January 2018

GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 8 • Number 5

The Epicenter of Geophysical Excellence

TABLE of CONTENTS

• • MEETINGS • •

• • FEATURES • •

• • CHECK THIS OUT • •

• • LOOK INSIDE • •

On The Cover...

Seismic Operations in Alaska.

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

Mar 2018 ..... **Jan 9**
Apr 2018 ..... **Feb 8**
May 2018 ..... **Mar 9**

GEOPHYSICAL SOCIETY OF HOUSTON ORGANIZATION CONTACTS

Karen Blakeman, Office Director • Kathy Sanvido, Webmaster/Membership Manager
14811 St. Mary's Lane, Suite 204, Houston, TX 77079 • Office Hours 8 a.m. - 5 p.m.
Phone: (281) 741-1624 • Fax: (281) 741-9364 • Email: office@gshtx.org • Website: http://www.gshtx.org
GSH Board of Directors = GSH Executive Committee + SEG Section Representatives

PRESIDENT	Tommie Rape		713-829-5480	tommiedr@aol.com
Sponsorship	Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
Doodlebugger Fund	Paul Schatz	713-975-7434	713-829-5254	Paul.Schatz@int.com
Editorial Board	Lee Lawyer		713-628-3513	llawyer@prodigy.net
Advertising Committee	TBD			
Historian	Art Ross	281-360-9331		artross@airmail.net
Office	Dave Agarwal	281-920-4450		dave0836@aol.com
	Glenn Bear	832-624-9950	281-250-4013	glenn.w.bear@exxonmobil.com
Outreach	Lisa Buckner	713-496-4256	713-252-9665	lbuckner@hess.com
Scholarship Liaison	Jim Schuelke	713-296-6801		Jim.schuelke@apachecorp.com
PAST PRESIDENT	Amy Rhodes		281-206-5826	amy.l.rhodes@cop.com
PRIOR PAST PRESIDENT	Glenn Bear	832-624-9950	281-250-4013	glenn.w.bear@exxonmobil.com
MEMBERSHIP				
PRESIDENT ELECT	Dennis Yanchak	713-296-6109		Dennis.Yanchak@apachecorp.com
GSH/SEG Membership	Fernando Enrique Ziegler		832-413-1260	fernando.ziegler@gmail.com
Volunteer Coordinator	Nicola Maitland	713-972-6209	281-507-6552	nmaitland@resolvegeo.com
Career Directions & Progressions	Whitney Blanchard		713-380-7255	wcharris26@gmail.com
Diversity & Women's Networking	Nicola Maitland	713-972-6209	281-507-6552	nmaitland@resolvegeo.com
TECHNICAL EVENTS				
FIRST VICE PRESIDENT	Xianhuai Zhu	832-850-7680	832-492-2298	xzhu@forlandus.com
FIRST VICE PRESIDENT ELECT	Maitri Erwin	713-380-4800	281-785-5814	maitri.erwin@gmail.com
Tech Luncheons	Xianhuai Zhu	832-850-7680	832-492-2298	xzhu@forlandus.com
Tech Breakfasts Northside	Glenn Bear	832-624-9950	281-250-4013	glenn.w.bear@exxonmobil.com
Tech Breakfasts Westside	Michael Obriain	713-689-6913	713-829-5238	obriain1@slb.com
	John Gilbert	713-689-7803	832-655-4197	JGilbert@exchange.slb.com
Spring Symposium	Xianhuai Zhu	832-850-7680	832-492-2298	xzhu@forlandus.com
Continuing Education	Mike Graul	713-465-3181	713-248-3562	mgraul@texseis.com
Webinars	Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
SEG DISC	Maitri Erwin	713-380-4800	281-785-5814	maitri.erwin@gmail.com
SPECIAL INTEREST GROUPS (SIGS)	Maitri Erwin	713-380-4800	281-785-5814	maitri.erwin@gmail.com
Data Processing and Acquisition	Clement Kostov	713-689-5752	832-506-6026	kostov1@slb.com
Microseismic	Werner Heigl		832-933-3573	werner.heigl@icloud.com
Potential Fields	Rao Yalamanchili	832-351-4824	713-818-3046	rao.yalamanchili@cgg.com
Rock Physics	Ratna Sain	832-624-8716		ratnanabha.sain@exxonmobil.com
SEG Wavelets	Lian Jiang		346-204-8684	jiang2015leon@gmail.com
SOCIAL / FUNDRAISING EVENTS				
SECOND VICE PRESIDENT	Katherine Pittman	713-972-6206		kpittman@resolvegeo.com
SECOND VICE PRESIDENT ELECT	Denise Dorsey		713-397-4487	denise.dorsey@katalystdm.com
Sporting Clays	Ryan Marshall	713-917-6772	713-962-9414	ryan.marshall@dawson3d.com
Icebreaker	Tony LaPierre	713-482-3845	281-733-5281	Tony.Lapierre@rpsgroup.com
Salt Water Fishing Tournament	Bobby Perez	832-554-4301	281-787-2106	r_perez@seismicventures.com
Tennis Tournament	Russell Jones	832-295-8350		rjones@Seitel.com
Annual Meeting & Awards Banquet	Katherine Pittman	713-972-6206		kpittman@resolvegeo.com
Golf Tournament	Wes Tyrrell	281.529.3246	713.485.9502	wesley.tyrrell@katalystdm.com
SECRETARY	Lillian Comegys	713-296-6123	318-422-2066	Lillian.Comegys@apachecorp.com
TREASURER	Katie Baker		713-822-5886	Kathleen.lizabeth.baker@gmail.com
Finance Committee	Glenn Bear	832-624-9950	281-250-4013	glenn.w.bear@exxonmobil.com
COMMUNICATIONS				
EDITOR	Dmitry Kulakov		832-525-7815	dkulakov@slb.com
Assistant Editor	Courtney Anzalone		713-689-5741	canzalone@slb.com
Assistant Editor	Chirag Parekh		713-689-2388	cparekh@slb.com
Assistant Editor	Kara Shiflett		713-689-6226	kdetro@slb.com
Assistant Editor	Christopher Walker	281 787 8764		cwalker@sbgs.com
Technical Article Coordinator	Scott Singleton		832-524-8382	Scott.Singleton@comcast.net
Website Coordinator	Paul Schatz	713-975-7434	713-829-5254	Paul.Schatz@int.com
Social Media Coordinator	Liza Yellott	713-881-2894	713-204-0998	lyellott@Seitel.com
SEG SECTION REPRESENTATIVES	Mike Graul	713-465-3181	713-248-3562	mgraul@texseis.com
	Sofia Campbell	713-668-5406	713-443-4436	sofia.campbell@comcast.net
	Amy Rhodes		281-206-5826	amy.l.rhodes@cop.com
	Tommie Rape		713-829-5480	tommiedr@aol.com
	Maitri Erwin	713-380-4800	281-785-5814	maitri.erwin@gmail.com
	Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
SEG ALTERNATE REPS	Bill Gafford	281-370-3264		geogaf@hal-pc.org
	Rita Creasy-Reed	281-509-8128	281-793-2808	rita.creasyreed@gmail.com
	Glenn Bear	832-624-9950	281-250-4013	glenn.w.bear@exxonmobil.com
	Scott Singleton		832-524-8382	Scott.Singleton@comcast.net
GEOSCIENCE CENTER	Bill Gafford	281-370-3264		geogaf@hal-pc.org
SPG-NA Rep.	Dave Agarwal	281-920-4450		dave0836@aol.com
ECH liaison	Bill Gafford	281-370-3264		geogaf@hal-pc.org
OTC Rep.	Roy Clark	281-723-8672		reclark48@aol.com
HPAC	Louise Andrews		713-774-1572	LouiseJAndrews1@gmail.com
NeosGeos	Sean Kimiagar		817-727-6424	seankimiagar@gmail.com

A Word from the Board

Technology Plus People

By Dmitry Kulakov, Editor

Starting any industry related paper with words "downturn" and "crisis" is almost a cliché these days. However, not mentioning the fact of continuous oil and gas field struggles would be almost an act of hypocrisy. I don't usually use car sharing services, but when I need them, 80% of the drivers I meet are highly educated, ex-petroleum related professionals "in transition". Most of the time, during conversations with these people, which I enjoy tremendously due to their experience and motivation, I learn about the new field they find themselves interested in, and how they consider switching their professional lives for good. That means a simple fact: if you don't see any other opportunity in our field, there are an infinite number of things we can do instead, and some of them sound much more exciting. Among my friends, there are people who recently deliberately resigned from oil and gas. They believe that the golden era of hydrocarbons is over and now it's time to move on to something more advanced.

Personally, I see the situation a little differently, and I don't share this opinion of oil and gas days being over. Actually, I believe that the simple days are over: we can't keep working by investing a necessary minimum into technology development and using existing approaches, while making good money. I think that market has changed forever, and that's a fact. Our industry strives to use the latest technological advances of modern science. Though many principles we work with are simple and have been around for more than a century, we keep using them. However, designing a deepwater well is very close to "Rocket Science". When we do contend with challenges, our past experience and cost minimization are dominating factors. The industry abandoned curiosity and innovation for the sake of being sure that all investments will be covered by returns. The fact that we appear unwilling to change our ways of doing business and technology development is, in my mind, a core driver of the "downturn" in our minds.

Independently from tomorrow's oil price, the level of competition that has been set by the ongoing market situation is only going to increase. These changes are effecting every single level of the industry starting from a single employee, to services offered, entire companies and, finally, every government in the world. I don't believe that there is a single place on the planet that is not involved with hydrocarbons (however, some native tribes may be the exclusion). If we will not adapt to the ongoing reality and change the way we work, both business and behavior, we will slowly transform from a high-end technology driven industry to a group of crude pumpers. We must integrate in this environment and accelerate developing technology as never before. While the economy is trying to absorb and accommodate new things like cryptocurrencies, blockchains and machine learning, we are just cutting costs rather than innovating to increase level of optimization and automation. Oil and Gas must catch up to other industries that are more open to technological advances, like every single IT company in the world. I do believe that our field is full of brilliant minds that can learn and adapt anything to our needs, we just need a strong motivation. Well, if that's not strong motivation, I don't know what is! So let's stop thinking about the good old days when the life of an oilman was simple, and start looking into the new realities of the market.

Dmitry Kulakov

Saying all that, I want to share another thought that I came across only while getting involved with the GSH. As any other young professional, I always believed that to succeed in our field, it only requires a good professional knowledge and technical skills. Since my senior colleague asked me if I want to help him with editing the GSH Journal, I've started to come out from my technological cocoon. Here I've been meeting outstanding professionals who do not stop their work in the office, but also, continue in their own free time by serving the community. These people are always listening to other colleagues' needs and providing them with educational, professional and recreational events of exceptional quality. They made a huge step forward and evolved from simple oil and gas employees into professionals who try to reach out to the community and improve it. I think that these people are key figures in an industry in transition. They care not only about technology, which is very important, but also about the most valuable resource any field can get: people. I do believe that if more of us would get involved with the society, communicate more often, and start participating in community activities, we will find additional sources of outstanding business and technological ideas.

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

As I told you in December (TLE 17 Dec), *"From the Other Side"* is over in TLE. But that doesn't mean there will be no From the Other Side (FTOS). There will be a seamless switch from TLE to the GSHJ (GSH Journal). If you read this column, I will continue to write it. I enjoy writing them, especially when answering a note from one of you.

Compared to the SEG we are sailing in a following breeze. We may be close to a lee shore but there is no financial risk of going on the rocks (Don't you love a metaphor). In contrast, the SEG has budgeted a significant loss. These numbers are available to the membership, either for the GSH or SEG. A huge difference between the two Societies is the number of technical meetings. The GSH sponsors about 100 events each year. In addition to that number there are 'social' events: golf, tennis, fishing, shooting. Throw in an Ice Breaker or two.

"So what?" you say. "What's your point?" Good questions. No point. I just like writing about them.

Some time ago, a group of "seasoned" geophysicists were referred to as "Living Legends" and asked to congregate at the SEG during an Annual Meeting. Since then, the GeoScience Center has scheduled a quarterly gathering of the local "Living Legends." There is no agenda, no speeches and no formality but there is a lot of "those were the good old days".

And it seems as if that is true. Those *were* the good old days! The post WWII decades. The experimental years in the geophysical professional. It started out slowly. Seismic field crews were autonomous. Paper records were brought in from the field and dried out over a bath tub. They were given headings with administrative detail. Often there was a "Seismologist" on the crew that "picked" the events. Maps were made of key events. Usually, the maps would be sent to a client office or a client representative could be permanently assigned to the crew.

That doesn't sound like the good old days, does it? That was the beginning followed in the early fifties with reproducible recording. No need to reshoot to get a different filter. Less paper. Instead of single records, displays of a line of data were developed. Variable area, variable density were common names. We tried everything to improve data quality. Soon the data processing centers were developed. This eliminated the need for interpretation in the field. The party chief era was over. Party Managers were in charge. I won't enumerate the experiments and the advances that those decades produced. You know what they were. The same changes occurred in Marine data acquisition and data processing.

There is an old saying that goes something like this. "This business of prophesy is very risky, especially about the future." There seems to be a lot of discussion about the future of our profession. The unconventional play seems to have done away with the need for seismic data. No need to know the structure. The downturn in the industry caused by $50 a barrel has affected us all. I marvel at our reaction to all of this. I was an officer of the SEG during the downturn in the mid-eighties. Not much different than this one. It took a long time to get back to "normal". Perhaps you recall the arguments about peak oil. Turns out there must be a mountain range involved to have that many predicted peaks.

We may not be able to predict the future in detail but we can be guided by constraints on the possible outcomes. First, the price of oil and gas. This is not rocket science. Oil is a commodity. In the good old days, the price of oil was set by Aramco. Now they are based more on supply and demand than on Aramco. One of these days we will get to peak production and start down the other side. An iron clad law says that the price of a commodity is set by the demand. I know that is a generality. There are other factors. With demand always on the rise, oil will become more valuable and cost more.

Our profession is based on technology. Geophysics is not going away. Some say there is not much room for innovation or improved techniques. There we go again, trying to predict the future. Our technology is not in a box with dimensions that limit our ideas. Two examples of working outside of the box are easy. Neidell's work shows we can extend our analysis beyond the Nyquist limit. Hardage has shown that conventionally acquired seismic data contain usable shear wave data. Both of these are clearly out of that box that some would fit over us. (If you don't know about Neidell or Hardage, tough. I don't do references!)

Let's don't do something dumb based on a bad prophesy. This applies to both the SEG and the GSH. Sounds as if I am preaching, doesn't it? Normally, FTOS is fun and games but sometimes I feel like preaching. So, I preach. Let me hear from you. We need anecdotal stories for Doodlebugger Diary. We need interviews, comments, controversy (within limits). It is up to you to set the tone of FTOS. So, do it.

Technical Luncheons

What is the "Holy Grail" of Machine Learning in Seismic Interpretation?

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch Northside

Speaker(s): Tom Smith, Geophysical Insights

Tom Smith

Westside

Tuesday, Jan. 16, 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, Jan. 17, 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)

Northside

Thursday, Jan. 18, 2017
11:00 a.m. – 1:00 p.m.

Location: Southwestern Energy Conference Center
10000 Energy Drive
Spring, TX 77389
(Free Parking onsite)

Abstract:

The presentation focuses on machine learning in seismic interpretation. Appropriate terms are defined and set in a framework for the real object of our applied science – prediction. Several examples illustrate how this new technology extends the context of seismic stratigraphic analysis (Mitchum, Vail and Sangree, 1977). Simultaneous multiple-attributes were autopicked by machine learning to deliver geobodies from a 3D survey in an unconventional resource play in the Eagle Ford in South Texas. From these, the time-depositional sequence relationships across the prospect (Wheeler diagram) were developed (Santogrossi, 2017) for basin assessment. These results were only possible through predictable seismic results far below conventional tuning thickness. An example in conventional exploration illustrates how a DHI (direct hydrocarbon indicator) computed with machine learning was demonstrably better than conventional amplitude conformance to structure (Roden and Chen, 2017) for reservoir assessment. Recently, a mathematical model was presented to define the factors to assess successful simultaneous multi-attribute seismic interpretation (Smith, 2017). It is clear with machine learning that cross-validation, automation and other tools are marked for their growing utility as a part of our efforts to make better models and better predictions. Many of our colleagues have bought into machine learning. Our bosses have certainly bought into machine learning. Like the processes developed by Google and Amazon, machine learning will be a fact of life in seismic interpretation. The good thing is that, like driving a car, you don't have to know how to rebuild a carburetor to drive to Katy, Texas. You just have to know how to stay on the road.

Biography:

Dr. Tom Smith received a BS and MS degree in Geology from Iowa State University. In 1971, he joined Chevron Geophysical as a processing geophysicist but resigned in 1980 to complete his doctoral studies in 3D modeling and migration at the Seismic Acoustics Lab at the University of Houston. Upon graduation with the Ph.D. in Geophysics in 1981, he started a geophysical consulting practice. Dr. Smith founded Seismic Micro-Technology in 1984 to develop PC software to support training workshops which subsequently led to development of the KINGDOM Software Suite for integrated geoscience interpretation with world-wide success.

The Society of Exploration Geologists (SEG) recognized Dr. Smith's work with the SEG Enterprise Award in 2000, and in 2010, the Geophysical Society of Houston (GSH) awarded him an Honorary Membership. Iowa State University (ISU) has recognized Dr. Smith throughout his career with the Distinguished Alumnus Lecturer Award in 1996, the Citation of Merit for National and International Recognition in 2002,

Technical Luncheon continued on page 8.

Technical Luncheon continued from page 7.

and the highest alumni honor in 2015, the Distinguished Alumni Award. The University of Houston College of Natural Sciences and Mathematics recognized Dr. Smith with the 2017 Distinguished Alumni Award.

In 2009, Dr. Smith founded Geophysical Insights, where he leads a team of geophysicists, geologists and computer scientists in developing advanced technologies for fundamental geophysical problems. The company launched the Paradise® multi-attribute analysis software in 2013, which uses Machine Learning and pattern recognition to extract greater information from seismic data.

Dr. Smith has been a member of the SEG since 1967 and is a professional member of SEG, GSH, HGS, EAGE, SIPES, AAPG, Sigma XI, SSA and AGU. Dr. Smith served as Chairman of the SEG Foundation from 2010 to 2013. On January 25, 2016, he was recognized by the Houston Geological Society (HGS) as a geophysicist who has made significant contributions to the field of geology. He currently serves on the SEG President-Elect's Strategy and Planning Committee and the ISU Foundation Campaign Committee for Forever True, For Iowa State.

RENEW NOW

GSH Membership for 2017-2018

All this for $60/year!

Member Year Begins July 1st

Renew online at **www.gshtx.org** or by phone at 281-741-1624.

Continue to be a part of one of the most active geophysical organizations in the country. Network with industry leaders and attend technical meetings covering relevant topics.

Multi-year Membership renewal available now! Contact Kathy at 281-741-1624 for your multi-year renewal.

Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 43.

