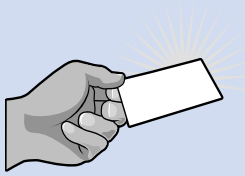

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Doodlebugger Diary

Peru – Land of the Inca Gods

Part 1 – Geology and History of Oil Exploration

By Scott Singleton

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

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. Usually these are not recent events, but more recent ones are just as welcome. Think back to an earlier time when you were on a seismic crew, operating a magnetometer survey, gravity stations, etc. I published a story about working in a data processing center. Please consider contributing a story about your past professional experiences. Contact me at Llawyer@prodigy.net *or our Editor at* editor@gshtx.org.

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

Introduction

In 1998 I had the pleasure of serving as a QC 'birddog' on a 2-D offshore survey in the Talara Basin of far northern Peru *(Figure 1)*. The acquisition portion was then followed by an extensive processing effort in the client's offices in Lima. All told I spent over a half year in Peru where I had a great time, met a lot of interesting people, wrestled with poor imaging on some of the seismic data, and ended up traveling to several very interesting parts of Peru. Over this period my wife finally became pregnant after years of trying, after which I decided I would no longer work overseas away from my family. I quit my job at Energy Innovations but went back to Lima to work for several months as a contract processor for Petrotech Peruana S.A. However, during my stay in Lima my ex-boss, at EI,

Doodlebugger continued on page 35.

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 34.

Figure 2: Sedimentary basins of Peru. From http://www.perupetro.com.pe/wps/portal/corporativo/PerupetroSite/informacion%20al%20inversionista/¿por qué invertir en el perú-/!ut/p/z1/

found out I was down there and was so pissed off that he won't speak to me, even to this day. Such is life.

I'll be describing this project in some detail so it's important to understand the geology and history of oil exploration in the basin so readers will understand the context of why things were happening the way they did.

Geology of the Talara and Tumbes Basins

The Talara and Tumbes Basins *(Figure 2)* contain thick sequences of Paleozoic to Tertiary age sediments that merge and pinch out onshore onto the Brazilian and Guyana Shields. The geological evolution of these sequences is controlled by two regional tectonic systems. The first, the pre-Andean System, encompasses three cycles of Ordovician, Devonian and Permo-Carboniferous rocks overlying the Precambrian basement of the Guyana and Brazilian Shields. The second, the Andean System, was initiated with the beginning of subduction along the western margin of Peru. It encompasses several mega-stratigraphic sequences and numerous minor sedimentary cycles, ranging from Late Permian to the Present (Perupetro basin evaluation report, 2005).

The initial phase of the Andean System developed during the Pangea break up. The development of an Andean subduction zone during late Permian to early Triassic times is supported by evidence of a Permo-Triassic continental volcanic arc along the Peruvian Eastern Range.

A thick succession of Mesozoic sediments was deposited both onshore and offshore of the subduction zone but these are mainly of interest for onshore reservoirs. Offshore the primary reservoir zones lie in the Tertiary fore-arc basin clastic sequence. The Talara Basin was the focus for rapid and thick Paleocene and Eocene sedimentation of 8-9 km. At the end of the Eocene the Talara Basin was uplifted, shifting the depocenter to the Tumbes Basin where 7 km of Oligocene, Miocene and Pliocene sediments was deposited.

By far the Eocene section constitutes the most important producing interval in the Talara Basin. It consists of three stratigraphic sequences totaling 6-7 km. Each sequence consists of a basal conglomerate followed by a succession of interbedded silty clays and shales and feldspatic sandstones. It is these basal conglomerates that cause considerable raypath distortion of acoustic waves. As a result, seismic data in the Talara basin have historically been poor and lacked penetration past the Eocene section.

Summary of Oil Exploration in the Talara and Tumbes Basins

(Note: this section is extracted from Spencer, 2010).

Oil development in Peru dates back to the mid-nineteenth century, but it was not until the early 1900s that it began to take off. By 1929, oil made up 30 percent of Peru's export revenues. But beginning in the 1940s, failed exploration efforts and political interference (such as policies that changed from government to government, refusal by various governments to grant new concessions, and fixed petroleum prices) left Peru with a trend of diminishing reserves and production. In response to increasingly

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Doodlebugger continued from page 35.

