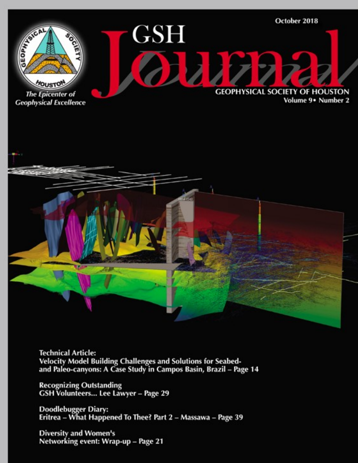
September 2019

GSH Journal

The Epicenter of Geophysical Excellence

GEOPHYSICAL SOCIETY OF HOUSTON
Volume 10 • Number 1





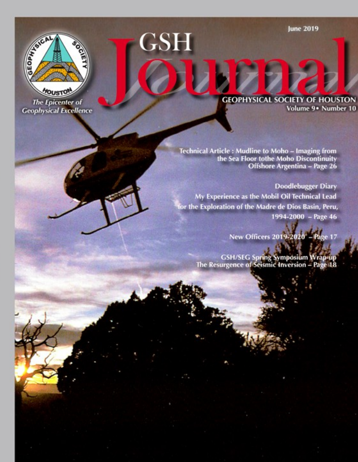



TABLE of CONTENTS

MEETINGS

FEATURES

CHECK THIS OUT

LOOK INSIDE

On The Cover...

Compilation of covers from the previous year.