We appreciate our Corporate Members

Apache Corporation

ConocoPhillips

Shearwater

TGS

For more information about becoming a Corporate Member, please contact the GSH office at 281-741-1624, or office@gshtx.org.

Technical Breakfasts

A New Technique for Lithology and Fluid Content Prediction From Prestack Data: An Application to a Carbonate Reservoir

Register
for Tech Breakfast
Northside

Peter Wang

Speaker(s): Peter Wang
Co Authors: Kamal Hami-Eddine*, Bruno de Ribet*, Pascal Klein[1], Loic Richard[2], and Maelle Grout[3], presented by Peter Wang*

Northside

Tuesday, Jan. 9, 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

Abstract:

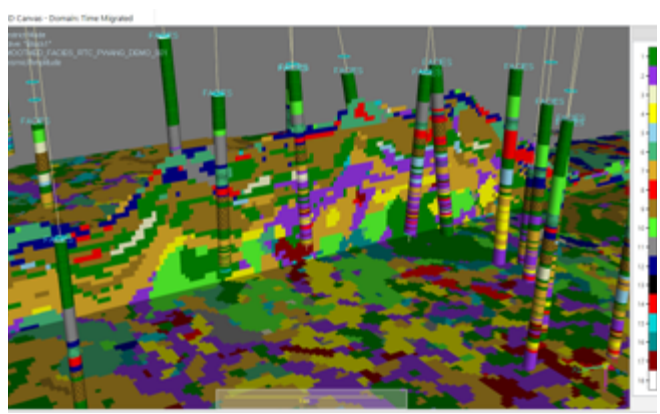
One of the leading challenges in hydrocarbon recovery is predicting rock types/fluid content distribution throughout the reservoir away from the boreholes because rock property determination is a major source of uncertainty in reservoir modeling studies. Spatial determination of the lateral and vertical heterogeneities has a direct impact on a reservoir model because it will affect the property distributions.

We developed a new neural network-based methodology called Democratic Neural Network Association (DNNA). The DNNA method is trained using facies logs from wells simultaneously with seismic data. The principle of DNNA, is to combine several networks, learning differently, to segment the seismic data space, according to facies interpretation validated by petrophysicists. For more than twenty years, the industry has relied on unsupervised waveform classification, also known as self-organizing maps (SOM), for seismic facies analysis. While this approach has proven to be highly efficient for stratigraphic interpretation, it ignores a wealth of information at well locations. DNNA is providing a bridge between domains from petrophysics to reservoir modeling, using geophysical data. Several case studies have been run, in different geological environments. In clastics, the use of DNNA has enabled us to differentiate more precisely different types of facies, which played an important role for reservoir connectivity analysis. In carbonates, this machine learning approach has overcome the lack of consistency in the seismic response and provided a geologically meaningful facies model calibrated to wells, in record time.

This technique, using a probabilistic approach, provides a way to predict lithology distribution and quantify uncertainty. From unsupervised to supervised, machine learning is bringing a new way to handle massive amounts of data.

Biography:

Peter Wang is a Geophysical Technical Advisor with Paradigm. He has a BS in Geosciences from Brown University, and an MS in Geophysics and MBA from the University of Houston. He has a thirty-one year history in the geophysical industry, having recently served at Schlumberger as the Seismic for Unconventionals Product Champion, and Amoco Production Company (now BP) as a Senior Petroleum Geophysicist onshore USA Gulf Coast and Gabon.



Permian reservoir classification on a land 3D prestack seismic volume (non-USA)

Technical Breakfasts

Estimation of Reservoir Properties by Regression Analysis of Relative Rock Properties… Relax the Need of a Rigorous Low Frequency Model (LFM)

Register for Tech Breakfast Westside

Alvaro Chaveste

Speaker(s): Alvaro Chaveste, TraceSeis, Inc.

Westside

Wednesday, Jan. 17, 2017
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

It has been customary to compute rock properties (P-Impedance, S-impedance and others) through seismic inversion and then estimate, from these, the reservoir properties that determine reservoir performance (porosity, mineralogy and fluids).

The inversion process is complex and can be lengthy. Inverting for absolute rock properties requires the generation of low frequency models (LFM) generally dependent upon the amount and quality of available well-log data and seismic velocities.

Many approaches exist to compute reservoir properties from seismic attributes estimated by inversion. Some are statistical and based on clustering (in cross-plots or multi-variate space) seismic attributes associated to the reservoir property of interest. Deterministic approaches compute reservoir properties (i.e. porosity) from rock properties (i.e. velocity) through effective media or empirical relationships.

The previous methodology is analyst intensive and prone to error as it requires the estimation and quality control of rock properties and then the reservoir properties.

An alternate methodology is presented. In the example shown, porosity and lithology are estimated from the seismic data through linear combinations of relative properties. The model parameters are obtained from regression analysis of the equivalent attributes computed from well-logs.

The methodology relaxes the need of a rigorous LFM and bypasses the estimation of absolute rock properties. It computes the reservoir property of interest through regression analysis of relative rock properties. Under this scheme, an LFM is required only when the reservoir property to be estimated has a low frequency component. If needed, the LFM does not have to be that of the inverted rock property and is input at the regression analysis stage, after the relative properties have been computed.

Biography:

Alvaro Chaveste holds a BSc in Geophysics from Montana Tech and has done graduate studies at the University of Houston. In 1983, upon graduation from Montana Tech, he joined GSI in Mexico where he acted as field geophysicist, data processor and administered a pioneering seismic interpretation system (SIDIS). In 1989, when GSI and Geosource merged, he was transferred to Houston where he has worked for: Halliburton, Western-Geco, Core Laboratories, Paradigm Geophysical, Geokinetics and Hess Corporation in managerial positions or as a contributor. His interests include: rock physics, seismic data processing, AVO/AVA and inversion. Currently he is the President at TraceSeis where he provides services and develops rock physics and inversion software.

Data Processing & Acquisition SIG

Seismic Imaging and Multiple Removal Via Model Order Reduction

Register for Data Processing

Speaker(s): Prof. Alexander Mamonov, University of Houston

Monday, Jan. 15, 2017
4:30 p.m. Sign-in, Snacks, Social Time
5:00 p.m. Start of presentation

Abstract:

We introduce a novel framework for imaging and removal of multiples from seismic data based on model order reduction. The reduced order model (ROM) is an orthogonal projection of the wave equation propagator (Green's function) on the subspace of discretely sampled time domain wavefield snapshots. Even though neither the propagator nor the wavefields are known in the bulk, the projection can be computed just from the knowledge of the seismic data using the block Cholesky factorization. Once the ROM is found, its use is twofold.

First, the projected propagator can be backprojected to obtain an image. ROM computation implicitly "orthogonalizes" the wavefield snapshots. This highly nonlinear procedure differentiates our approach from the conventional linear migration methods (Kirchhoff, RTM). It allows to resolve the reflectors independently of the knowledge of the kinematics and to untangle the nonlinear interactions between the reflectors. As a consequence, the resulting images are almost completely free from the multiple reflection artifacts.

Second, the ROM computed from the original seismic data can be used to generate the Born data set, i.e. the data that the measurements would produce if the propagation of waves in the unknown medium obeyed Born approximation instead of the full wave equation. Obviously, such data only contains primary reflections and the multiples are removed. Consecutively, existing linear imaging and inversion techniques can be applied to Born data to obtain reconstructions in a direct, non-iterative manner.

Sponsored by Schlumberger

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

Alexander Mamonov

Biography:

Prof. Mamonov received his formal education with an undergraduate degree in Mechanics at Lomonosov Moscow State University in 2003 and a Ph.D. in Computational and Applied Mathematics at Rice University in 2010.

His career spans both the oil industry and the academia. As a graduate student he completed four internships with Schlumberger at SDR and AbTC centers working on optimal grid coarsening for reservoir optimization. He completed two postdoctoral fellowships at the Mathematical Sciences Research Institute at Berkeley, CA and at the University of Texas at Austin in 2010-2013. In 2013-2014 he joined Schlumberger as a full time research scientist, first in Moscow and later at the FWI group at WesternGeco in Houston, TX. While at Schlumberger he began his work on using data-driven model order reduction for inversion and imaging with seismic waves.

Currently Prof. Mamonov continues his research at the Department of Mathematics at the University of Houston where he holds a position of an Assistant Professor since 2015.

Potential Fields SIG

True Polar Wander and the Origin of the Hawaiian-Emperor Bend: New Evidence

Register for Potential Fields

Richard G. Gordon

Speaker(s): Richard G. Gordon,
Daniel Woodworth,
Lily Seidman,
and Lin Zheng
Department of Earth Science,
Rice University,
Houston, TX, 77005, USA;
rgg@rice.edu

Thursday, Jan. 18, 2017
5:30 p.m. - 8:00 p.m.

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

Abstract:

It may not be well appreciated that skewness (asymmetry) analysis of marine magnetic anomalies due to seafloor spreading can be used to obtain Pacific plate paleomagnetic poles with high age resolution and compact confidence limits. We present an updated apparent polar wander (APW) path for the Pacific plate constructed from paleomagnetic poles determined from the skewness of marine magnetic anomalies, from equatorial sediment facies, and from paleocolatitudes of vertical cores of igneous rock. While paleocolatitude data provide some constraints, their usefulness is limited because they only limit the pole position in one direction, and the uncertainty in that direction is large because of the challenges of averaging secular variation. In contrast, secular variation contributes negligibly to the poles from skewness data, which give compact confidence limits for a well-defined interval of time.

An APW path for Pacific hotspots can be obtained by moving each Pacific plate paleomagnetic pole with the Pacific plate relative to the hotspots to a reconstruction that corresponds to the age of the pole. Our results imply that global hotspots have moved in unison with respect to the spin axis and that the Hawaiian-Emperor Bend (HEB) does not record a change in motion through the mantle of the Hawaiian plume. Instead the HEB records a change in Pacific plate motion over a stationary plume as originally proposed by W. J. Morgan.

Biography:

Dr. Richard G. Gordon is the Keck Professor of Geophysics at Rice University where he also served 5 years as Department Chair. Before moving to Rice in 1995, but after receiving his Ph.D. in Geophysics from Stanford University in 1979, he successively served as Assistant Professor, Associate Professor, Professor, and Department Chair at Northwestern University. Dr. Gordon has contributed greatly to our understanding of the dynamic solid Earth, in particular plate tectonic and regional tectonic processes, lithospheric deformation, and true polar wander, through his research involving paleomagnetic, marine geophysical, space geodetic, and seismological data. His fieldwork includes land-based paleomagnetic investigations in North America and ship- and airplane-based investigations in the Pacific and Indian Oceans. Together with students and colleagues, he developed the widely used NUVEL-1 and MORVEL sets of plate relative angular velocities. He has published about one hundred papers in refereed journals and co-edited one book. He is a highly cited geoscientist and has received many awards including a Sloan Fellowship, the Macelwane Medal of the American Geophysical Union (AGU), and the Day Medal of the Geological Society of America (GSA). He has served both the AGU and GSA in leadership positions, has performed many editorial duties, including being an Editor of the Journal of Geophysical Research. He currently serves on the Honors and Recognition Committee of the AGU and as an Associate Editor of Terra Nova.

Identification of Potential Lacustrine/Embayment Stratigraphic Intervals in the Woodford Shale, Oklahoma, Using Multi-Attribute 3-D Seismic Displays and a Supervised Probabilistic Neural Network

By Torres, E.J., Roger M. Slatt*, Kurt J. Marfurt*, Lennon E. Infante* and Luis A. Castillo***
**The University of Oklahoma, ConocoPhillips School of Geology and Geophysics. Norman, Oklahoma,*
***G&L Energy Co. Dallas, Texas, U.S.A.; e-mail to: etorres@ou.edu*

Summary

With the latest exploration and development of unconventional shales focused on predominantly marine deposits, the potential of hypersaline, highly restricted marine lacustrine-embayment deposits has not been studied systematically. The primary goal for this study is to resolve whether there are seismic indicators for such rocks within a predominantly marine shale, targeting specifically within the Woodford Shale formation in Oklahoma U.S.A. Several of the North American resource shales have been characterized as marine mega-sequences with the common characteristic of being deposited unconformably above a carbonate formation where paleo sea level fluctuations allowed the development of erosional topography that might lead to restricted hypersaline lacustrine-embayment settings.

The differences in hydrocarbon generation and cracking kinetics result in different thermal maturity windows for marine and saline lacustrine-embayment deposits, where these lacustrine-embayment rocks require higher thermal maturity for oil generation and cracking. Therefore, where high thermal maturity for a rock of a marine depositional environment thermally cracks the oil, in that same maturity yield, the oil might be preserved for a lacustrine-embayment deposit, thus providing previously unidentified exploration and prospectivity targets.

A model based seismic post-stack acoustic impedance inversion and a supervised Probabilistic Neural Network (PNN) analysis was performed to predict the Total Organic Carbon (TOC [weight %]) variation along the Woodford shale in South-Central Oklahoma, U.S.A. The results are tied with the Woodford Shale regional context for the identification of geological variations that potentially allowed the deposition of lacustrine-embayment rock intervals. The neural network confirms that amplitude anomalies and discontinuous reflectors within the Woodford shale window correspond to internal lateral and vertical TOC-bearing facies variation.

The Woodford shale is both thicker and more TOC-rich where the underlying Hunton Group (carbonates) is completely eroded and the topographic relief is high. Seismic analysis at and above the unconformity surface produced by the erosion of the Hunton Group, reveals pod-shaped intervals of high TOC that may have been deposited as a very restricted interval. For this reason, we hypothesize that the structural lows may have been isolated lake/embayment areas represented by locally increased accommodation space and highly restricted Woodford shale organic rich deposits, therefore providing opportunities for more innovative unconventionals exploration targeting.

Introduction

Research over the past few years has focused on the stratigraphy and sedimentology of the Devonian-Lower Mississippian Woodford Shale. The Woodford is not only a good Mid-Continent (U.S.A.) oil and gas producer, but also a good analog for other 'siliceous' unconventional resource shales, particularly if they are underlain by carbonates. The studies have emphasized detailed mapping and stratigraphic characterization of the Woodford (*Figure 1 and Figure 2b*), but have also provided a foundation for extending into relating stratigraphy to geophysical, geochemical and geomechanical characterization.

Shale researchers interpret that the Woodford (and most analog resource shales) is wholly of open marine origin and generally assume it. RockEval Pyrolysis analyses usually indicate Type II kerogen, however, occasionally a Type I kerogen is detected. Other unconventional resource shales show a similar pattern, but these anomalies are often shrugged off as analytical error.

Regional isopach maps of the Woodford Shale and Hunton Group in the Cherokee platform (*Figure 1, Figure 2a and Figure 2b*) and a 3D seismic survey in South East Cherokee Platform, Oklahoma, reveal an unconformity surface on top of underlying carbonate rocks (Hunton Group), with considerable karst topography and ~ >100m of vertical relief (*Figure 5, Figure 6 and Figure 7.*) From this, a geological model claims that during lowstand of sea level, karst topography forms an irregular surface, which can provide discontinuous

Technical Article continued on page 14.

Technical Article continued from page 13.

catchment areas for ponding of hypersaline-lacustrine water masses, forming restricted water circulation and establishing conditions for higher deposition and preservation of organic matter (*Figure 2 and Figure 3a.*) The 3D seismic survey is inverted to predict TOC variability that shows discontinuous "pod like" areas of local anomalously high TOC in the deeper paleo-topographic Woodford Shale zones *(Figure 2a.)* This contrasts with common thinking that organic-rich strata are deposit from marine waters in a blanket fashion.

Geological Background

According to Cardott (2009 and 2012) and Jarvie et al (2005 and 2007), the Woodford Shale is a very effective and prolific gas and oil shale reservoir in the world, therefore, there is a specific interest to characterize the possible occurrence of internal lacustrine or highly restricted intervals within this open marine mudstone. This formation is from Upper Devonian-Lower Mississippian age, and its principal lithology has been described as an organic-rich black shale with intercalations of chert, siltstone, sandstone, dolostone, and light-colored shale (Slatt et al., 2011; Molinares, 2013; Turner, 2015.) In addition, laminations of reddish-brown clay, greenish clay and organic matter with scattered siliceous concretions are also present in the formation (Kirkland et al., 1992; Comer, 2007.)

The Woodford Shale unconformably overlies the limestones and dolomites of the Hunton Group (Silurian-Devonian age) and grades conformably into fine-grained silty limestones interbedded with thin layers of dark-gray shales from the Sycamore Formation (*Figure 1*; Perry, 1995 in Portas, 2009; Slatt et al., 2011). Cardott (2012) emphasize that the Woodford Shale has a series of stratigraphic equivalents that extend over central and Eastern United States (e.g. Chatanooga Shale, Arkansas Novaculite, Antrim Shale, Bakken Shale, New Albany Shale, Marcellus Shale) that represent the global marine transgression which occurred during the Late Devonian (*Figure 3*; Sullivan, 1985; Kirkland et al., 1992; Northcutt et al., 2001; Comer, 2005; Slatt et al., 2011; Cardott, 2012.)

Methods: 3D Seismic Multi-Attribute Analysis, Organic Facies (TOC) Identification and Low Frequency Background Model Seismic Inversion.