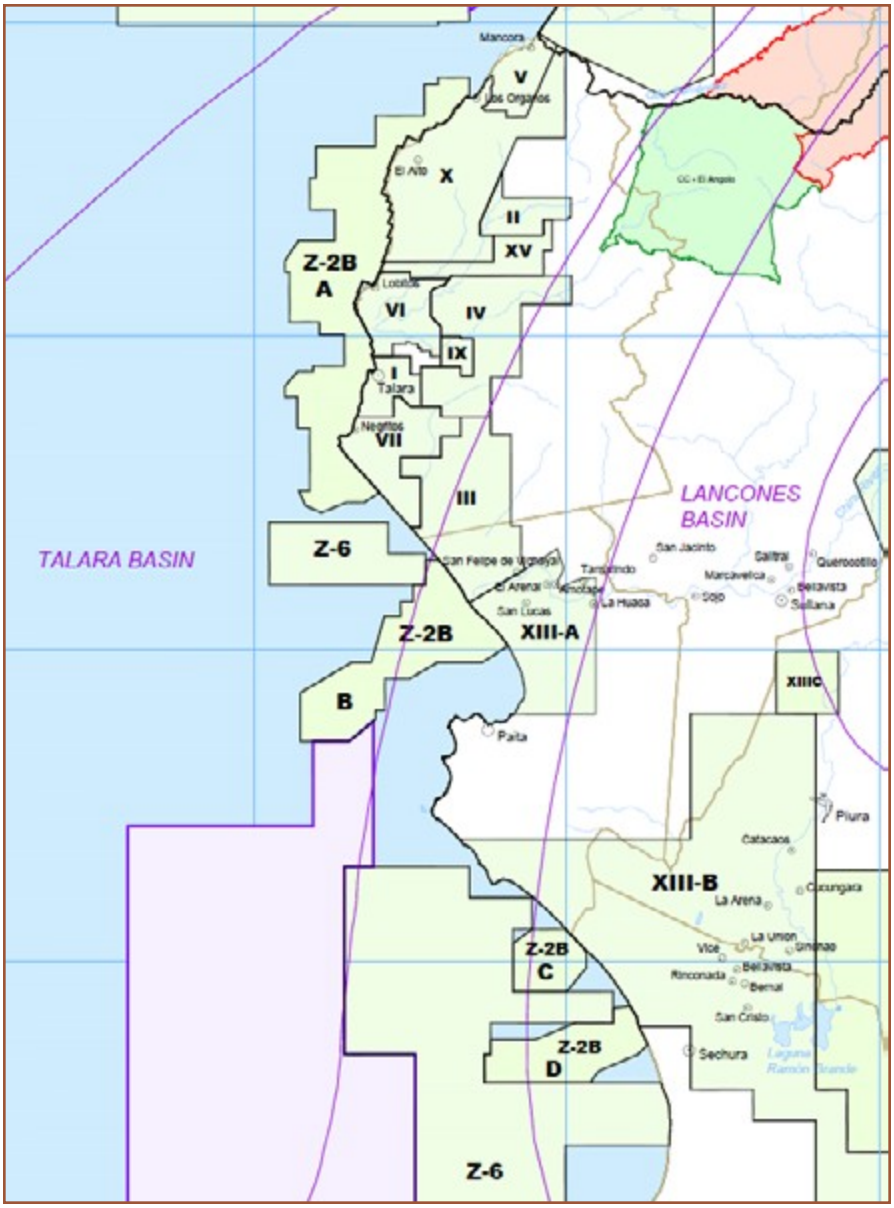

Figure 3: Block chart map of the northwestern portion of Peru. From http://www.perupetro.com.pe/wps/portal/corporativo/PerupetroSite/informacion%20al%20inversionista/mapa%20de%20lotes/

unfavorable policies governing the sector, private investment waned. In 1968, the military dictatorship expropriated the International Petroleum Company, a major presence in Peru at that time, and created state oil company Petroperu. For nearly 25 years, Petroperu controlled all aspects of Peru's oil and gas industry. Even though Petroperu sought the participation of private companies in exploration and production, only a few firms remained in Peru during this time. After years of industry decline, Peru became a net importer of oil in the late 1980s/early 1990s.

Heavy state intervention in the energy sector mirrored the role of the state in the rest of the economy during the latter part of the twentieth century. After decades of low economic growth, Peru's economy worsened in the second half of the 1980s. Real wages fell by almost half, accompanied by hyperinflation and huge deficits. In 1990, political outsider Alberto Fujimori won the presidency and used "shock" measures to stabilize the economy. In addition to implementing fiscal and monetary reforms, Fujimori greatly reduced the role of the state in the economy. His hardline approach to combating the Shining Path insurgent movement also improved security.