EDITOR'S NOTE

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

GSH JOURNAL DEADLINES

Oct 2019	Aug 16
Nov 2019	Sept 13
Dec 2019	Oct 11

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

		Phone	Cell	Email
PRESIDENT	Craig Beasley		713-689-6818	cbeasley@slb.com
Sponsorship	J 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	281-531-5347	713-628-3513	llawyer@prodigy.net
Historian	Art Ross	281-360-9331		artross@airmail.net
Office	Frank Dumanoir		713-594-2371	dumanoir@swbell.net
Outreach	Lisa Buckner		713-252-9665	outreach@gshtx.org
Scholarship Liaison	Jim Schuelke	713-296-6801		Jim.schuelke@apachecorp.com
PAST PRESIDENT	Dennis Yanchak	713-296-6109		Dennis.Yanchak@apachecorp.com
PRIOR PAST PRESIDENT	Tommie Rape		713-829-5480	tommiedr@aol.com
MEMBERSHIP				
PRESIDENT ELECT	Peter Duncan	713-395-2408	713-725-4806	pduncan@microseismic.com
GSH Membership	Chris Egger		361-658-5480	christopher.egger@tgs.com
Volunteer Coordinator	Nicola Maitland		281-507-6552	coronster@gmail.com
Diversity & Women's Networking	Nicola Maitland		281-507-6552	coronster@gmail.com
TECHNICAL EVENTS				
FIRST VICE PRESIDENT	Peter Wang	713-393-4013		pwang01@gmail.com
FIRST VICE PRESIDENT ELECT	Matt Blyth	281-285-6987	832-444-4206	mblyth@slb.com
Tech Luncheons	Peter Wang	713-393-4013		pwang01@gmail.com
Tech Breakfasts Northside	Oscar Vasquez		281-290-0492	oscarvasquez@deepimaging.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
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
Spring Symposium	Peter Wang	713-393-4013		pwang01@gmail.com
Fall Forum	Scott Singleton		832-524-8382	Scott.Singleton@comcast.net
Geoscience Day	Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
SEG DISC	Peter Wang	713-393-4013		pwang01@gmail.com
SPECIAL INTEREST GROUPS (SIGS)				
Data Processing and Acquisition	Caroline Wilkinson	713-689-7667	949-887-3394	cwilkinson2@slb.com
Microseismic & Unconventional	Scott Singleton		832-524-8382	Scott.Singleton@comcast.net
Potential Fields	Daniel Minguez	832-854-3249	626-818-2114	xdminguez@gmail.com
Rock Physics	Ellen Mallman		346-252-8462	Ellen.mallman@bp.com
Wavelets (U of H)	Matthew L Storey			matthewlstorey@gmail.com
SOCIAL / FUNDRAISING EVENTS				
SECOND VICE PRESIDENT	Kenneth Mohn	713-485-9696	713-485-9696	kwmohn123@gmail.com
SECOND VICE PRESIDENT ELECT	Phil Schearer	281-921-8047	281-948-9312	phil.schearer@shearwatergeo.com
Warm Up Shoot	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	Nathan Lenz		281-468-5459	nathaniel.lenz@tgs.com
Tennis Tournament	Russell Jones	832-295-8350		rjones@Seitel.com
Sporting Clays	Ryan Marshall	713-917-6772	713-962-9414	ryan.marshall@dawson3d.com
Golf Tournament	Wesley Tyrrell		713.485.9502	wesley.tyrrell@katalystdm.com
Annual Meeting & Awards Banquet	(unassigned)			
SECRETARY	Jennifer Graf		972-795-8888	secretary@gshtx.org
TREASURER	Marie Clavaud	281-509-8450		marie.clavaud@pgs.com
Finance Committee	Gabriela Suarez		832-818-6832	suarezc2001@yahoo.com
COMMUNICATIONS				
EDITOR	Alvaro Chaveste	713-393-4941	832-707-6505	Alvaro.Chaveste@emerson.com
Assistant Editor	Hailey Byers		832-494-7436	Hailey.Byers@Emerson.com
Assistant Editor	Ryan Egger		361-947-8650	Ryan.egger@emerson.com
Assistant Editor	Tom Trowbridge		832-282-5147	Tom.Trowbridge@emerson.com
Assistant Editor	(unassigned)			
Technical Article Coordinator	Scott Singleton		832-524-8382	Scott.Singleton@comcast.net
Publications	J Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
Website	Paul Schatz	713-975-7434	713-829-5254	Paul.Schatz@int.com
Advertising Committee	(unassigned)			
Social Media Coordinator	Liza Yellott	713-881-2894	713-204-0998	lyellott@Seitel.com
SEG SECTION REPRESENTATIVES	Tommie Rape		713-829-5480	tommiedr@aol.com
	Maitri Erwin	713-380-4800	281-785-5814	maitri.erwin@gmail.com
	J Haynie Stringer	281-491-2045	832-606-3993	hayniestringer47@yahoo.com
	Dennis Yanchak	713-296-6109		Dennis.Yanchak@apachecorp.com
	Craig Beasley		713-689-6818	cbeasley@slb.com
	Peter Duncan	713-395-2408	713-725-4806	pduncan@microseismic.com
SEG ALTERNATE REPS	Mihai Popovici	281-945-0000		mihai@z-terra.com
	Mike Graul	713-465-3181	713-248-3562	mgraul@texseis.com
GEOSCIENCE CENTER	Bill Gafford	281-370-3264		geogaf@hal-pc.org
SPG-NA Rep.	(unassigned)			
ECH liaison	Bill Gafford	281-370-3264		geogaf@hal-pc.org
HPAC	(unassigned)			
NeosGeos	(unassigned)			

A Word from the Board

The Value Proposition

By Craig J. Beasley, 2019-2020 GSH President

It is my pleasure to be serving the GSH for the 2019-2020 season, to quote JFK, "not because it is easy, but because it is hard". In some sense, it's easy because we have a great set of individuals on the board this year, as well as the GSH staff, and it's a pleasure to work with them. The GSH is composed of individuals who share a love for and employment in geophysics-related endeavors. Beyond that, as can be expected, our desires for and needs from the GSH can be quite different. Even in the best of times, it can be challenging to satisfy everyone, and we certainly are not experiencing the best of times as our industry is still struggling to come out of a deep downturn. Your board and the GSH are challenged in many ways by these circumstances.