In order to highlight the presence of potential "lacustrine type" deposits, time thickness interpretation, coherent energy, most-positive and most-negative curvature volumes were computed and interpreted for the Hunton Group horizon which represents the base of the Woodford shale (*Figure 4, Figure 5, Figure 6 and Figure 7.*) Using a coherent energy attribute, negative response features were identified as karsts, and in the study area the Hunton group is almost completely eroded, characterized by low energy values (*Figure 6 and Figure 7.*)

Also, most positive/most negative curvature attribute was a useful tool in identifying karst features. These collapse features (*Figure 5 and Figure 7*) can be recognized as negative values of most-positive curvature (*Figure 5*; Baruch, et al 2009). Also the Hunton Isochrone map shows in the central and north part of the study area a "lake type" topography (*Figure 4 and Figure 7.*)

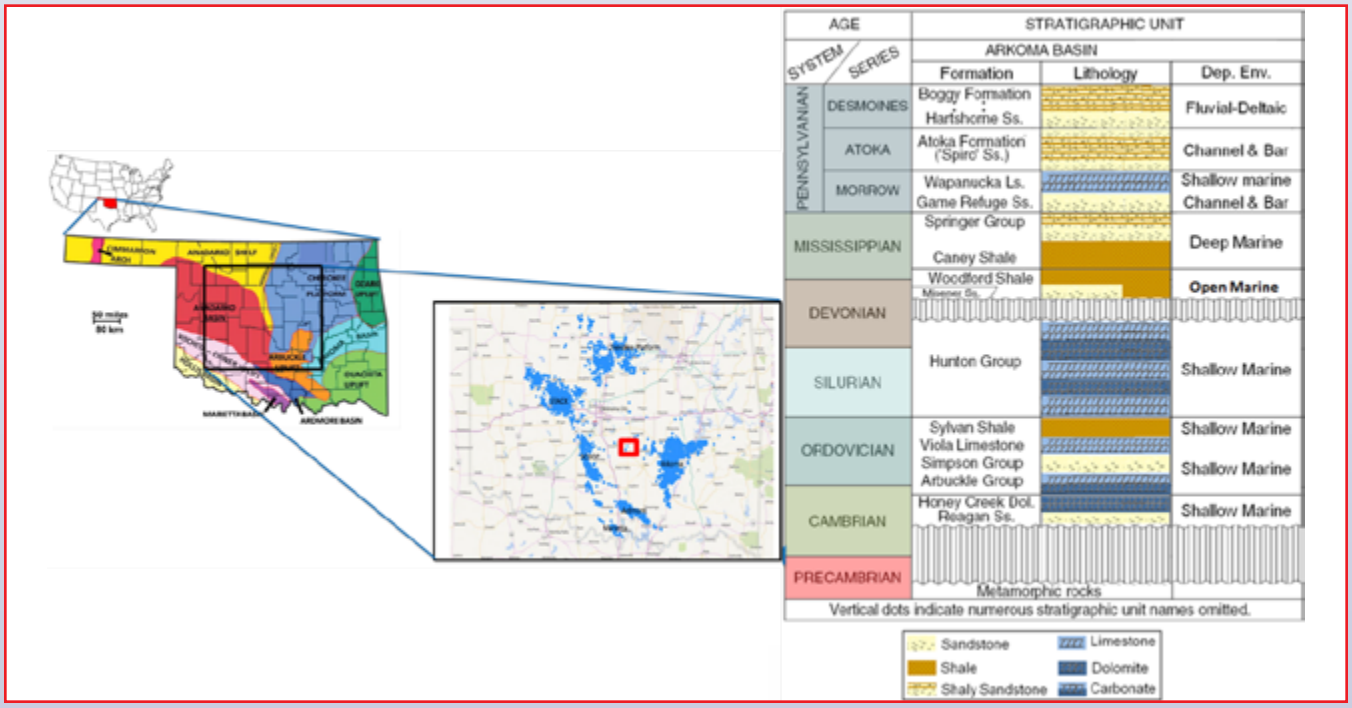


Figure 1. Location Map of the Cherokee Platform (in light blue), and principal geologic provinces in Oklahoma (Northcutt et al., 2001); Image on the right corresponds to the Stratigraphic chart for the Arkoma Basin, southeastern Oklahoma (Perry, 1995 in Portas, 2009.)

Technical Article continued on page 15.

Technical Article continued from page 14

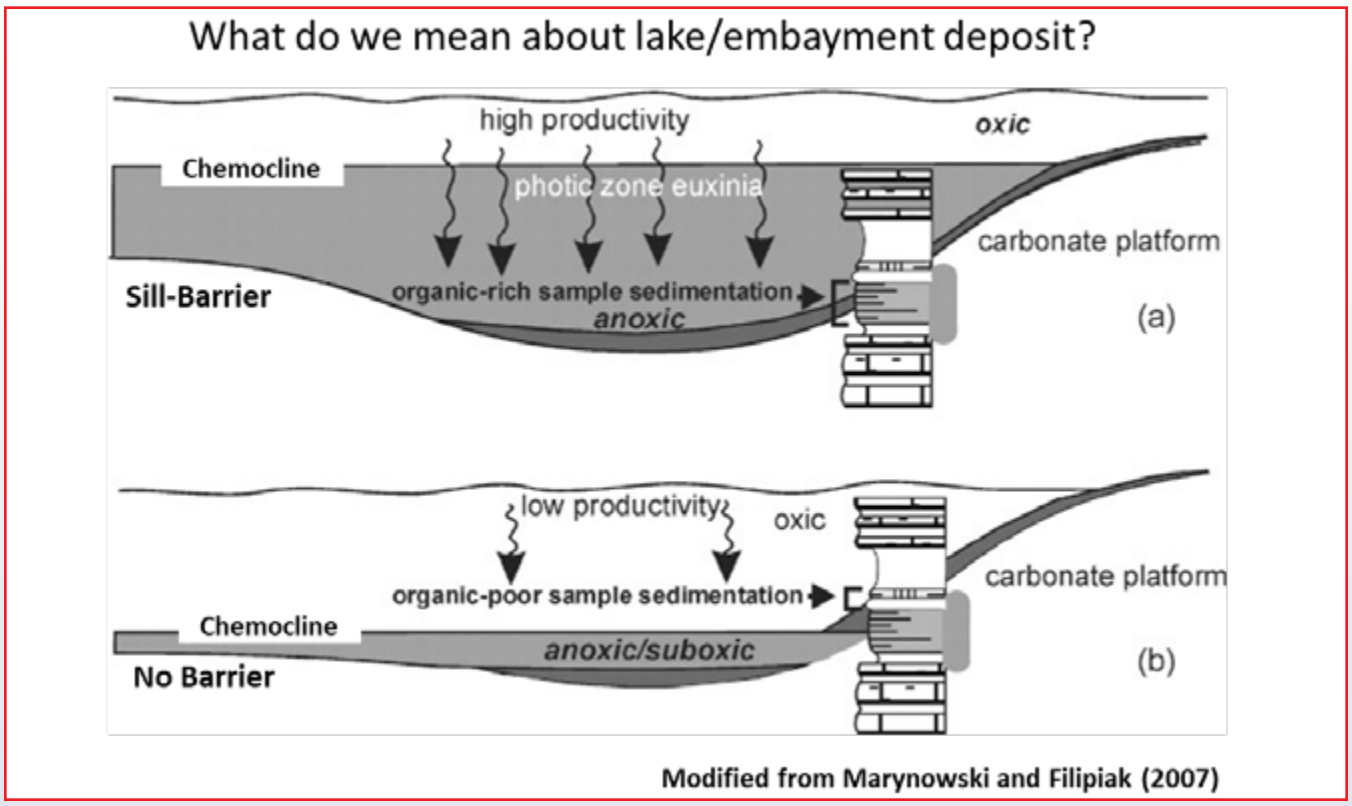


Figure 2a. Schematic illustration of paleo lacustrine/embayment deposit in the Woodford Shale: a) Illustrates silled basin over a carbonate platform, shallow chemocline and more preservation of organic matter; b) Illustrates non-silled basin over a carbonate platform, deeper chemocline and less preservation of organic matter. Modified from Marynowski and Filipiak (2007.)

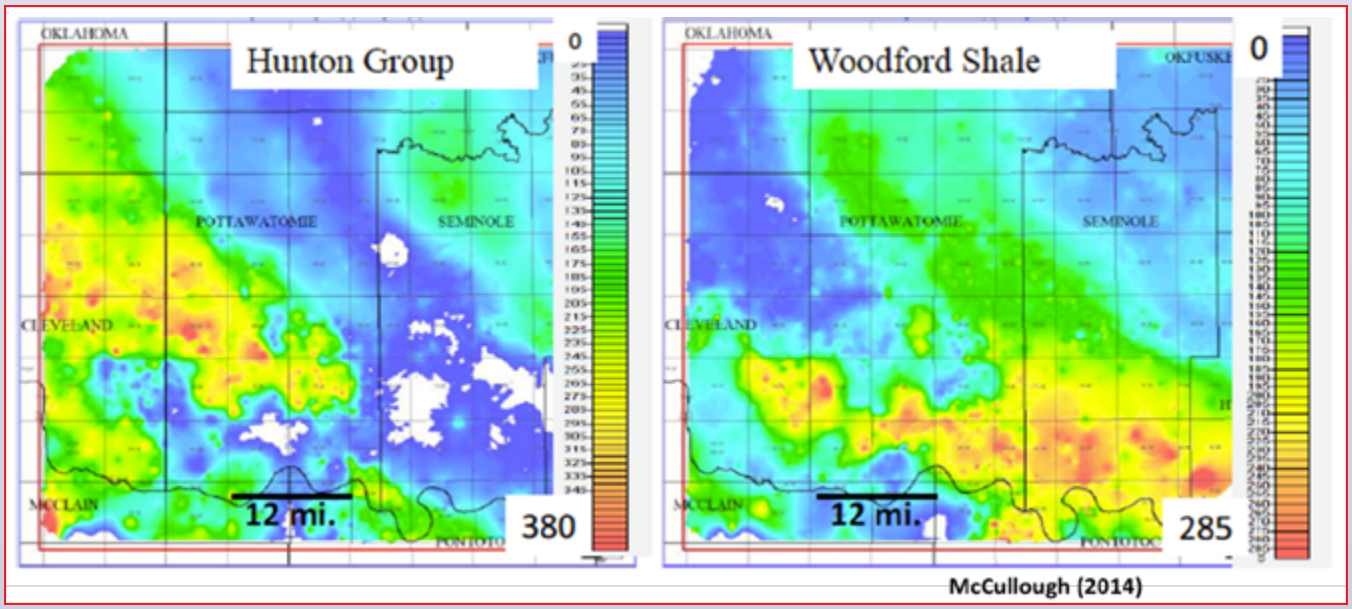


Figure 2b. Regional Isopach maps created from well tops (McCullough, 2014). On the left, the Hunton Group regional thickness map. On the right, the Woodford Shale regional thickness map. The study area is located in the red box of the Southeast Pottawatomie and Pontotoc border, Oklahoma U.S.A. Note the inverse correlation of the formation thickness, where the Hunton is eroded the Woodford shale is thicker, this is attributed to the depositional model of the Woodford shale where karstifications occur to the Hunton exposure leading into more accumulation space for the Woodford depositional fairway.

Technical Article continued on page 16.

Technical Article continued from page 15.

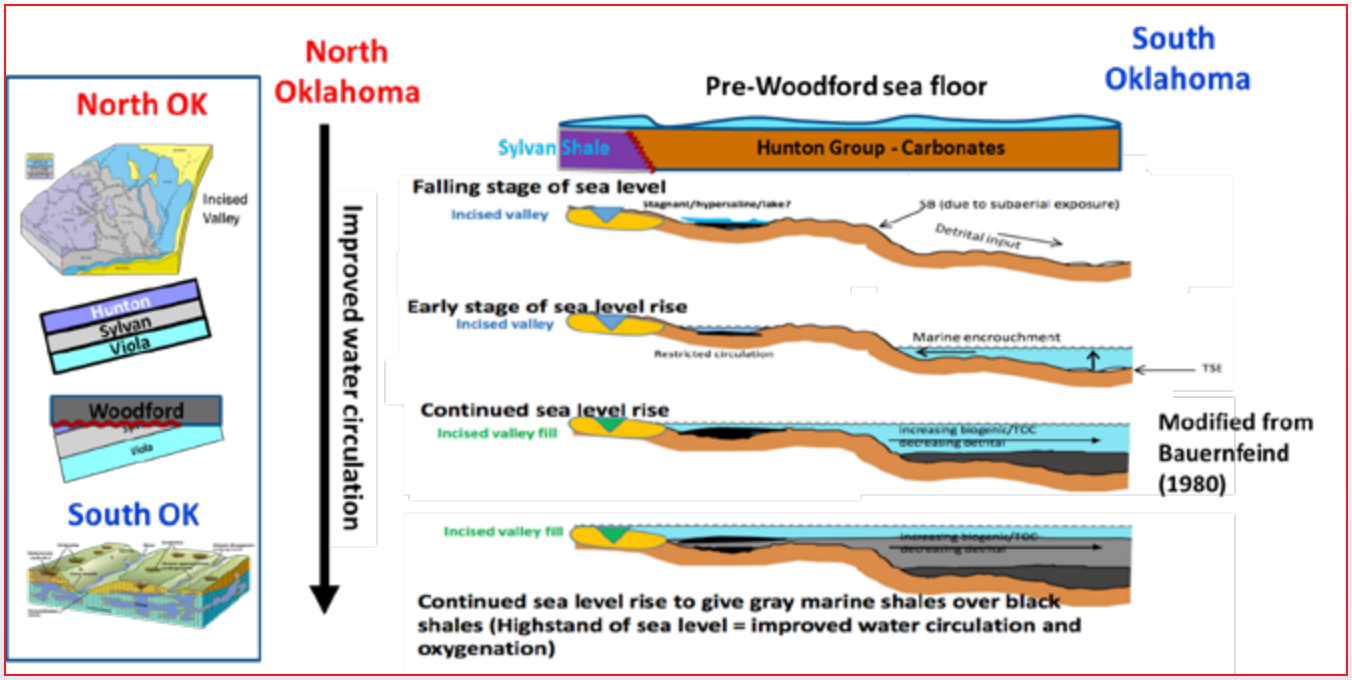


Figure 3a. Depositional model of the Woodford shale through one eustatic sea level cycle: The early stage of falling sea level may result in water mass isolation and restricted water circulation over topographic depressions left by karst/incised valley development on the underlying carbonate (Hunton Group carbonates in the case of the Woodford) surface.

As a proposed strategy for determining the geological and internal organic facies variations, the TOC was calculated in six wells of the study area applying the Passey et al. (1990) methodology, additionally the seismic attributes were extracted and the impedance inversion computed (*Figure 8a and Figure 8b*). The model-based inversion workflow begins with a low frequency background geological model that it is modified until the error has been minimized between the synthetic created by that model and the original seismic data (*Figure 9.*)

Figure 3b shows a representative vertical slice through the seismic time migrated data volume where the zone of interest can be seen. A phase rotation of -7º was applied to the data subsequent to the horizon interpretation in order to represent the base of the Woodford and the top of the Woodford as peak and trough respectively. Horizon interpretation was done by manually picking a grid of 1 inline by 1 crossline. *Figure 3b* shows the time structure map of the top of Woodford. There is a noticeable northwest dip direction and a structural high in the southeast part of the survey. Once the target zone is

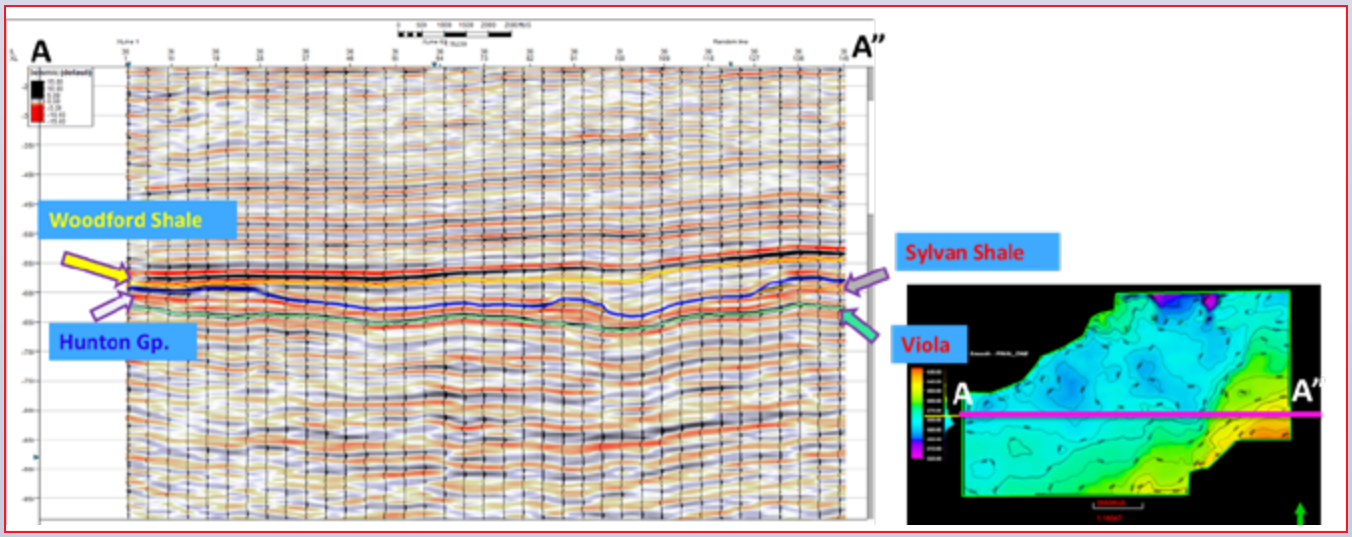


Figure 3b. Vertical seismic section showing the paleo topography of the erosion of the Hunton Group and a "lake-pod" area in the central part of the seismic section.

Technical Article continued on page 17.

Technical Article continued from page 16.

mapped and the wells are tied to the seismic data the next step is to perform a post-stack inversion to statistically relate the Zp and Vp to the calculated TOC Passey et al. (1990) method.

The main objective for generating a model-based inversion of the Woodford Shale was to identify vertical and lateral facies changes that may help delineate the "lake type" deposits (*Figure 10*). All six wells were used for the initial model, and the wavelet extracted from the wells was used on the model-based inversion. The inputs for this model (low frequency model) include (a) a geological model created from seismic horizons and (b) Vp and Density logs from all the wells selected for the inversion, which were band passed through a low frequency filter. The Woodford shale has the lowest impedance due to its low velocities and low densities (*Figure 10.*) The initial model revealed a higher vertical resolution and lateral impedance changes within the Woodford shale (*Figure 10.*)

According to Passey et al. (1990) the presence of organic matter and the presence of generated hydrocarbons can have a large response on the resistivity well log (*Figure 8a.*) The technique presented by Passey et al. (1990) uses the overlap of a porosity log, usually the sonic on a deep resistivity curve (*Figure 8a*). Passey et al. (1990) attribute this well-log separation in high organic-rich intervals as the result of the low density/low velocity kerogen, where the resistivity responds to the formation fluid. To calculate TOC using this method, the LOM (Level of Organic Metamorphism, reached by the organic matter in the rock) must be known or estimated. In this case, the previous work by Miceli (2010) and conclusions by Cardott (2012) for the Southeast Cherokee platform acted as valid LOM values in order to calculate the TOC for the wells in the study area. The revised graphic relation of logR vs. derived TOC published by Passey et al. (2010) was used for the calculations. A base line was drawn at the Sylvan shale and a LOM of 8 was applied which is equivalent to a vitrinite reflectance (%Ro) value of 0.56% to honor the published %Ro data of the study area (Cardott, 2012; *Figure 8a and Figure 8b*). For providing an input to the neural network for estimating TOC in three dimensions along the seismic survey, the calculated Passey-methodology TOC is then referred as "actual TOC" (*Figure 8 red curve, and Figure 12 black curve*), and the neural network calculated after estimating the non-linear relationships with the 3D seismic attributes is then named as "modelled TOC" (*Figure 12 and Figure 14 red curve.*)

Results: Post-Stack Seismic Inversion and Supervised Probabilistic Neural Network (PNN) analysis

To predict and distribute TOC along the study area in a confident manner, a supervised probabilistic neural network (PNN) workflow was applied to incorporate the post-stack 3D seismic data in combination of the calculated Acoustic Impedance (Zp) from the seismic inversion with Principal Components Analysis (PCA) of Spectral Decomposition data every 5Hz, and also to include into the calculations the Coherent Energy volumes (directly related to karstification features of the pre-Woodford Strata). Three attributes generated from the seismic interpretation and inversion were used to generate statistical relationship with the calculated TOC log form Passey et al. (1990), these input attributes in the PNN were: Zp, Coherent Energy and Spectral Components, and the PNN operator length was of nine points.