By the time Fujimori came to office, Petroperu was losing money, and reserves and production in Peru were declining as a result of low investment in the sector. Management recognized the need for a substantial restructuring of the company and embraced the goal of privatization. While full privatization was never achieved, Petroperu was able to streamline its operations by shutting down underperforming businesses, shedding unnecessary staff, selling off business units, and limiting political interference in business decisions.

It was in this climate of market openness that a new hydrocarbons law was passed. Legislation approved in 1993 ended Petroperu's monopoly over oil and gas and allowed for the participation of private companies in all aspects of the sector. Improvements to exploration and production contract terms and recourse to international arbitration in case of dispute made Peru more competitive. As a result, from 1990 to 1997 investment in the sector increased from $20 million to $4.3 billion. Areas under operation went from 1 million to 23 million hectares in the same period. Prices were no longer set by the state but reflected the market. A new state company, Perupetro, was created. Perupetro is a non-operating company whose sole purpose is to

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Doodlebugger continued from page 36.

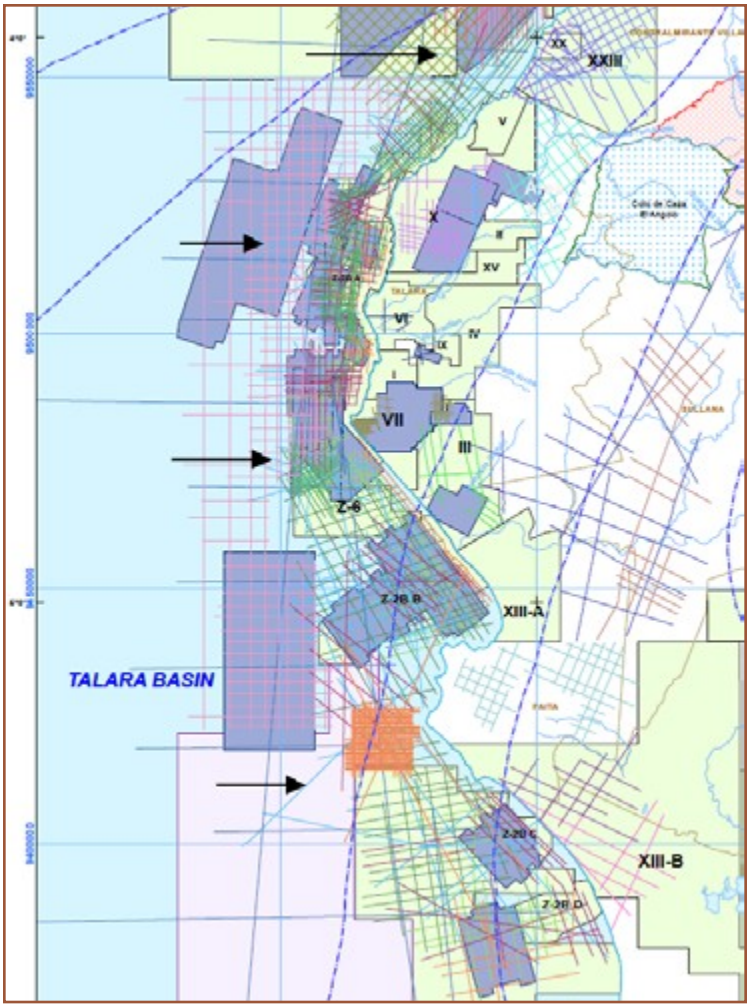

Figure 4: Seismic surveys acquired in northwestern Peru. The light blue 2D seismic lines are from the 1998 Petrotech survey over Block Z-2B (indicated by black arrows). From http://www.perupetro.com.pe/wps/portal/corporativo/PerupetroSite/informacion%20al%20inversionista/mapa%20de%20lotes/

administer oil and gas resources and to contract with private companies seeking exploration and production rights.

Petrotech Peruana S.A. and Talara Basin Offshore Block Z-2B

One of Perupetro's early actions was to compartmentalize the old onshore fields into smaller production units that were operated by separate entities. In the 1970's, the offshore extension to the Talara basin was the first offshore production in South America. In the mid-1990's this acreage was taken over by Petrotech Peruana S.A., a private company backed by American money and management. Their acreage was known as Block Z-2B, sections A through D (Figure 3). Block Z-6 was also taken over by Petrotech but at that time it was an unproducing block. (Perupetro basin evaluation report, 2005).