Efforts to deal with the downturn precede my tenure, but I am sure we have all noted cost-cutting efforts to keep the organization fiscally responsible, while at the same time meeting members needs and expectations. Fortunately, the membership have supported GSH by attending key social and technical events even in tough times. However, from my experience in business, you cannot cut your way to success. Thus, we have taken action to increase the value of what it means to be a member of the GSH in hope that people will have the desire to attend events and spread the word about GSH, even in difficult times.

The value proposition is with us in just about every decision we make, even if we are not aware. The board is keenly aware that our members choose which organizations they will continue to be a part of, and we firmly believe that their decisions are made based on membership value. So, how can we add value to the GSH membership? There are several ways. First, we take note of successful events such as the Spring Symposium, and then we reflect on our various other technical and social events to see where we are doing well and where we can improve. We believe people vote with their feet. Second, we listen to our members. People will tell you their opinions, trust me. We value and appreciate that our members take the time to let us know their thoughts and ideas.

For example, maybe you responded to a recent poll concerning the Spring Symposium? Well, with the help of your feedback, I am pleased to announce that we have made some changes that we believe will be valuable to our members. First, we have a new event called the Fall Forum, which will be a one-day event combining technology, business concerns, and growth in our industry. We will be focusing on unconventional resource development, and how the science, business, and the outlook of geophysics plays into it. Watch for the details in the GSH newsletter – it's coming soon, in early November. A second addition is the fall sporting clays "warm-up" event, which stems from the popularity of our sporting clays event. It will be August 24th and is open for registration.

Finally, we want you to know that the search for value for our members isn't a new concept, and also not something we do only when times are tough. There's a long tradition practiced here at the GSH of working to help geophysicists collaborate, communicate, learn, and network with others. Monthly technical events such as breakfast talks and SIG meetings are well attended and are a benefit of membership. Our policy of allowing non-members to attend these free events without charge has been under review, but at this time, has not changed because we see it as an opportunity to bring in prospective members. GSH offers almost of its events free of charge, and most other paid events are offered at nearly break-even prices,

Word From the Board continued on page 5.

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,

Alvaro Chaveste, editor, at Alvaro.Chaveste@emerson.com

Word From the Board continued from page 4.

which we believe contributes value. Even our events that only generate little profit are a bargain in comparison with industry standards. For example, our premier event, the Spring Symposium has a registration fee that's around half of what one could expect to pay with a larger, non-local society. We are not a for-profit organization, but the revenue we do generate is used to provide our standard services while attempting to add as much additional value to the membership as possible.

All of this doesn't matter if you, the GSH members, are not being served. So please get involved, attend events, and let us know what works and what doesn't. Make sure to volunteer and consider running for the board. The GSH Icebreaker is just around the corner, which would be a great place to start the year. I hope to see you there on September 5th. □

Dear Editor,

The GSH was well-represented at the recently completed 2019 URTeC Conference (July 22-24). Our booth was in an excellent location (second booth off of the main isle), giving us plenty of foot-traffic. The booth was ably staffed by none other than Bobby Perez (left in the picture), long-time chair of the popular GSH Fishing Tournament.

Scott Singleton (right) was the SEG Technical Program Co-Chair. The conference itself was hugely successful. Attendance was 5200, just shy of the 2014 conference which was the last time it was held in Denver.

Feedback has been extremely positive, both for foot traffic on the exhibition floor but also in the technical program. The conference will make its return to Austin next year followed by Houston in 2021 and Denver in 2022 and 2023.

Thanks,

Scott Singleton

From the Other Side

By Lee Lawyer

Back in the June FTOS, I recommended that the SEG and the AAPG merge into one great Earth Science Professional organization. I sent a copy of the column to the three Presidents of the SEG: Past, Present, and Elect. Rob Stewart was the Present at that time. He wrote an excellent response, which appeared in the same issue of the June GSHJ. He is correct in saying that the SEG doesn't need to merge with the AAPG. The SEG is doing fine. No complaints from me. Remember I have been Chair of the San Francisco Convention, 2nd VP, President-elect, President, Chair of the Council for three years, and author of FTOS in TLE for 25 years. Let no one suggest that I am anti-SEG (or AAPG). I have heard from several SEG members on this subject. Although opinions vary, so far, they are favorable. However, this is an extremely small sample.