All these three seismic calculated volumes acted as external attributes for the supervised neural network analysis. The input attributes applied in the workflow for

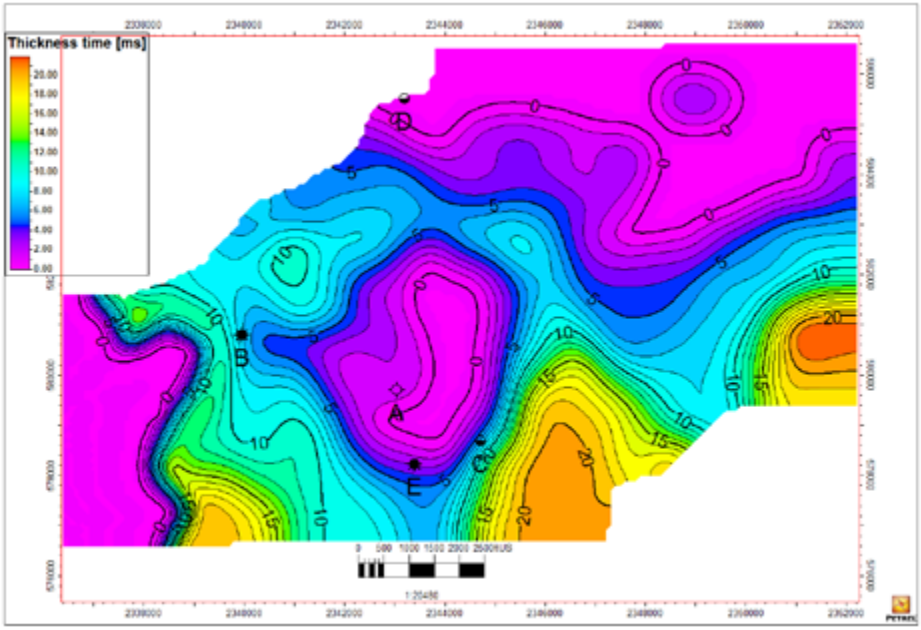


Figure 4. Time thickness map of the Hunton group. Low isochron areas with potential of lake type deposits.

Technical Article continued on page 18.

Technical Article continued from page 17

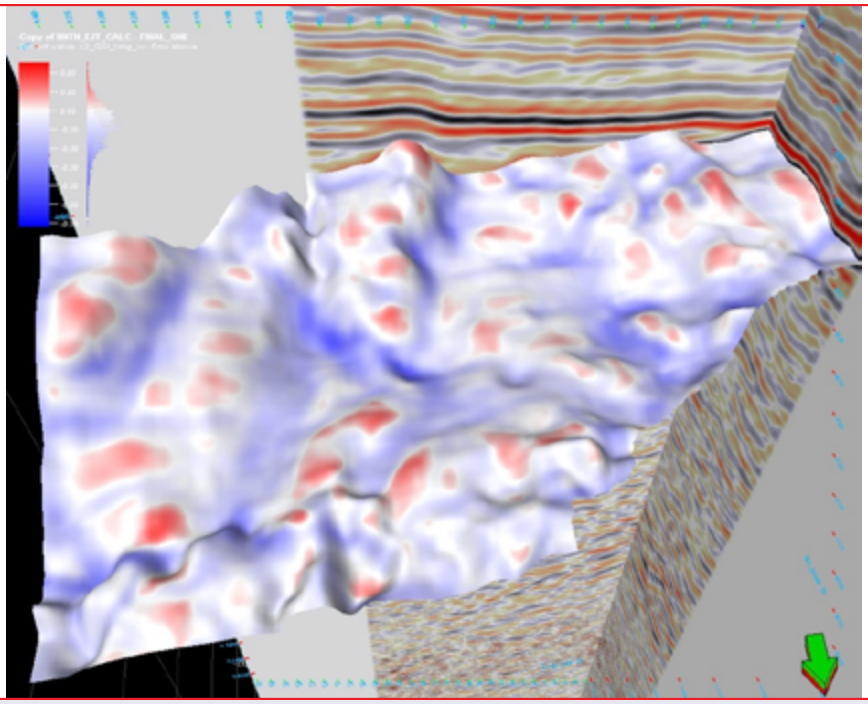


Figure 5. Horizon slice along the top Hunton through the most positive curvature and most negative curvature volume. Most negative curvature (blue areas) associated with major karsting.

properly training the neural network, are shown in the *Figure 12*. During the supervised neural network training (*Figure 12*), the weighting function is adjusted to optimize the prediction of TOC (*Figure 13*) as a directly indicator of organic facies variations, and for avoiding the neural network "overtraining". High TOC zones correlate with the location of karst features of the Hunton and potential restricted hypersaline/lacustrine deposits (*Figure 14 and Figure 16.*)

The analysis window of the supervised PNN, its training and calculations, were limited only to the Woodford shale seismic window (±50 ms from Woodford Shale top and base), and were aimed to be within the stratigraphic zone of

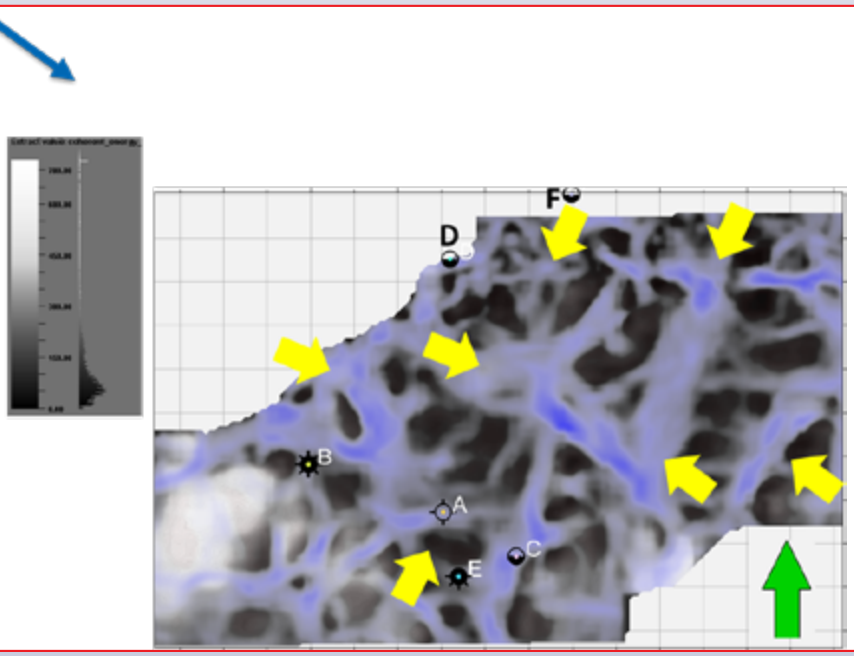


Figure 6. Hunton time-structure co-rendered with coherent energy and most negative curvature (Yellow arrows indicates karst features and possible lake pods, the Hunton Group is eroded (almost gone) in the study area).

Technical Article continued on page 19.

Technical Article continued from page 18.

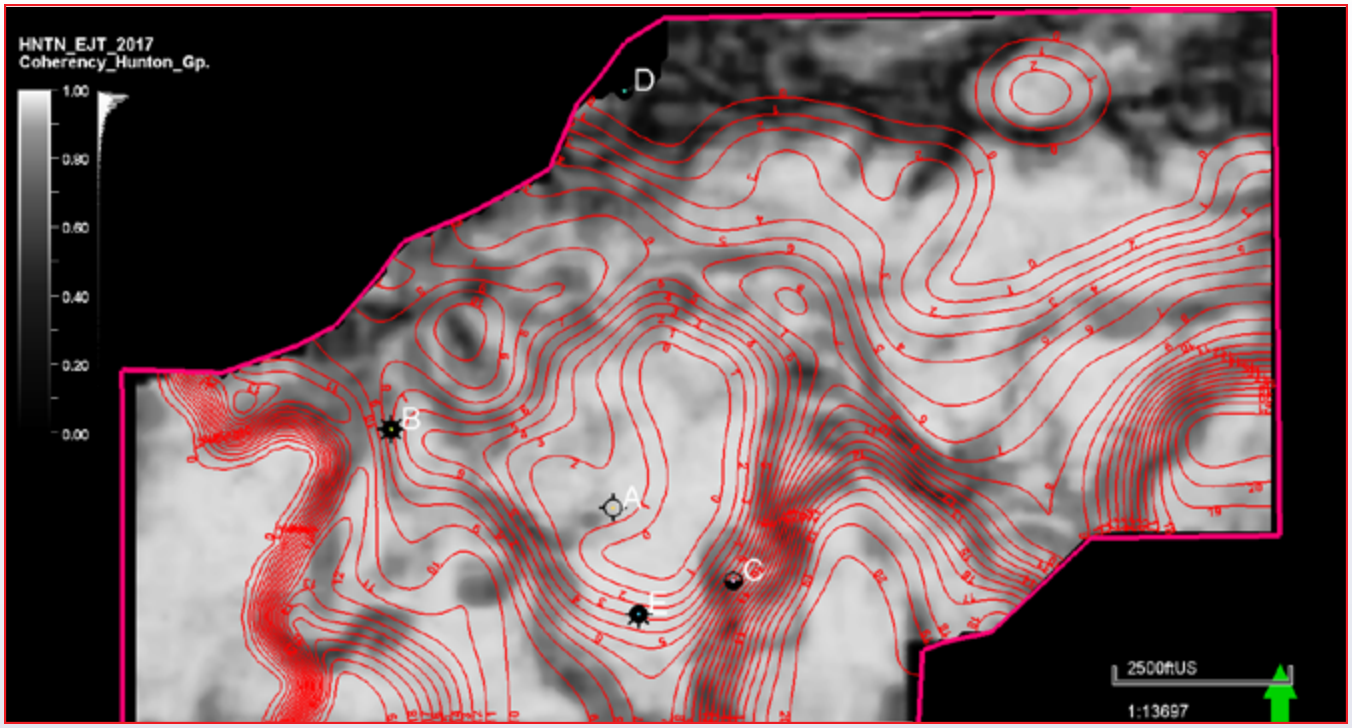


Figure 7. Hunton time-thickness co-rendered with coherent energy (zero and near-zero that correlate with dark coherency features contours indicate karst features and possible lake pods.) Note that the Hunton Group is eroded (almost gone) in the study area.

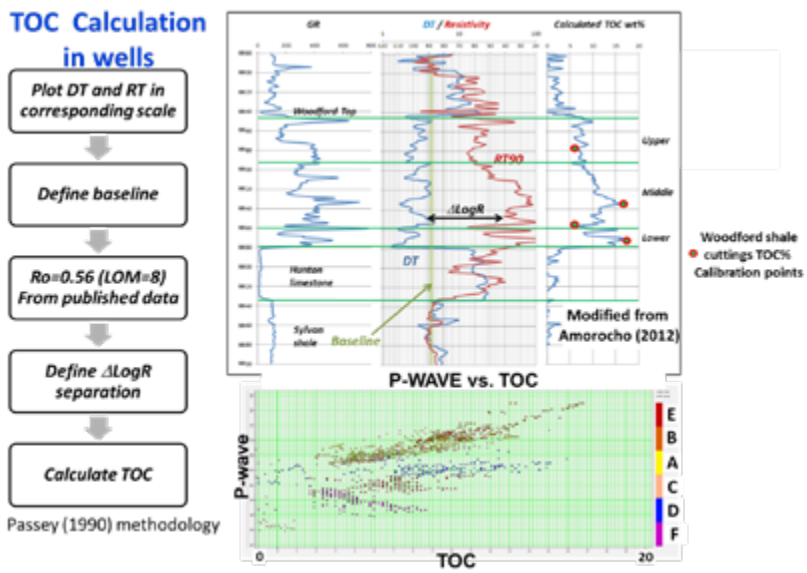


Figure 8a. TOC calculations applying Passey (1990) methodology. TOC from cuttings as calibration points in well D.

interest to obtain a better correlation in the TOC calculations (*Figure 14 and 15.*) *Figure 11* shows a cross plot of calculated TOC from well logs vs. predicted TOC from the probabilistic neural network with the previous multi-attributelist as input (Zp, Coherency and Spectral Components). The neural network performed the non-linear relationship calculation process at every sample location in the seismic volume (Heggland, 2004), and compared in each stratigraphic interval one data sample of the calculated TOC-log in wells with nine data samples of the selected 3D seismic attributes as network inputs (Zp, Coherency and Spectral Components Principal Component Analysis Vector1 [PC1]; *Figure 12.*)

Technical Article continued on page 20.

Technical Article continued from page 19.

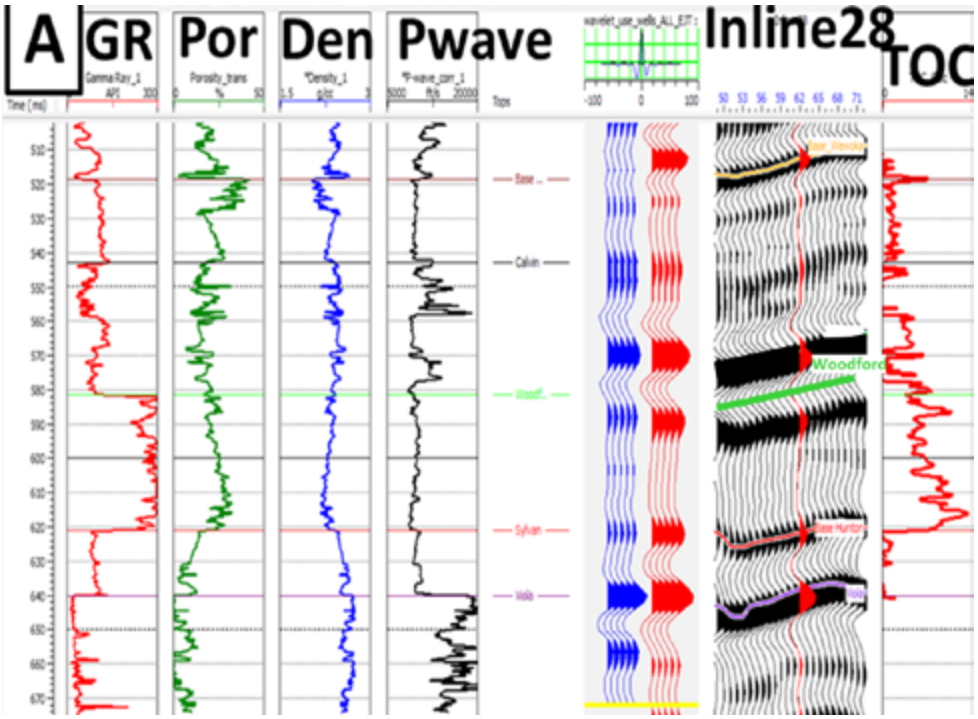


Figure 8b. TOC Calculation and seismic tie for Well A using the Passey et al., (1990) method.

Figure 16 shows the wells used in the PNN as well an as average TOC map for the entire Woodford Formation. Hot colors represent ~~s~~weet spots with higher TOC values. Notice that higher concentrations of organic richness occur in the central part of the survey, where the Hunton group is eroded and the karstification features lead into the paleo lake pod shape. Also, high TOC is calculated in the Northwest part of the survey.

Conclusions

The Probabilistic Neural Network property extensions confirm that the amplitude anomalies and discontinuous reflectors within the Woodford Shale stratigraphic window correspond to internal lateral and vertical TOC facies variation (*Figure 9, Figure 10, Figure 15, Figure 16 and Figure 17.*) The Woodford shale is thicker and with more TOC where the

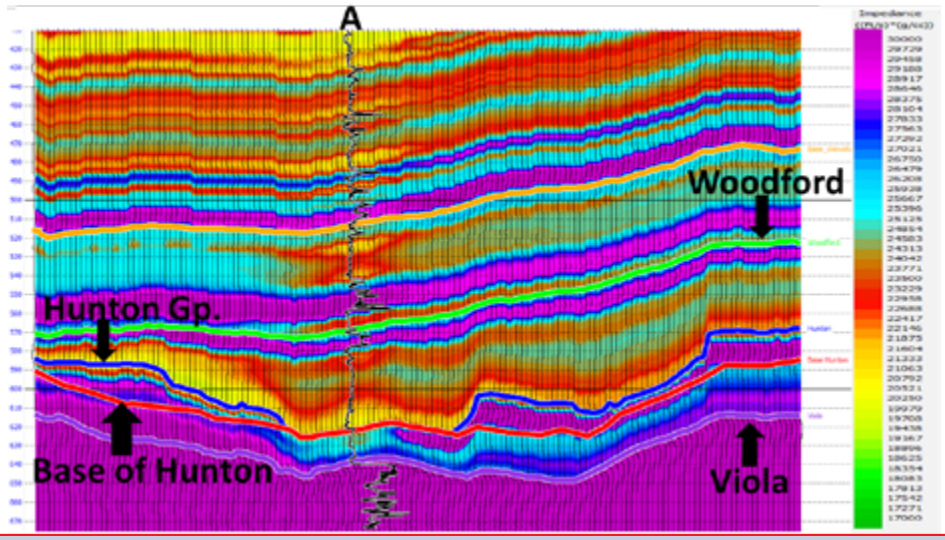


Figure 9. Initial low frequency background model on an in-line passing through well A.

Technical Article continued on page 21.

Technical Article continued from page 20.

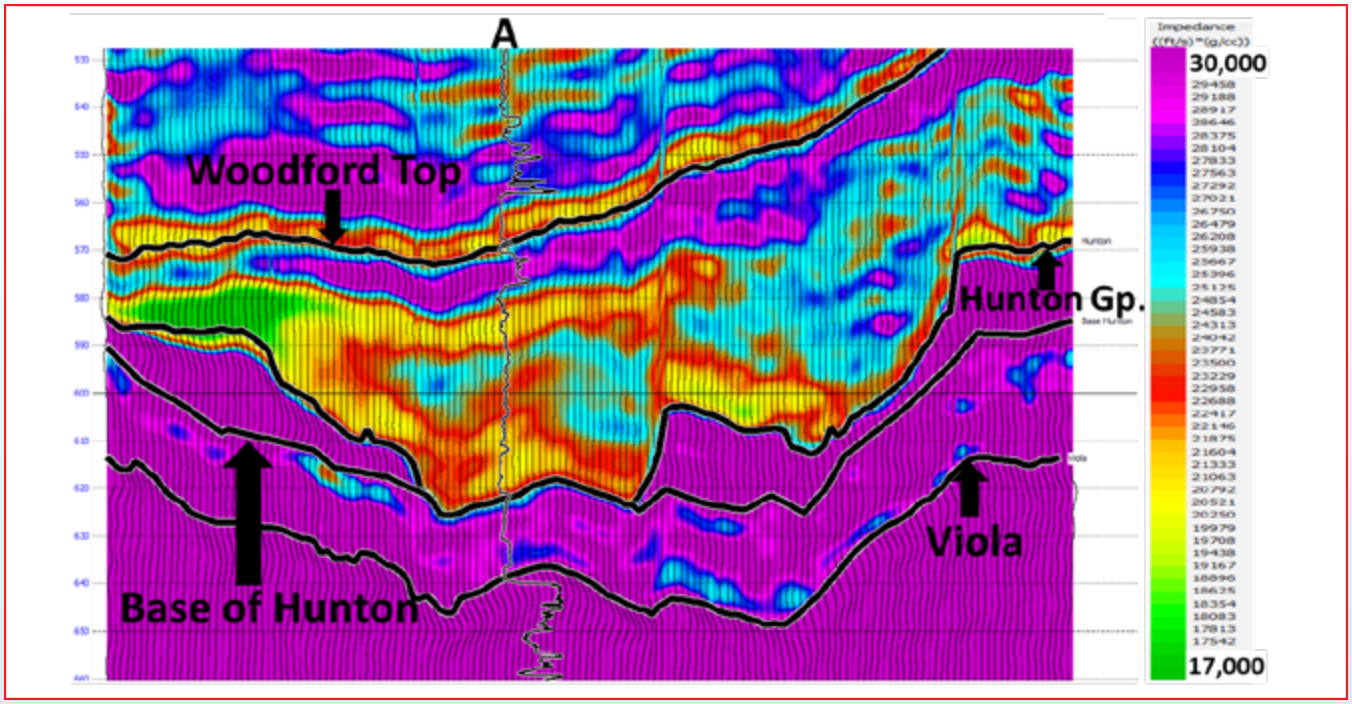


Figure 10. Inversion Zp results in an arbitrary impedance in-line showing well A.