Petrotech then proceeded to plan and initiate a 'modern' 2D seismic program over its acreage holdings. In 1998 this program was undertaken *(Figure 4)*. It was quite extensive, requiring the acquisition of seismic lines along about 200 km of coastline. It was the acquisition of this survey for which I was called in to be, one of, a rotating crew of QC birddogs. So early in 1998 I flew to Lima and made my way up to Talara to catch the seismic vessel which was waiting at the dock.

Next month: Part 2 – The Survey

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HGS Foundation Scholarship & Calvert Memorial Fund February 11, 2019
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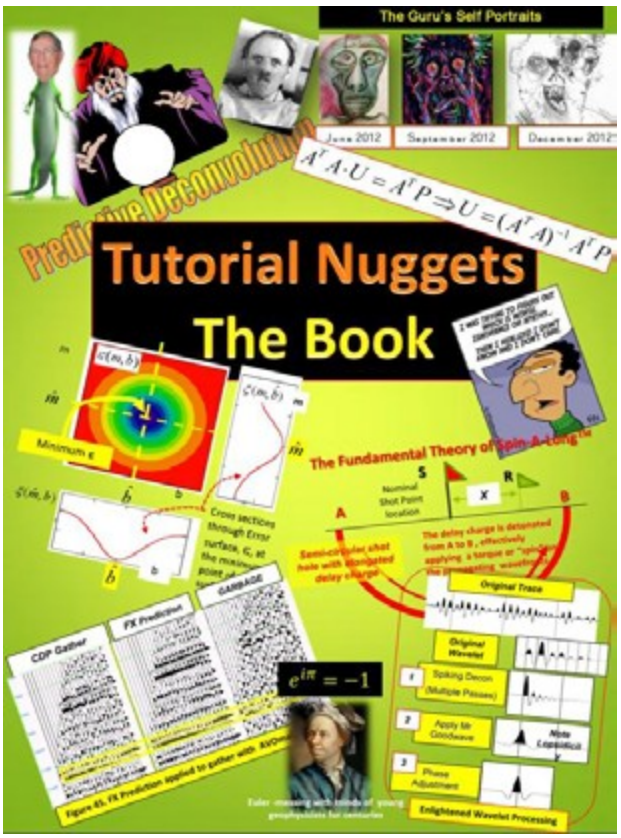

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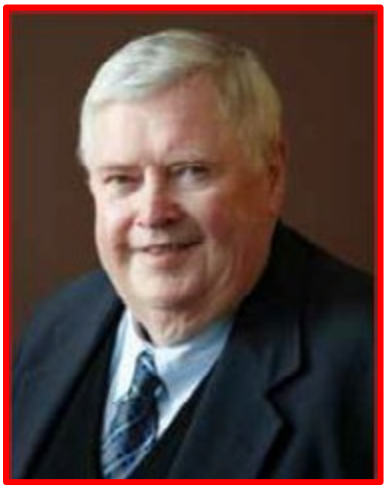

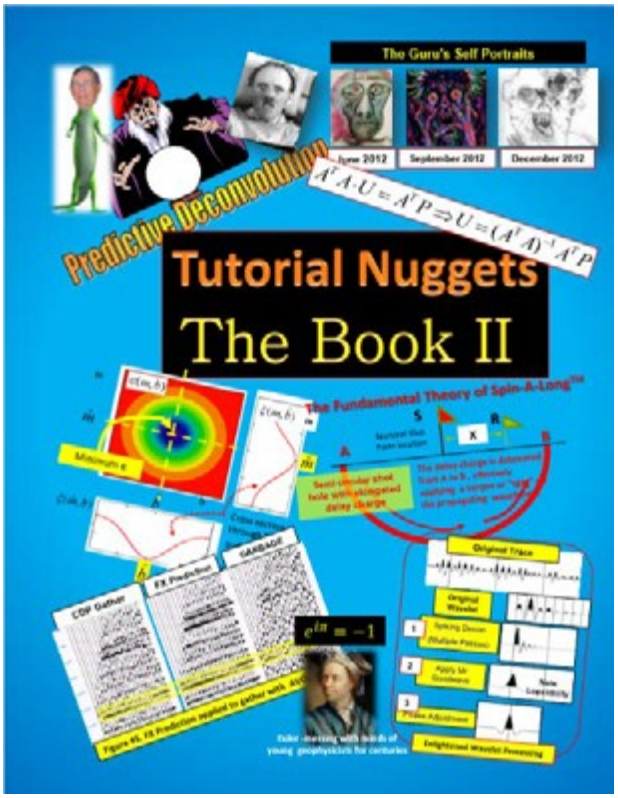

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