Hunton Group is completely eroded (*Figure 2a and Figure 2b, Figure 4 and Figure 10*) and structural features lead into the identification of lake pods that can be intervals of very restricted Woodford organic rich deposits (*Figure 7, Figure 15 and Figure 17*), thereby providing opportunities for more innovative exploration strategies. As a future analysis, the pre-stack inversion must be done for estimating the elastic properties, and therefore reduce the inversion error, which can provide better TOC estimates.

Acknowledgements

The authors would like to express the immense gratitude to Pathfinder Exploration LLC. A huge thank you to Mr.

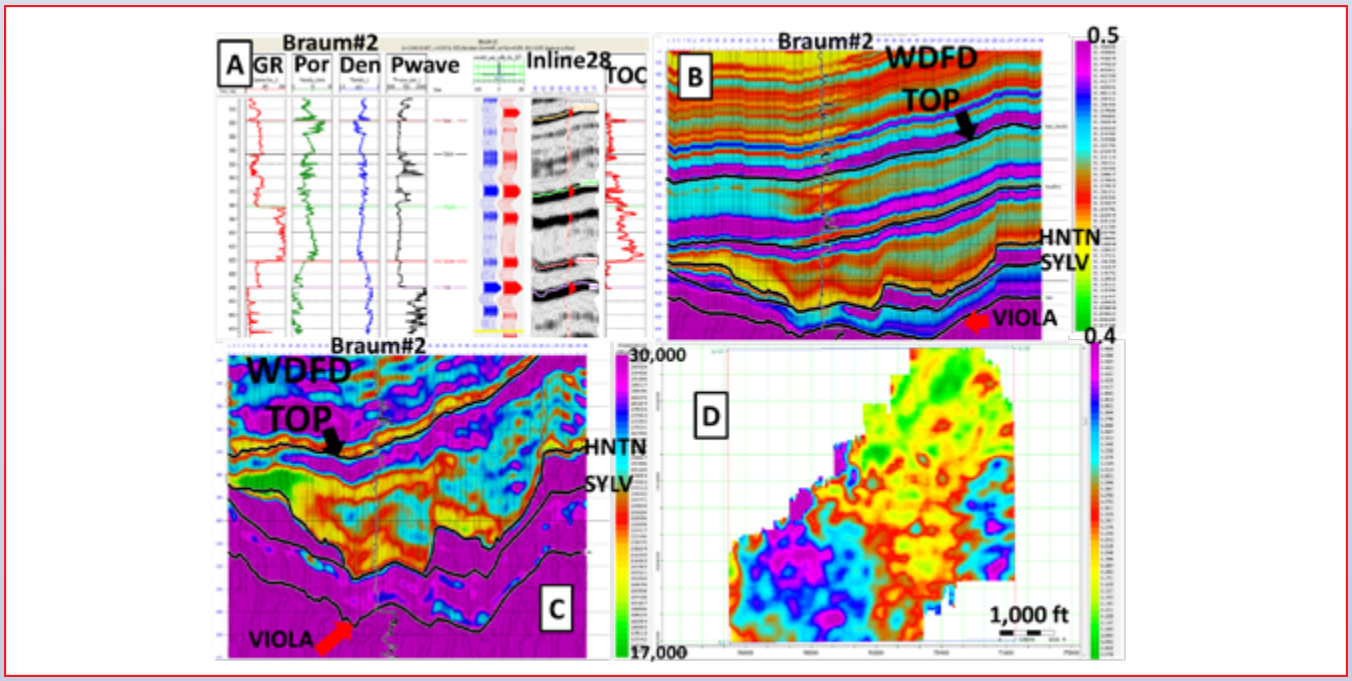


Figure 11. Data-Error slice calculated 2 milli-seconds [ms] below the Woodford shale seismic horizon.

Technical Article continued on page 22.

Technical Article continued from page 21.

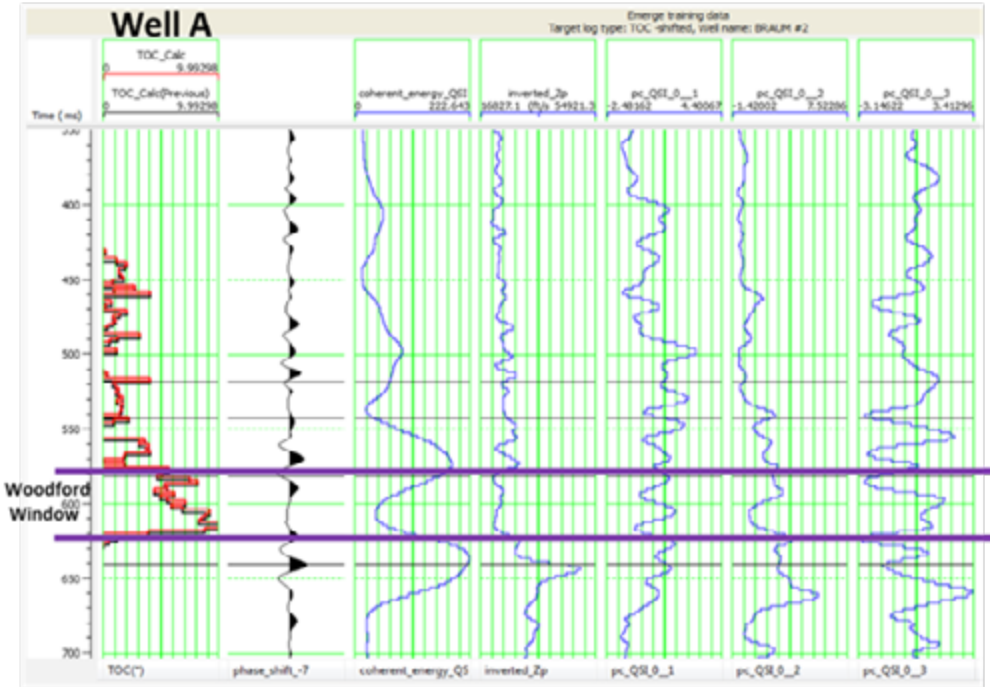


Figure 12. Neural Network Training data in Well A. TOC (red) with extracted seismic data, Coherent Energy and Zp from Seismic Inversion, Spectral Decomposition every 5Hz Principal Components 1, 2 and 3.

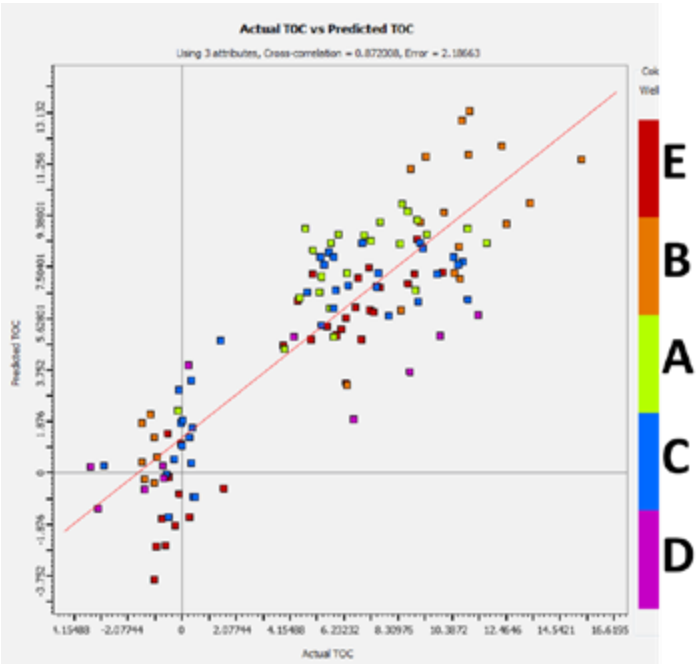


Figure 13. Multi-attribute regression of actual TOC (Passey method calculated) vs. predicted TOC. Three attributes were used in the regression: Zp, Coherent Energy and Spectral PC 2. Negative TOC values correspond to the Hunton Group.

Gerald Wilson (in memoriam) and The Wilson Family, for providing the 3D seismic surveys and the well-log data for this exercise. Special acknowledgements for the kind financial and technical assistance to all the company sponsors of both University of Oklahoma Institute of Reservoir Characterization (IRC) and Attribute Assisted Seismic Processing and Interpretation (AASPI) consortiums. Special thanks to CGG for allowing us to use their Hampson and Russell Emerge package. Special thanks to Schlumberger for providing us the Petrel licenses.

Technical Article continued on page 23.

Technical Article continued from page 22.

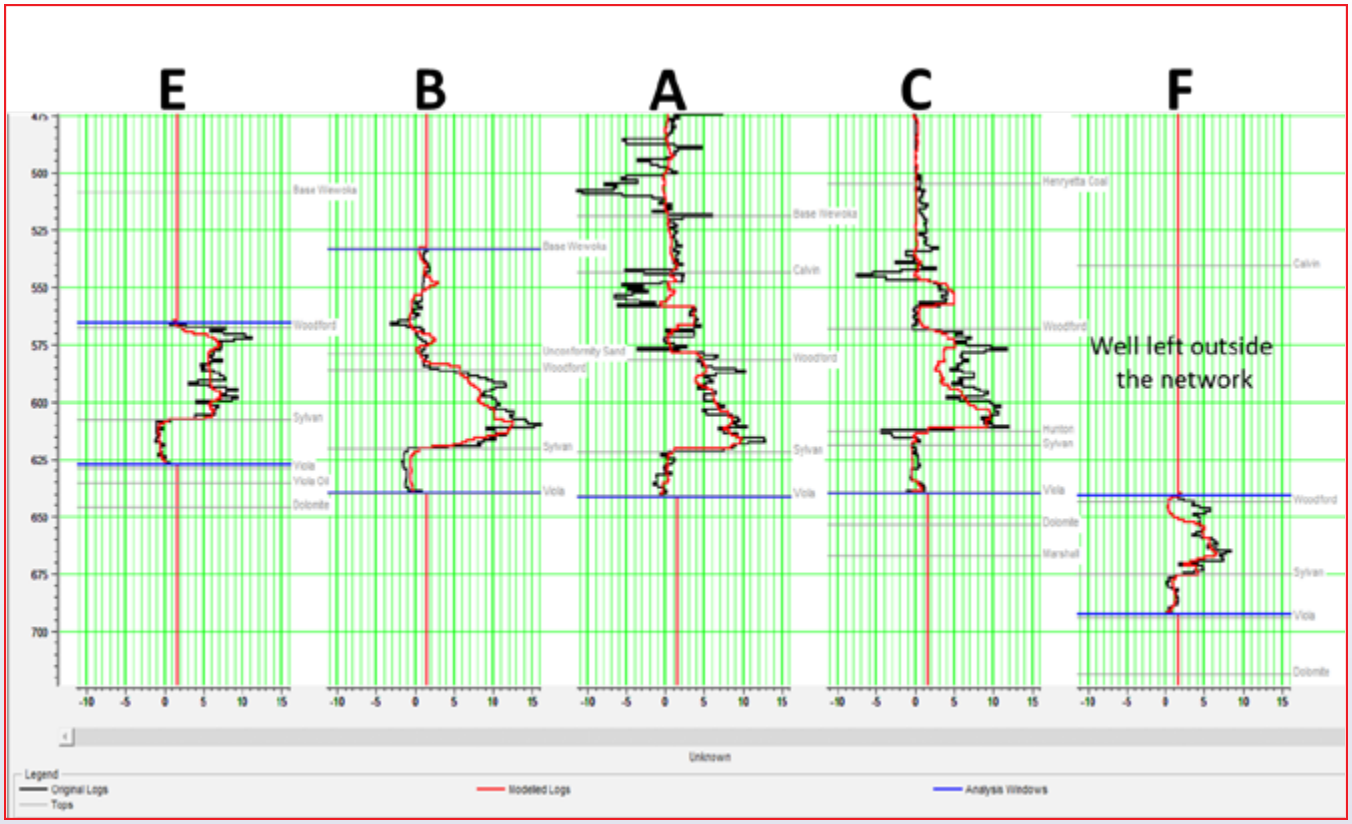


Figure 14. Probabilistic neural network using three attributes. TOC calculated with Passey methodology in black curve, TOC modelled from the supervised neural network in the red curves. Well locations in Figure 6.

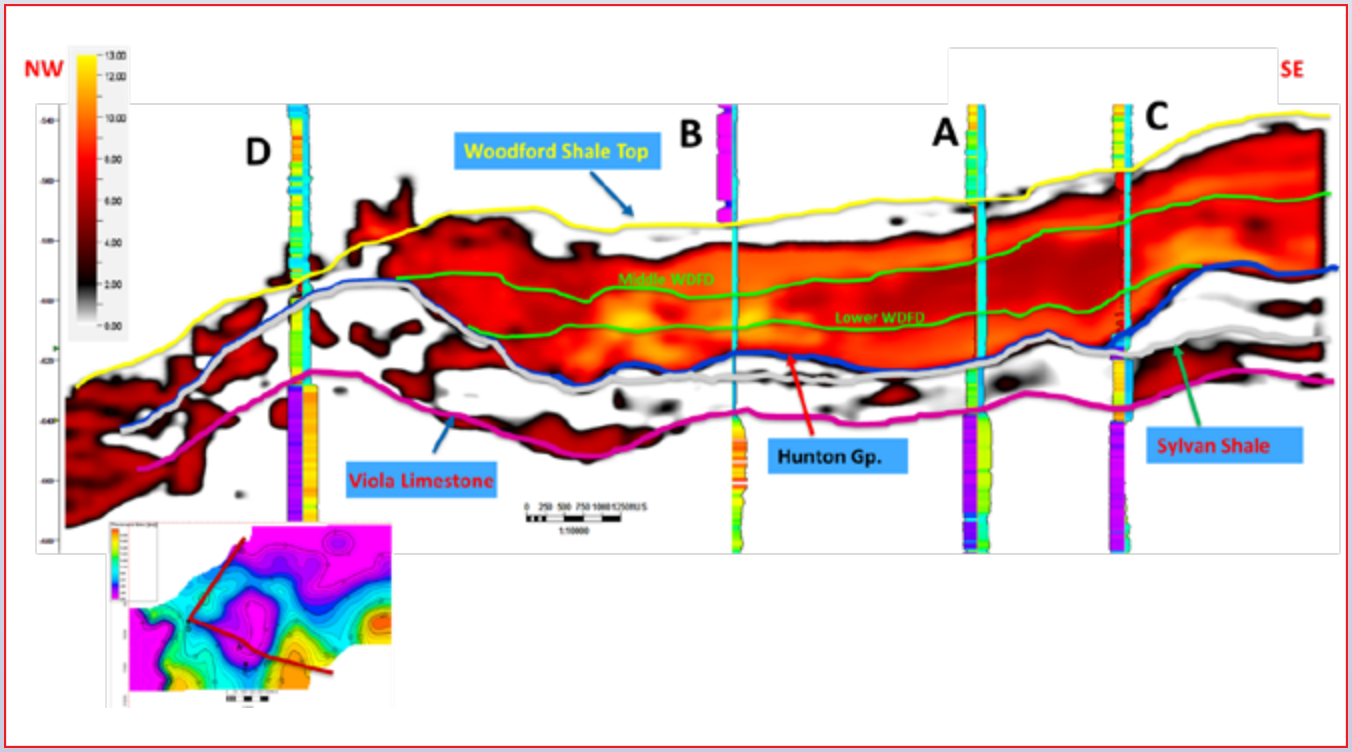


Figure 15. Composite section that correlates all wells in the study area and their TOC calculation for the Woodford shale seismic window. Note the lake-pod shape of the woodford where the well A and C are located.

Technical Article continued on page 24.

Technical Article continued from page 23.

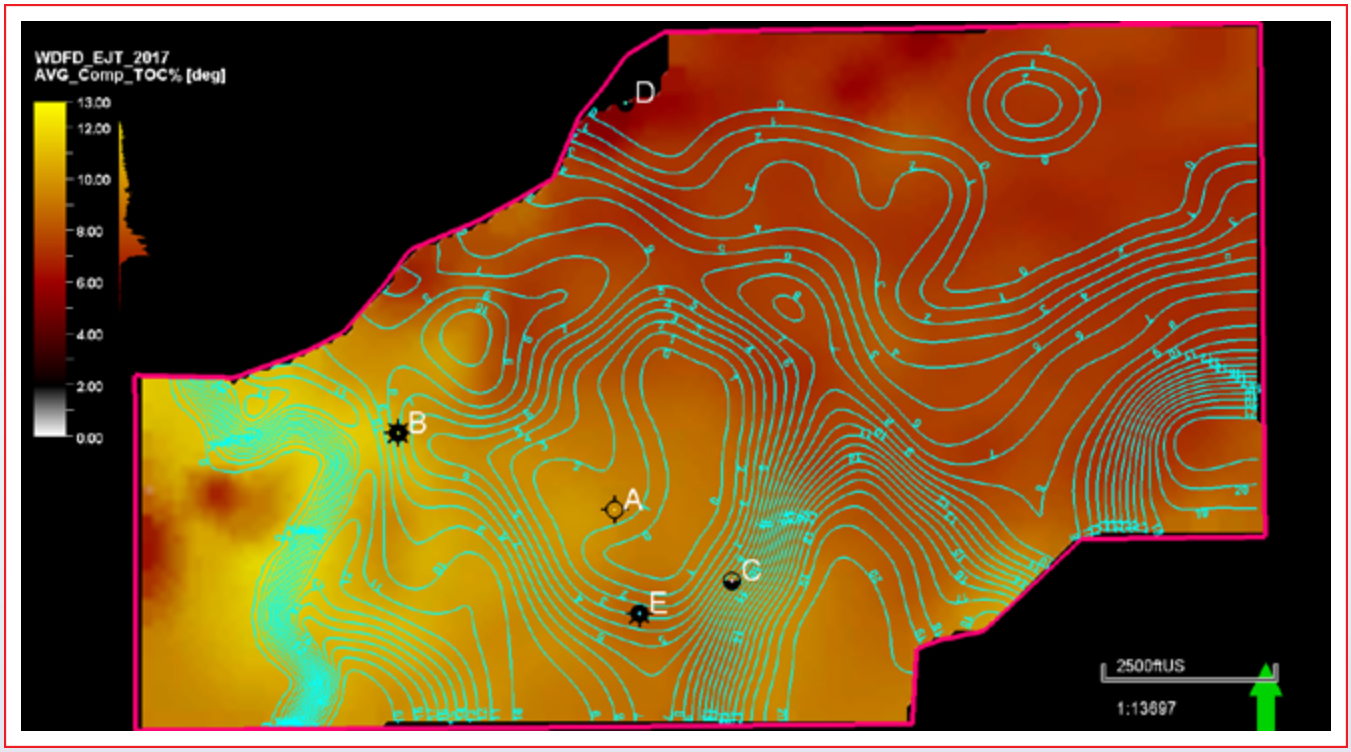


Figure 16. Calculated TOC from the supervised neural network analysis. Average TOC values are extracted for the Woodford shale stratigraphic interval and are shown in the display colors of the map. The contours correspond to the Hunton Group seismic isochrones in milli-seconds [ms].

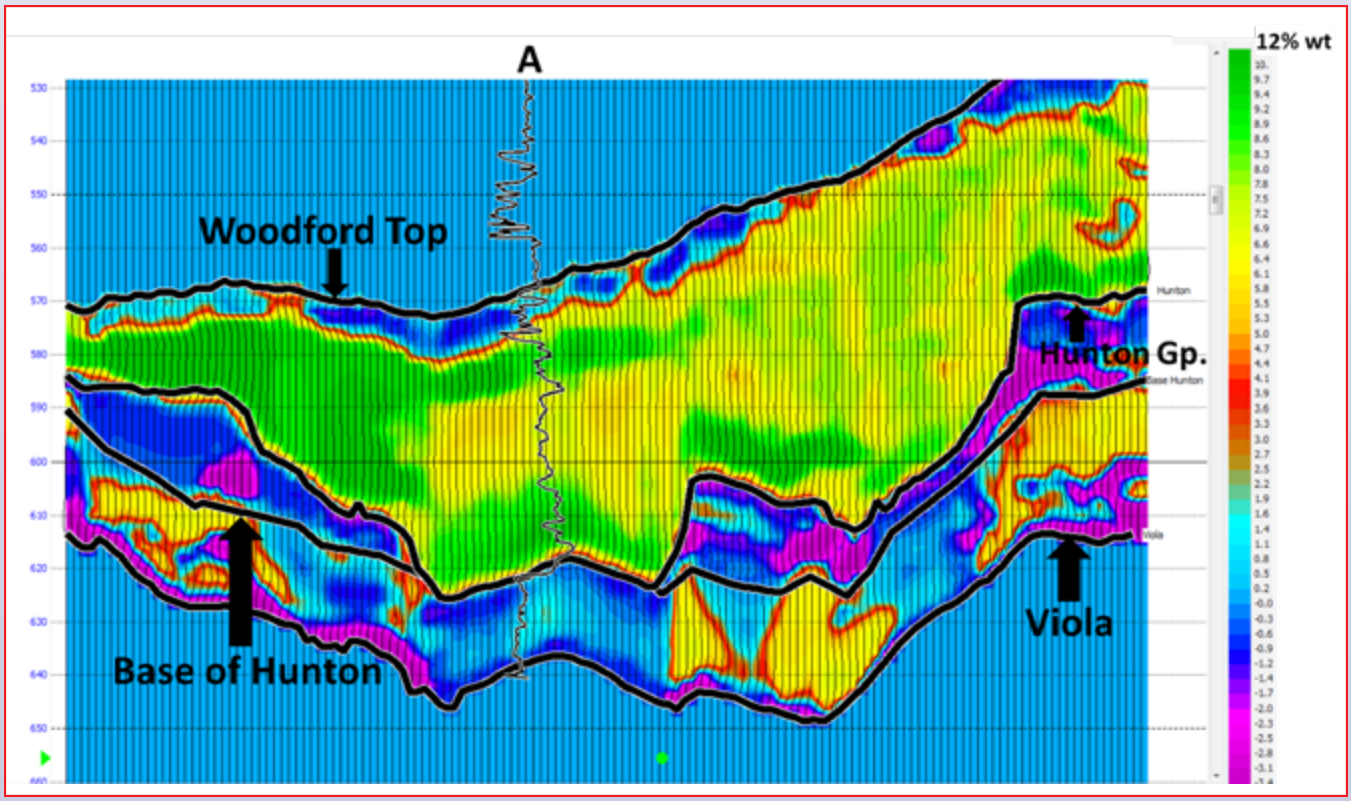


Figure 17. Inline showing the TOC modeling with PNN for the well A. Note the bottom portion that is highly restricted paleo topography has the highest TOC calculated values.

Technical Article continued on page 25.

Technical Article continued from page 24.

References

Amorocho, J. D., 2012. Sequence Stratigraphy and Seismic Interpretation of the Upper Devonian-Lower Mississippian Woodford Shale in the Cherokee Platform: A Characterization Approach for Unconventional resources. M.Sc. Thesis Manuscript. The University of Oklahoma, School of Geology and Geophysics, pp. 127.

Baruch E., O. Elebiju, and R. Perez, 2009, Geophysical evidence of basement controlled faulting in the Ellenburger Group and Viola Limestone, Fort Worth Basin, Texas: 79th Annual International Meeting, SEG, Expanded Abstracts, 995–999.

Bauernfeind, P.E., 1980. The Misener Sandstone in portions of Lincoln and Creek Counties, Oklahoma. Shale Shaker Digest, 30. 1-30.

Cardott B. J., 2009. Woodford gas-shale plays of Oklahoma. Louisiana oil & gas symposium, May 20, 2009. Oklahoma Geological Survey. http://www.ogs.ou.edu/fossilfuels/pdf/LAoilgas2009.pdf; accessed on October 4, 2009.

Cardott, B. J., 2012. Thermal maturity of Woodford Shale gas and oil plays, Oklahoma, USA, International Journal of Coal Geology, p. 1-13. doi:10.1016/j.coal.2012.06.004.

Comer J. B., 2005. Facies distributions and hydrocarbon production potential of Woodford Shale in the Southern Midcontinent. In Cardott B. J. (ed.) Unconventional energy resources in the Southern Midcontinent, 2004 symposium. Oklahoma Geological Survey Circular 110, 51-62.

Heggland, R., 2004, Definition of geohazards in exploration 3-D seismic data using attributes and neural network analysis: AAPG Bulletin, 88, 857–868.

Jarvie, D.M., Hill, R.J., Pollastro, R.M., 2005. Assessment of the gas potential and yields from shales: the Barnett Shale model. In: Cardott, B. (Ed.), Oklahoma Geological Survey Circular 110: Unconventional Gas of the Southern Mid-continent Symposium, March 9e10, 2005, Oklahoma City, Oklahoma, pp. 37-50.

Jarvie, D.M., Hill, R.J., Ruble, T.E., Pollastro, R.M., 2007. Unconventional shale-gas systems: the Mississippian Barnett Shale of north-central Texas as one model for thermogenic shale-gas assessment. AAPG Bull. 91, 475-499.

Kirkland D, W., Denison, R, E., Summers, D, M., and Gormly, J, R., 1992. Geology and organic geochemistry of the Woodford Shale in the Criner Hills and western Arbuckle Mountains, Oklahoma, Oklahoma Geological Survey, Circular 93, p.38-69.

Marynowski, L. and Filipiak, P., 2007. Water column euxinia and wildfire evidence during deposition of the Upper Famennian Hangenberg event horizon from the Holy Cross Mountains (central Poland). Geol. Mag. 144 (3), 2007, pp. 569–595. Cambridge University Press.

Miceli Romero, A., 2010. Geochemical characterization of the Woodford Shale, central and southeastern Oklahoma. M.Sc. Thesis manuscript, The University of Oklahoma, pp. 149.

Molinares, C. E., 2013. Stratigraphy and palynomorphs composition of the Woodford Shale in the Wyche Farm Shale Pit, Pontotoc County, Oklahoma. c

Northcutt, R. A., Johnson, K. S., and Hinshaw, G. C., 2001. Geology and petroleum reservoirs in Silurian, Devonian, and Mississippian rocks in Oklahoma. In Johnson K. S. (ed.) Silurian, Devonian, and Mississippian geology and petroleum in the southern Midcontinent, 1999 symposium. Oklahoma Geological Survey Circular 105, 1-29

Passey, Q. R., S. Creaney, J. B. Kulla, F. J. Moretti, and J. D. Stroud, 1990. A Practical Model for Organic Richness from Porosity and Resistivity Logs: AAPG Bulletin, 74, p. 1777-1794.

Passey, Q. R.., K. M. Bohacs, W. L. Esch, R. Klimentidis, and S. Sinha, 2010. From Oil-Prone Source Rock to Gas-Producing Shale Reservoir – Geologic and Petrophysical Characterization of Unconventional Shale-Gas Reservoirs: CPS/SPE International Oil & Gas Conference and Exhibition in China, 29 p.

Portas R., 2009. Characterization and origin of fracture patterns in the Woodford Shale in southeastern Oklahoma for application to exploration and development. Master of Science Thesis, the University of Oklahoma, pp. 113.

Slatt, R. M., N. Buckner, Y. Abousleiman, R. Sierra, P. Philp, A. Miceli-Romero, R. Portas, N. O'Brien, M. Tran, R. Davis, and T. Wawrzyniec, 2011. Outcrop/ behind outcrop (quarry), multiscale characterization of the Woodford Gas Shale, Oklahoma, in J. Breyer, ed., Shale reservoirs—Giant resources for the 21st century: American Association of Petroleum Geologists AAPG Memoir 97, p. 1–21.

Slatt, R. M., 2016. Woodford shale consortium report, Phase III. The University of Oklahoma, Institute of Reservoir Characterization (IRC), pp. 210.

Turner B., 2015. The Use of Chemo stratigraphy to Refine Ambiguous Sequence Stratigraphic Correlations in Marine Shales: An Example of the Woodford Shale, Oklahoma. AAPG Education Directorate, Woodford Shale Forum: Focus on Optimization, Oklahoma City, Oklahoma, May 12, 2015. AAPG Datapages/Search and Discovery Article #90241.

https://doi.org/10.1190/segam2017-17783467.1

A Live Webinar

Sponsored Jointly by the SEG and GSH

Seismic Amplitude 20/20: An Update and Forecast

Mike Graul

January 23-26, 2018
10:00 AM to 2:00 PM
Central Time
4 Half-Day Sessions
In your Home or Office

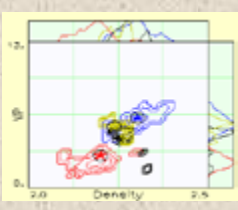
Sign Me Up!

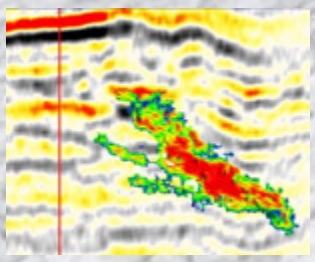
Learn about Group Rates & Recordings

Fred Hilterman

INTRODUCTION:

Course includes an overview of empirical and theoretical rock physics and the relationship to reservoir attributes derived from seismic amplitude.



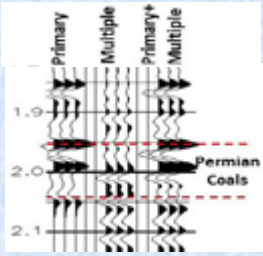


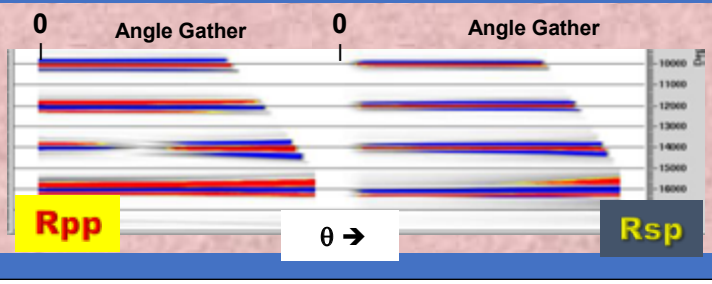
UPDATE TOPICS:

Examples such as inversion at well-log resolution where (Lith, Sw φ) $\Rightarrow$ (Vp, Vs, ρ) calibrates model-based inversion at seismic resolution for (Lith, Sw φ). Other amplitude attributes related to rock proprieties discussed. Case histories highlight technical principles.

FORECAST TOPICS:

Signal and noise wavefields are separated to recognize and suppress multiples. The propagating wavefield is decomposed into Signal and Noise Coda. Case histories with synthetic matches below coal sequences, anhydrite beds, salt layers, etc.





FORECAST TOPICS:

Extraction of S-P converted waves from ordinary "P-wave" data, allows joint AVO (Rpp and Rsp) analysis and enhanced elastic inversion.

Bayes in Action

Let's look first at … **The January Puzzle**

The GSH Athletic Club offers 5 sports for Members: Football, Basketball, Soccer, Hockey, and Quidditch. Members can play as many as they choose (or none). The Chief Statistician tells us that 90% play Quidditch (**Q**), 60% play Hockey (**H**), and 50% play both (**Q&H**). As probabilities: **P(Q) = 0.9, P(H) = 0.6**, and **P(Q&H) = 0.5.**

Quidditch – Don't ask

For cases of two events (**A** and **B**) which occur simultaneously, the probability of this may be expressed by The General Rule of Multiplication: **P(A&B) = P(A)·P(B|A) = P(B)·P(A|B).** The notation, **P(B|A)** means the probability of event **B** happening, given that **A** has occurred. Applying this venerable rule to events **Q** and **H**, determine the probability of randomly selecting a Member who plays **Q**uidditch, given that he plays **H**ockey: **P(Q|H).**

While you're at it, what is the probability of a Member playing Hockey, given that she plays Quidditch, **P(H|Q)**? Is this conditional probability the same as **P(Q|H)**?

GSH Chief Statistician

Before jumping into the equations (be careful not to impale yourself on sharp objects), let's consider the following issue: suppose the Chief Statistician (left) failed to tell you that the P(Q&H) = .5. Would you now be able to determine P(Q|H) or P(H|Q)?

You and Co-Worker

Even if you use the wisdom of your co-worker (unspecified as to who plays what role in the picture above, right), the answer will remain ambiguous, having only **P(Q)** and **P(H).** The new information that 50% of the members play both Quidditch and Hockey, **P(Q&H)**, allows us to compute the conditional probability, **P(H|Q)** or **P(Q|H)**. This will be shown to be analogous to the process of Geostatistical Bayesian **AVO Inversion**, in which information, in the form of statistical data, is added after the initial probabilistic model is given. The latter is the **Prior** Probability, while the added data transforms it to the **Posterior** Probability, yielding results which allow us to measure the uncertainty and other useful statistics.

To determine the conditional probability **P(Q|H)**, we use the multiplication Rule:

$$P(Q|H) = \frac{P(Q\&H)}{P(H)} = \frac{0.5}{0.6} = 0.833\ (83.3\%)$$

Tutorial Nuggets continued on page 28.

Tutorial Nuggets continued from page 27.

The second issue, in JK Rowling's Quidditch world, is the conditional probability of a GSH Member playing **H**ockey given that she plays **Q**uidditch, **P(H|Q).**

$$P(H|Q) = \frac{P(Q\&H)}{P(Q)} = \frac{0.5}{0.9} = 0.556\ (55.6\%)$$

P(Q|H) ≠ P(H|Q), in answer to the earlier query. Note, however, that the Multiplication Rule shows that,

$$P(Q\&H) = P(Q|H)P(H) = P(H|Q)P(Q) = 0.5$$

This means, in a grand flurry of algebraic magic, that:

$$P(H|Q) = \frac{P(Q|H)P(H)}{P(Q)}$$ **and** $$P(Q|H) = \frac{P(H|Q)P(Q)}{P(H)}$$

The Above are versions of The Bayes Theorem

The classic and probably the most controversial example of Bayesian logic is the **Monty Hall** problem. Named after the host of a popular Game Show "Let's Make A Deal", featuring a game in which the **contestant** selects one of **3 doors** behind one of which resides a **luxury car**. The other two doors open to **goats,** of no practical or financial value to the contestant. After selecting one of the doors, let's say Door 1 = **D1**, Monty (who knows the door to the valuable prize), opens another door, say door 3 = **D3**, revealing a goat. With this new information, the problem to solve is should the contestant **switch** her pick to the other door (**D2** in this case).

We presented this problem with a **greasy disguise** to the Nugget readers in the early fall of 2015, The expanded answer appeared on the GSH website in the Nugget Puzzle Solutions section. With luck, it's still there. Below, we give a **Bayesian** approach to the Monty Hall version.

P(Cn) = Prior Probability Car choice, Cn, is behind door n. **P(C1) = P(C2) = P(C3) = 1/3**.

Dn is the Event of Monty opening Door **n.** Assuming the contestant chooses **Door 1,** the prior probability **P(D3) = P(D2) = 1/3**. The posterior conditional probability, **P(D3|C1),** depends on where the car is known to be by Monty: if it's behind **D1**, **P(D3|C1) = ½.** If it's behind **D2, P(D3|C1) = 1**, and if it's really behind **D3**, **P(D3|C1) = 0**. (He won't reveal the car).

Let's put it all together and solve the switching issue (from Door 1 to Door 2), by Bayes.

Tutorial Nuggets continued on page 29.

Tutorial Nuggets continued from page 28.

The Monty Hall Problem solved by Bayesian Logic Continued …

P(D3|C2) = 1. It's the only choice since the D1 was chosen by the contestant.
P(D3|C3) = 0. Monty would never give away the Company Car.

So here's Bayes coming through the side door:

$$P(C1|D3) = \frac{P(D3|C1)\cdot P(C1)}{P(D3)} = \frac{\left[\frac{1}{2}\right]\left[\frac{1}{3}\right]}{\left[\frac{1}{2}\right]} = \left[\frac{1}{3}\right]$$

Stick with Door 1

$$P(C2|D3) = \frac{P(D3|C2)\cdot P(C2)}{P(D3)} = \frac{[1]\left[\frac{1}{3}\right]}{\left[\frac{1}{2}\right]} = \left[\frac{2}{3}\right]$$

Switch to Door 2

The Message is switch. You improve your chances by 2 to 1.

Yo, Dr Guru, my podiatrist just gave me a test for FEEF, and sure enough, it was positive. Am I going to die?

Tommie, The GSH President

Why is this man smiling? FEEF? Ugh.

[The Guru answers from Off-stage] Mr president, I am sorry to say that yes, you will die, but probably not from the dreaded **FEEF***. I have researched the statistics of **FEEF** tests and like so many disease tests, the results are often mis-interpreted, not just by the un-nerved patient, but the doctor as well. Here are the brutal facts. *[FEEF: Flesh-Eating Explosive Flatulence]

This affliction is enjoyed by some 0.**1%** of the world population: **P(F) = .001**. The **test** for it is credited with being **80% accurate**, meaning if you have it, the test will be **positive** (settle your affairs), with probability **P(POS|F) = 0.80**. It also means that the **False Negative** (missed it, when you've got it) is **P(NEG|F) = 0.20.**

On the other hand, those folks who **don't have FEEF**, **P(NO-F) = 0.999**, when tested, have a **False Alarm** rate of **9.6%**, that is **P(POS|NO-F) = .096**. This means that if you're FEEF-free, the test will be correctly **negative (NEG) 90.4%** of the time: **P(NEG|NO-F) = 0.904**.

So, Tommie, your Chances of actually having FEEF are given by **P(F|POS)** = ? Let's let the readers solve this for you. They will call with the good news. **This is the February Puzzle**

A Paid Commercial Announcement by The Guru (parsimonious as he is)

At the end of **January (23 – 26, 4 days from 10AM to 2PM)**, **one of the Guru minions (the elderly fat one)** and some guy named **Fred Hilterman** are giving a **Webinar** cleverly named ***Seismic Amplitude 20/20: An Update and Forecast***. This Fun and Frolic show will cover all manner of important stuff, including elements of AVO Inversion, Azimuthal AVO (AVAZ), Converted wave (S to P) AVO, Rsp(θ), and some all-new amplitude twists and insights by the always entertaining Fred. (Both Fred and Mike are certified FEEF-Free.). Register with GSH.

32nd Annual GSH Sporting Clays Tournament

RAIN OUT DATE:

Saturday, January 27th, 2018

American Shooting Centers
16500 Westheimer Pkwy.

9:00 am - 3:00 pm

To be a sponsor and secure a spot for your team, please contact:

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

GSH Education and Development for Unemployed Professionals

By Whitney H. Blanchard, Chair

GSH hosted its fourth event for professional development of its members on November 8th, 2017 at the GSH Geoscience Center located at 1790 W. Sam Houston Parkway North, in northwest Houston. This venue contains various geophysical equipment that was used in past exploration practices, it also holds a fully stocked library that is available to all GSH members.Pic 1

The first presenter was Niven Shumaker from Noble (Niven Shumaker, left & Fernando Ziegler, right). He discussed the financial aspects of oil & gas prospect development and explained who most commonly generates the greatest profit margins in development; the early mover, the fast follower, or the lease holder. He also explained the results of using "innovation" in company's core values and whether or not it pays to innovate whilst exploring new prospects. His talk was well received by all attendees with a good question and answer session afterwards.

The second speaker to present was Thomas Cullison from NVIDIA (Whitney Blanchard-left, Thomas Cullison-middle, Fernando Ziegler-right). His talk illuminated the need for geophysicists to work as domain experts with computer programmers in the realm of data analytics. As data is the most valuable resource for exploration, he discussed the increasing demands for domain experts to be trained as programmers instead of hiring data scientists to be trained as domain experts. Ultimately, becoming the bridge between the two skillsets opens a variety of roles for geophysicists and may be a lucrative future for upcoming geophysical students.

Overall, the event was considered a success and attendees were thankful for the talks and guidance our speakers provided. We appreciate the sponsorship of Noble for this event, and ask that members look for our next event in 2018.

Sponsored by

noble energy

U of H Wavelets

SEG Wavelets Volunteer at Earth Science Week

By Monica Guerrero

On October 14, 2017, the University of Houston's Society of Exploration Geophysics chapter, SEG Wavelets, participated in the 19th annual Earth Science week held at the Houston Museum of Natural Science. The event was hosted by the Houston Geologic Society and is the third year in a row that the Wavelets have participated. The Wavelets had the opportunity to demonstrate several techniques used in the field, as well as, a geology demonstration.

The geology demonstration consisted of one half of a model Earth that showcased three tectonic settings and rocks that could be found in these environments. Young children were fascinated with touching the rocks and analyzing the differences while, adults were intrigued with learning about the igneous rocks and what their kitchen counters were telling them.

The 2-D seismic line was enjoyed by all ages, as children were thrilled to use the hammer source to cause the seismic waves, while adults were fascinated by having a better understanding of how exactly geophysicists read the interior of the earth. Many questions were asked about earthquakes and how energy travels through the earth's interior layers. *(figure 1)*

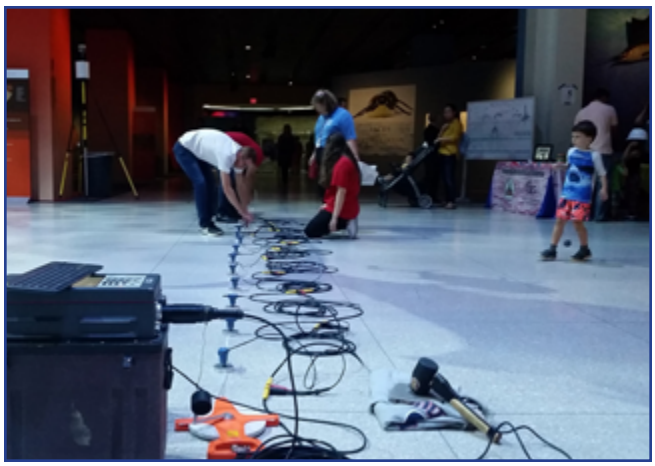


Figure 1. Graduate students, Matt Sexton and Ezzedeen Alfataierge setting up the seismic line.

The GPR device had a constant flow of children who were given the opportunity to push the device around the room and observe the readings displayed. *(figure 2)*

The LIDAR garnered attention of many parents and teens as wavelet members demonstrated and explained its field use. As the event wrapped up, as per annual tradition, the wavelets had a group photo taken by the LIDAR. The event was once again successful, as many questions were asked at each demonstration by, not just young children but, many adults who left with a better understanding of the importance of geosciences. The Wavelet's

Figure 2. Graduate student, Somaria Sammy demonstrating the GPR to children during Earth science week.

have been asked to participate next year with a larger booth, and have therefore formed a subcommittee to come up with future ideas for the event. *(figure 3)*

Figure 3. Undergraduate student, Lynn Nguyen demonstrates use of LIDAR to a family during Earth Science week.

Figure 4. Photo taken by LIDAR of SEG members at Earth Science week.

SAVE THE DATE

2018 GSH – SEG SPRING SYMPOSIUM & EXHIBITION
April 4th & 5th 2018 • Norris Conference Center

HONORING DAVE HALE

Sharper Imaging: Case studies highlighting advances in seismic acquisition and processing that impact drilling decisions on & offshore

Symposium Chair: Xianhuai Zhu
Technical Chairs: Grant Byerley, Dan Whitmore, Dennis Yanchak & Jon Etgen

More information to follow!

GSH Outreach

Committee Activities *By Lisa Buckner*

We participated in two events in celebration of Earth Science Week (ESW) which is sponsored by the American Geological Institute and it's Member Societies (including SEG) on behalf of the geosciences community. It is celebrated annually during the second week of October and the 2017 theme was "Earth and Human Activity".

Saturday, October 14 was the **14th Annual Earth Science Week Celebration at the Houston Museum of Natural Science** organized by our friends & colleagues, the Houston Geological Society (HGS). Forty educators who attended the event received an AGI Earth Science Week Toolkit for their classrooms from the HGS. The festival consisted of seven "passport stations" with hands-on activities. The UH SEG Wavelets brought their GPS/LiDAR and laid out a seismic line on the floor with a hammer source. Scott Singleton (GSH member) volunteered at the Houston Gems and Mineral Society station which brought samples of petrified wood and explained how wood becomes petrified and what plant fossils can tell us about the Earth's environment in the past. The GSH hands-on activities station included the geophone and laptop oscilloscope emulation, our Ocean Drilling Activity and the animated shot diagram. Over 350 enthusiastic children and parents participated in the event. Young and old enjoyed using a pencil to wildcat drill for oil (shoe polish) in a box of fresh cat litter. We talked extensively with several college students, early career professionals and interested adults throughout the day. We gave away 150 GSH logo plastic coiled toy springs. A huge "Thank You" goes out to our tireless volunteers who worked alongside me: Loralee Dickson, Karina Cheung and Laurie Green.

Saturday, October 21 was the **7th annual Consumer Energy Alliance "Energy Day".** 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 50+ interactive exhibits highlighting a wide range of energy sources and technologies that help shape our everyday lives and the Houston economy. Please visit the Energy Day website at http://energydayfestival.org/ for more information and photos. 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 and the animated shot diagram. GSH volunteer Loralee Dickson said "Energy day was a lot of fun. We were told that attendance this year was a record high with over 30K people!! We quickly ran out of slinkies and the drilling platform pencil toppers, but everyone was perfectly happy searching for oil with undecorated pencils." I placed a new order for GSH logo coiled toy springs since that was our last box. A huge "Thank You" goes out to our volunteers who dealt with the high Houston heat and humidity: Loralee Dickson, Jennifer Holley, Huw James and Larkin Spires.

Outreach continued on page 35.

Outreach continued from page 34.

UPCOMING EVENTS – Volunteers Needed

Friday, January 19, 2017 - **First Colony Middle School Career Day (Sugar Land)** – Career Booth

Saturday, January 20, 2018 - **The Educator Event @HMNS** – Talk to K-12 teachers

Tuesday, January 23, 2018 – **WEN Young Women Energized** – Talk to 11th & 12th grade girls (Women's Energy Network membership required to volunteer)

Thursday, January 25, 2018 - **Morales Elementary School Science Night (Pasadena)** – Science Booth

Monday, February 12, 2018 – **B.E.S.T. Family Science Night (Bellville)** - Science Booth

Saturday, February 24, 2018 - **AAUW Expanding Your Horizons in Science & Mathematics (Houston)** – hands-on activity workshops for middle school girls

Saturday, February 24, 2018 - **Science & Engineering Fair of Houston (UH Main Campus)** - Judges Needed

Saturday, April 14, 2018 – **Scout Fair (NRG)** - Science Booth

Saturday, April 14, 2018 - **HISD When I Grow Up Career Expo** – Science Booth

If you are interested in volunteering for any event, please contact Lisa Buckner at lbuckner@hess.com or LisaAg84@aol.com.

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

2017-2018 GSH Scholarships

The GSH offers two scholarships as part of our continuing effort to support young professionals. They are the **Carlton-Farren Scholarship** and the **Hugh Hardy Scholarship** for worthy college students in the field of geoscience. Both funds are administered by the SEG and funded by the GSH. The funding for these programs increases and decreases depending on our finances and the amount of donations received. The goal is to build the funds to be self-sustaining. The scholarship endowments were named in honor of outstanding individuals in the GSH.

Emily Geyman

The 2017-2018 GSH/Hugh Hardy scholarship awardee is Emily Geyman, a sophomore from Seattle, WA studying geosciences at Princeton University. She wants to pursue a career in geoscience research. She states this about her current research, "I am studying water and sediment from the Great Bahama Bank, a region of active carbonate formation. Recent studies of the Bahamas suggest that facies (grain size distributions) are not unique recorders of water depth. However, specific *transitions* of facies may consistently record sea level change. We have started to use Markov Chain Monte Carlo (MCMC) simulations to compute the probability that certain facies transitions are attributed to sea level fall rather than random variability. I traveled to Andros Island in the Bahamas to survey a grid of points on the Great Bahama Bank, measuring water depth, documenting facies and bed forms, and collecting water and sediment samples for geochemical analysis. The integration of chemical and physical field observations with probabilistic techniques will enable us to develop a quantitative method for calculating the relative likelihoods that observed facies transitions or isotope gradients in ancient stratigraphy represent global changes in sea level rather than natural shelfal variability. This modern calibration study is crucial to refining our interpretation of past sea level variation recorded in carbonates, which is in turn necessary for predicting future sea level change." Emily states that she is honored to be awarded the GSH/Hugh Hardy Scholarship and is looking forward to using it to support her undergraduate degree in geosciences.

Somaria Sammy

The 2017-2018 GSH/Carlton-Farren scholarship awardee is Somaria Sammy a master's student in Geophysics at the University of Houston under Dr. Robert Stewart. Her thesis will focus on Ground Penetrating Radar (GPR) applications. She is originally from Trinidad and Tobago and did her undergraduate work in Oklahoma, but now considers Houston her home. Somaria states that she was immediately enamored with Houston. She identified many aspects that she admires about our city including the diversity of its people, the technology & industry, the arts & culture and the availability of wide ranging employment opportunities. She does not know yet what her role will be when she graduates, but she does know she is eager to participate in Houston's continued growth and development.

The GSH appreciates the support provided by our members and the companies that sponsor our social events which fund this scholarship effort.

Geoscience Center News

By Bill Gafford

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

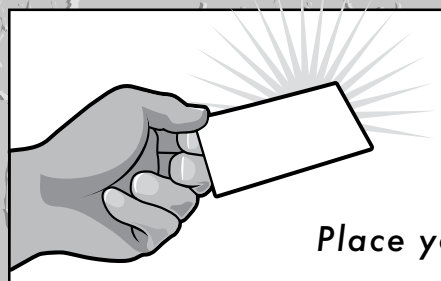
In previous articles I have given some history of the GSH Museum Committee and described a few of the activities of the volunteers. The Mystery Items shown each month are from our collection of geoscience artifacts and only represent a small portion of our Museum Collection, which now includes over 1500 items. One of the goals of our Geoscience Center is to "preserve and educate", and we try to accomplish this by having items on public display at various locations. Below is a brief description of these displays of our museum items.

Our first public display was opened at North Harris College (Now Lone Star College-North Harris) in 1994, which included the Petty Collection in addition to other items from the 1920's and 1930's and 1940's. This display is still the largest display of items from the GSH Museum Collection. In a continuing effort by the Museum Committee to make some of the collection of artifacts available to the public, additional display locations include San Jacinto College North

(1998), the Bob Bullock Texas State History Museum in Austin (2000), ExxonMobil Greenspoint (2003-2014), Canmore Museum and Geoscience Center, in Canmore, Alberta, Canada (2003-2013), and the University of Texas, Bureau of Economic Geology, Houston Research Center

(2004). This location is a core and cuttings storage facility and our display is located in the core layout room. Most of the Petty Collection including some display cabinets and other items were moved to the University of Texas, Jackson School of Geosciences in 2007. A display was added at Geophysical Pursuit in 2011, and a display at the GSH office was added in 2012. We currently have a torsion balance on loan to the Lafayette, Louisiana Science Museum, and it is part of their new exhibit "Energy Unearthed: The Science of Petroleum Exploration". The GSH is also the custodian of the SEG Iverson Collection of gravity instruments which were on display at Fugro Gravity and Magnetic Services from 2010 until 2014 and are now on display at CGG Multi-Physics.

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



Here's My Card

Place your Business Card in The GSH Journal.
Call or Email for Rates.

Telephone: 281-741-1624
email: karen@gshtx.org

Click on the card to access the company's website.

PARAGON GEOPHYSICAL SERVICES, INC.
AARON BATEMAN
President
Cell: (316) 640-0423 • abateman@paragongeo.com
(316) 636-5552 • Fax (316) 636-5572
3500 N. Rock Rd., Bldg. 800 • Wichita, KS 67226

Coggins Geosciences, Inc.
Seismic Interpretation / Technical Assurance
Jerome L. Coggins
Principal Geophysicist
Katy, Texas USA
281-717-4011
JLC@CogginsGeosciences.com

ikon Science
Sue Pritchett
Business Development Manager
D +1 713 914 0300 - Ext 219 · C +1 281 451 6522
E spritchett@ikonscience.com · Sue Pritchett

Katherine Pittman
Vice President of Sales & Marketing
Resolve GeoSciences, Inc.
Seismic Attribute Services
431 Mason Park, Suite B
Katy, Texas 77450
Direct: 713-972-6206
Cell: 281-615-3339
Fax: 281-395-6999
www.resolvegeo.com
Email: kpittman@resolvegeo.com

RPS
Tony LaPierre
Technical Director
Seismic Operations
and Site Investigations
411 N. Sam Houston Parkway E.
Suite 400
Houston, Texas 77060, USA
T +1 281 448 6188
F +1 281 448 6189
D +1 713 482 3845
M +1 281 733 5281
E Tony.Lapierre@rpsgroup.com
W rpsgroup.com

Z-TERRA Technology for Energy
Frank Dumanoir
Business Development Consultant
Z-Terra Inc.
17171 Park Row, Suite 247
Houston, TX 77084
E-mail: frank@z-terra.com
www.z-terra.com
Main: +1 281 945 0000
Fax: +1 281 945 0001
Cell: +1 713 594 2371

Nicola Maitland
Client Training & Support Manager
Resolve GeoSciences, Inc.
Seismic Attribute Services
431 Mason Park, Suite B
Katy, Texas 77450
Cell: 281-507-6552
Direct: 713-972-6209
Fax: 281-395-6999
www.resolvegeo.com
Email: nmaitland@resolvegeo.com

dug
DownUnderGeoSolutions
Julie Willmore
BUSINESS DEVELOPMENT MANAGER
M +1 346 302 6006
E juliew@dug.com
DOWNUNDER GEOSOLUTIONS
16200 Park Row Drive, Suite 100
Houston, TX 77084
United States of America
T +1 832 582 3221
www.dug.com

CNPC BGP
BGP International, Inc.
Tom Wood, Jr.
Sales Manager, Houston Processing Center
10630 Haddington Drive
Houston, Texas 77043
E-mail: twood@bgprdc.com
Tel: (713) 465-2999
Cell: (210) 232-2137
Fax: (713) 465-9777

TRICON
DAVE WILLIAMS
VICE PRESIDENT OF BUSINESS DEVELOPMENT
PHONE: 713-532-5006
FAX: 713-532-5076
10111 RICHMOND AVENUE, SUITE 230
HOUSTON, TEXAS 77042
DAVE.WILLIAMS@TRICONGEOPHYSICS.COM

Allied Geophysical Laboratories
UNIVERSITY of HOUSTON

SEIMAX TECHNOLOGIES
Robert D. Perez
Senior Marketing Representative
4805 Westway Park Blvd., Houston, TX 77041
p: 832.554.4301 d: 832.554.4315 c: 281.787.2106
rperez@seimaxtech.com

OvationData
Total Data Management Solutions
John Hood
Strategic Development Account Manager
john.hood@ovationdata.com
Mobile: 832-298-3723 Direct: 713-375-1235

VSP Consultants L.L.C.
Allan Campbell
Borehole Geophysicist
allan@vspconsultants.com
+1 281-352-1168
- VSP survey design assessment & feasibility
- VSP acquisition & processing analysis
- Customized training
www.vspconsultants.com

BOREHOLE SEISMIC
Microseismic Data Acquisition | Data Processing | Data Reprocessing
Anisotropic Modeling | Dynamic Ray Tracing | Joint Inversion
Combined Surface-Downhole Co-Location
boreholeseismic.com

Click on the card to access the company's website.

Kenneth W. Mohn
Managing Director and Vice President Americas

MultiClient Geophysical LLC
Email: kenneth.mohn@mcg.no
Tel: +1 281 888 1535
Mob: +1 713 485 9696

9525 Katy Freeway
Suite 495
Houston, Texas
77024, USA

www.mcg.no

James C. Jackson
President

GeoTomo

15995 N. Barkers Landing Rd, Suite 110
Houston, TX 77079 USA
Office: 281-597-1429
Fax: 281-597-1201
james.jackson@geotomo.com
www.geotomo.com

POLARIS E&E SERVICES, INC.

2700 Technology Forest Blvd., Ste 100
The Woodlands, Texas 77381

PATRICK W. KLEM
Executive VP
email pklem@polarisdata.com

phone (281) 367-6000 fax (281) 367-6160 cell (713) 252-0130

KATALYST
DATA MANAGEMENT

10311 Westpark Dr.
Houston, TX 77042
US

DENISE DORSEY
BUSINESS DEVELOPMENT MANAGER

MAIN +1 281-529-3200
DIRECT +1 281-529-3271
CELL +1 713-397-4487

denise.dorsey@katalystdm.com
www.katalystdm.com

---

flamingo
SEISMIC SOLUTIONS

Steve Davidson
President

11777 Katy Freeway, Ste 570 | Houston, TX 77079 | 281.977.7432
4815 S. Harvard Ave, Ste 401 | Tulsa, OK 74135 | 918.492.3773
cell: 713.202.7838 email: steve@flamingoseismic.com

www.flamingoseismic.com

Geotech & Design Services
7171 Highway 6 North, #202
Houston, Texas 77095
Data digitizing, drafting & computer graphics

Tel: (281) 858-7100
Fax: (281) 500-8534
elias.mendoza@geotechmaps.com

Elias Mendoza
Vice President of Operations

www.geotechmaps.com

---

energyprofessionalsearch
Technical and Executive Recruiting

SOFIA CAMPBELL
B.Sc. Geology & Geophysics, Hon.

713-668-5406
Houston, Texas USA
sofia.campbell@comcast.net
www.energyprosearch.com

Z-TERRA
Technology for Energy

Alexander Mihai Popovici, Ph.D.
CEO and Chairman

Z-Terra Inc.
17171 Park Row, Suite 247
Houston, TX 77084
E-mail: mihai@z-terra.com
www.z-terra.com

Main: +1 281 945 0000 x101
Fax: +1 281 945 0001
Cell: +1 650 219 5389

Duane A. Pankhurst
Principal Geophysicist
1001 Euclid Street, Houston, TX 77009-7136

duane.pankhurst@edgegeophysics.com
www.edgegeophysics.com

713.864.7700 (office)
713.444.7177 (cell)
713.864.7701 (fax)

AVO Feasibility Studies • Rock Property Modeling and AVO Analysis • Well Log Conditioning and Fluid Substitution • Seismic Inversion • Seismic Processing • Post-Migration Data Conditioning • Geologic Interpretation • Vendor Supervision • On-site Contract Assignments

---

Miguel Silva
V.P. USA and Canada

LUMINA
The New Light in GeoSciences

C: (281) 827-6710
P: (713) 650-3200
F: (713) 650-3201
Email: miguel.silva@luminageo.com

1001 Texas Ave. Suite 1020
Houston, TX 77002 - USA

www.luminageo.com

What's Worse: An Empty Portfolio or Risky Prospects?

NEARFX

Near Field Exploration with leading-edge interpretation, AVO & Inversion, Rock Physics, Attributes, Log-seismic Data Mining and more...

Proven oil finder record in Texas, Alberta, Colombia & Thailand...

NearFX.com

Steve Tobias, President
Steve@NearFX.com
281-908-9072

HARDIN
Quality Geophysics

William L. Sass
Sr. Exec. Vice President
Sales & Marketing

www.hardinintl.com

Hardin International Processing, Inc.
5300 Democracy Drive, Suite 100
Plano, Texas 75024
Bus. 972.312.9221 x110
Cell. 214.695.1126
Fax. 972.312.9226
Email. wsass@hardinintl.com

Geophysical Technology, Inc.
GTI

Geophysical Technology Inc.
Sean Siegfried
Global Sales Manager
800 Mulberry Lane
Bellaire, TX 77401
Office: 713.893.5655 x104
Mobile: 832.808.0203

sean.siegfried@geophysicaltechnology.com

SEIMAX™
TECHNOLOGIES

Matthew Mohr
Marketing Representative

4805 Westway Park Blvd., Houston, TX 77041
p: 832.554.4301 d: 832.554.4317 c: 281.851.3974
mmohr@seimaxtech.com

Carlos Moreno
President

LUMINA
The New Light in GeoSciences

C: (832) 671-3246
P: (713) 650-3200
F: (713) 650-3201
Email: carlos.moreno@luminageo.com

1001 Texas Ave. Suite 1020
Houston, TX 77002 - USA

www.luminageo.com

Place your Business Card in The GSH Journal.

Get it in color and add a link to your website or email at no additional charge!

A Live Webinar
Sponsored Jointly by the SEG and GSH

Affordable S-Wave Reflection Seismology

4 half-days 10 AM – 2 PM

February 27 – March 2, 2018

Presented by
Dr. Bob A. Hardage

Senior Research Scientist, Bureau of Economic Geology
University of Texas, Austin

So, Dr Bob, what makes it affordable?

Skeptical

Good Question, my skeptical friend. The answer is simply this: **you have already recorded the S –Wave Data – it's hiding in your P-wave data**!

How is that possible? I used P-Wave sources and regular geophone receivers!

Because, oh you of little faith, we have proof that **"P-wave Sources"** – **Dynamite, Vibroseis** – actually generate **Direct, High Amplitude S-Waves** that are recorded as converted waves, **Sv-P**, by **vertical receivers**. The Webinar will reveal all and show you some **Valuable Applications on Real Data.**

Attend this Course in the comfort of **your office** or even **your own home**. It works on **PC's, iPads, iPhones**, or even two tin cans with a taut string (not recommended). **No travel costs.**
With major discounts for Groups and Students.

What If I have to miss a session?

Worry Not. All sessions are recorded and available to registrants.

Register Now! **GSH Website: gshtx.org**

Doodlebugger Diary

Reflections on the Early Days of Vibroseis

By Lee Lawyer

The title to this DD column was selected by the author, Don Frye. He mentioned the magic word, Reflections. Today, a large percentage of land seismic data acquisition uses vibroseis as the source. Don is starting with the swinging weight vibroseis which is pictured below. Imagine having a different source sweep sent to us for every correlation and no summations. I recall an early seismic survey undertaken by a group of companies on the Central Basin Platform for the New Mexico Federal Unit. Conoco was the operator. This was in the mid-sixties. During a meeting of NMFU, I suggested that we conduct the survey using Vibroseis. All other partners thought that was a great idea except for one, Conoco! We used vibroseis despite the operator's objections. There is some quote about a prophet in their own land that could be applied in that NMFU project. Don has had a broad base of experience in our profession. He fully qualifies as a real, live doodlebugger. Lee Lawyer

This Doddlebugger Diary by Lee Lawyer first appeared in the September 2013 issue of the Journal. If you have an item for the Doodlebugger Diary, send it to llawyer@prodigy.net or to editor@GSH.org

The concept of the Vibroseis system was undoubtedly out of the early fifties MIT GAG group. Conoco was a participant in that industry/academic undertaking which lead to the emergence of many of the industry's giants.

The first patent for Vibroseis was issued to Bill Doty and John Crawford in 1954. Early tests included attaching a large number of geophones to a platform and driving them with a frequency varying voltage. My first experience with the system was as a Conoco trainee in 1957 in Fort Stockton, Texas, an area notorious for poor data quality. The new crew was equipped with a so called swinging weight vibrator. Two off center weights were rotated in opposite directions so that the energy was predominately vertical. It was a 14,000 pound steel wheel trailer that had an electric motor to increase the rotational speed of the weights until the trailer was bouncing off the ground. The power was released and the weights were allowed to return to resting position. This sweep from the resonant frequency (adjustable by choosing the size of the weights) was measured by a phone on the vibrator base and transmitted to the recording truck. Each sweep was potentially different so no summing was possible. With the computing power available at that time, all the data was sent to Ponca City headquarters for processing and it was often a month before the results were known.

A later patent was granted to Nigel Anstey for a modification to generate shear waves. Nigel was also inventor of what was called a "copperhead", a means to correlate data in the field on the analog systems that were still being used in the mid 1960's

By late 1958 I was on an early servo hydraulic vibrator crew working the city streets of the Los Angeles area. The crew worked nights when traffic was light. The vibrator truck was a regular truck with the vibrator assembly mounted behind the rear wheels. It was soundproofed as much as possible but still would cause a lot of house lights to come on because of the noise and shaking. By then the sweeps were transmitted to the vibrator so summing was possible and there was a correlation facility on the crew. Later the hydraulic vibrator was replaced by multiple pickup truck based electronic units. Think loudspeaker voice coils with weights driven by 1000 watt amplifiers. Not sure about total success of the project but there was a successful well drilled on the MGM movie lot while the crew was still in the area.

My next experience was as a data processor in 1965. I went out on the first real test of the marine vibrator system. Two vibrator units, a recording dog house and short streamer were loaded on a chartered WW2 minesweeper and tested in Cook Inlet with the project completion on Halloween night with snow blowing across the deck. The vibrators were modified land units with a steel plate mounted on the frame and another like plate mounted to the vibrator shaft.

Doodlebugger continued on page 43.

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 42.

Something similar to a tire on a rim joined the two plates. Later units were about four feet in diameter and all enclosed in a clamshell configuration plus having a much greater stroke displacement. In most surveys four vibrators were towed at about 30 feet depth.

In 1966 Conoco began licensing the system to contractors and I was assigned to help train the purchasers. One contractor with a land license from Conoco had a plan to not pay for the marine license; they modified one of their vessels with 4 wells from deck to the water. These wells were 4 feet in diameter and each had a land type vibrator mounted. To say it didn't work according to plan is an understatement. It did a great job of vibrating the boat.

Olympic Geophysical was chosen as the 1967 Gulf of Alaska group shoot contractor and Conoco as operator and I was the project supervisor. Fairly uneventful project except for the first trip back to Houston with tapes. The Yakutat bush pilots airplane only had one brake, so slip the other wheel off the pavement to help slow down after landing. Toward the end of the survey the crew did lose most of the streamer in deep water offshore Kodiak; believed taken by a submarine.

A similar situation developed for the 1968 Atlantic Coast group shoot with Delta Exploration as contractor, Conoco as operator and I was project supervisor. Again, it was uneventful once we got started. First day, about 150 miles off the coast of Florida we lost all power. The switch box between the two ship's generators malfunctioned. Some nervous rewiring at least got us going again. Further north, offshore New England area the natives did not want the survey. The group had a number of townhall type meetings with major oil company participation, but the fishermen, especially in Massachusetts were not happy.

In 1969, the crew count, all 2D at that time, hit a low, and Conoco among other majors were cutting back. I turned down an assignment to HBOG in Calgary, and later decided to accept a position with Seiscom Delta. Working with Elwin Peacock, Tury Taner and others such as Norman Neidell was an interesting change from chasing marine crews, however, less than two years later I was in England as Operations Manager. At the time we had two marine crews, a land crew in Sweden and a shallow water crew in the Adriatic. We later added a land crew in Spain. We, meaning family, enjoyed our time in England with several trips to the Continent, including learning to ski. The Austrian instructor knew little English; the most intelligible phrase was "bend ze neez" and after the second day said "give momma schnaps for breakfast".

Two years in England then a transfer to Singapore. Seiscom had a number of land crews in Indonesia so a lot of traveling was involved; looking for new contracts or making sure things were going well on active crews. Most of the Indonesian based companies gave their professional staff extra vacation time in Singapore, and believe me, they were ready to party late into the evening.

Two and one half years in Singapore, then back to Houston for about three years before taking a job with Houston Oil & Minerals. Back to interpretation and some crew supervision before being named Geophysical Manager.

HO&M merged into Tenneco E&P and I was named Manager of Geophysical Data Processing as the company changed from a single minicomputer to a mainframe processor. A small applied research group evolved and the Rutherford paper on classification of AVO anomalies was an effort of that group.

Tenneco E&P couldn't carry Case tractors losses (another part of the conglomerate) so we were sold off in 1988. Most of the field technical staff joined the purchasing groups, but the processing group was not needed. I had an offer from friend Prentiss Fatheree at American Coastal Energy. He provided a place to sit and some data to work, and if I sold a prospect I would get paid.

After a number of years with Prentiss, I had an involvement in a field in South Texas that we got Cabot Oil & Gas to shoot a 3D survey over the area for an interest. I did the first interpretation of the survey at home on a Pentium 133 computer and a single 17 inch monitor. At that time the Kingdom software came on two floppies and could not draw down lines at wells, only a derrick at the top of the section. That interpretation lead to a contract at Cabot that lasted for about 8 years. In 1998 Cabot participated in a 255 square mile 3D survey in Terrebonne Parish, LA. I was assigned to work it and a Geologist named Gar Willis was added to staff. Gar and I have continued to work the general area, from Cabot to Palace Exploration to now Magnum Producing. Over time we have been involved in 31 wells which have produced more than 30 MMBbls and 300 Bcf gas. We still have a lot of prospects, but of course current interest favors unconventional plays.

Mystery Item

The Mystery Item on page 8 is a Portion of a Pantograph, which was used to convert maps to different scales.

Memorial Tribute

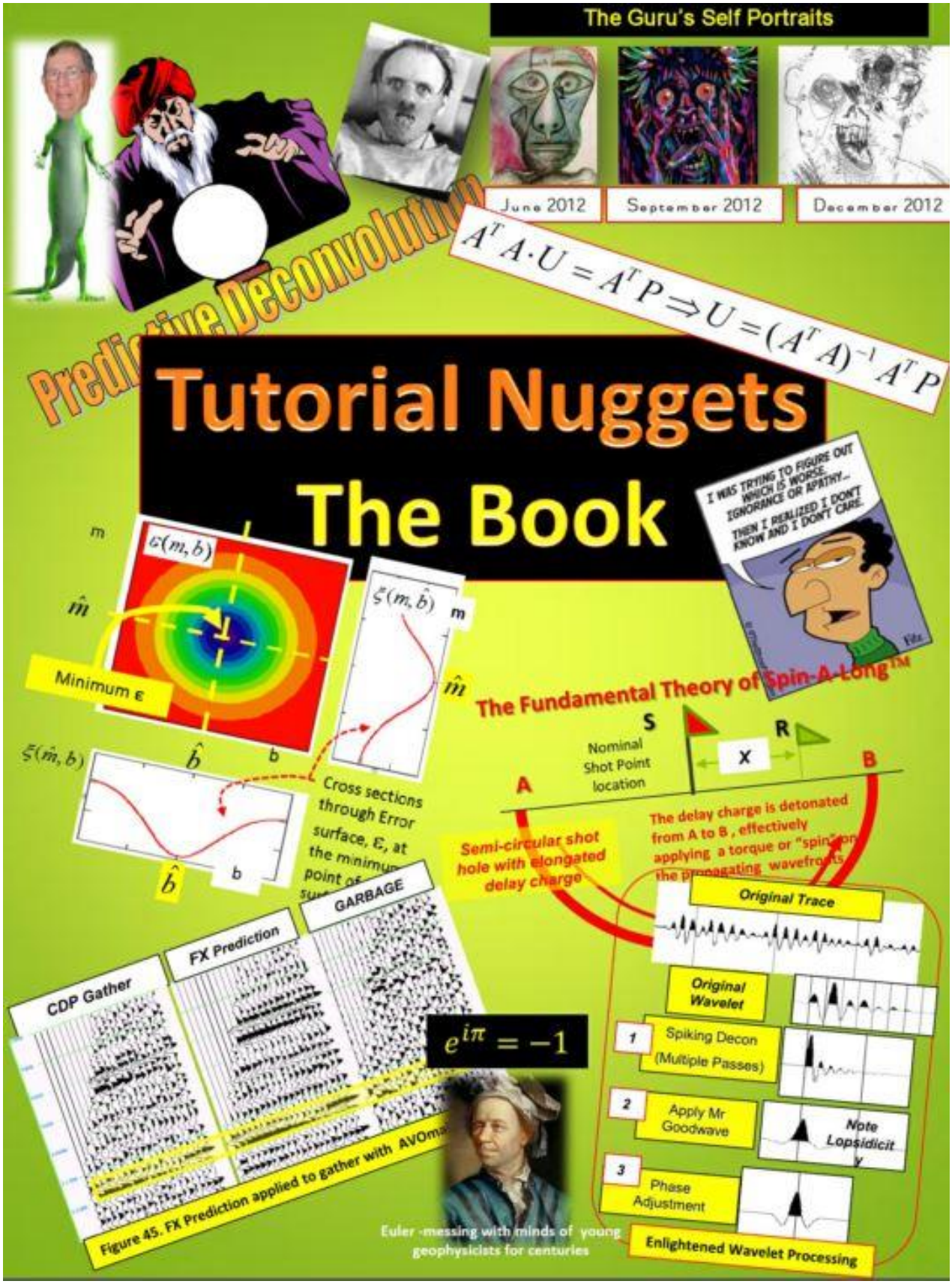
Reid Carter

By Lee Lawyer

Reid Carter left this world a few weeks ago after 97 years of a very interesting life. I knew him well. I can't call this an obituary. I call it a tribute to a real doodlebugger. We were both Chevrons. Our paths crossed frequently. Reid is one of the few survivors of WWII. He is originally from New York City and was the right age to be a target of the local Draft Board. In 1942 he received "salutations from the local draft board, which had some deadly connotation." They gave him thirty days to enlist in and be accepted by any branch of the military or else it was the Infantry. He chose the Navy.

He applied for Navy Aviation Cadet training but was found to be color blind. He continued in Naval Air Corpse but as a radioman/navigator/rear gunner on a Lockheed twin engine Ventura. After a year hunting submarines in the Caribbean and off shore Brazil, his unit was sent to Southeast Asia. He saw almost continuous action in what was called search and destroy missions. He returned to stateside a few months prior to the end of hostilities.

He was interviewed for a job by a well know geophysicist named Miller Quarles, with United Geophysical. Thus, he began a long career in the oil business. He spent a few years in Spain, at the end of which he applied for employment with Chevron Geosciences in Houston. He stayed with Chevron until retirement many years later. He is survived by his wife, Janet and family. I recommend that you check out the interview published in the February, 2013 issue of the GSH Journal. It gives a much better view of Reid's colorful life.



$75 Member Price