We need to think about professions a little. Can we merge Petroleum Geology and Geophysics? I read an interesting column in the April Explorer (Yes, I am also a member of the AAPG). In her President's Column, Denise Cox said her theme was, *"…to define the role of petroleum geoscience in energy transition."* I liked her phraseology; particularly the word "geoscience". To me, petroleum geologists and geophysicists *are* geoscientists. She also said, *"Sustainable development would become an important topic for the petroleum industry in 2019." Amen…*

I joined Chevron in 1954. Newly-hired geologists and geophysicists were required to spend time on seismic crews. I spent three years. Many of the geologists spent only one year. Both interpreted the data in the field, made maps that were used to acquire leases and drill wildcats. BUT the geophysicist and geologists were in separate organizations. It was not until the eighties that the two groups were structurally "merged". Strange, what? I believe that a geologist who has a practical understanding of geophysics is far more valuable than one that doesn't. It follows that a geophysicist with a practical understanding of geology (sedimentary/structural) is more valuable than one who doesn't. I guess my viewpoint is bolstered (biased) by my long tour with Chevron.

I don't like to think that geophysics is just a tool geologists use to determine the character of the sedimentary section. It seems to be going that way. Bah! Does the SEG have geophysicists who do geological interpretations of geophysical data? Of course, they do. And vice versa. I don't want to patronize anyone, but sedimentary geology has many specialties. The same is true for geophysics. In a merged organization, highly specialized geologists and geophysicists will not lose out. Life will go on for each profession. I am confident we can better meet the worldwide objective of sustainable energy with a combined professional society.

The SEG is a *"member driven Society"* as is the AAPG. Generally speaking, the SEG/AAPG staff is administrative. There would be minimal change at the membership level. But a big change at the administrative level. I haven't poled the AAPG/SEG management, but they would probably be against a merger for obvious reasons. That is why I titled the merger a "Financial/Administrative" merger. Linking two professions that have a huge overlap in technology and objectives seems obvious. As stated in the June issue of GSHJ, I like the idea of a combined SEG/AAPG. I like the idea of one geoscience society that would become more active and larger than two separate societies.

Okay, okay, already. I have used up two columns with the 'merge' stuff. I grow weary with trying to convince the seemingly inconvincible. This column is in the GSH Journal (surprise, surprise). I know I am preaching to many SEG members, and I invite you to comment. "To be or not to be, that is the question". □

Technical Luncheons

Register for Tech Lunch Westside

Register for Tech Lunch Downtown

Register for Tech Lunch North

Integrated Geophysical Imaging Using Seismic and Gravity Data to Unravel the Structural Complexities of the Campeche Basin Offshore Mexico

Wilson Ibañez

Speaker: Wilson Ibañez, Schlumberger

Westside

Tuesday, Sept. 24, 2019
11:00 a.m. – 1:00 p.m.

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

Downtown

Wednesday, Sept. 25, 2019
11:00 a.m. – 1:00 p.m.

NEW LOCATION this Month

Location: Hilcorp
1111 Travis St.,
RM 9.327 - Old Ocean
Houston, TX 77002

Northside

Thursday, Sept. 26, 2019
11:00 a.m. – 1:00 p.m.

NEW LOCATION

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

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

Abstract:

In the recently opened exploration frontier area of the deep-water Salina Del Istmo Basin, Southern Gulf of Mexico, we successfully applied a multi-physics workflow to integrate wide-azimuth seismic and potential field data.

In areas of poor signal-to-noise ratio subtle variations in structural style due to salt kinematics and deep-seated thrusting impose challenges for seismic imaging. High-velocity (impedance) contrasts at the interfaces between salt and carbonate rafts within the background sediments result in strong reflection, refraction at small angles of incidence, diffractions with complex wave patterns, and lack of illumination near and below these features. This creates high noise levels in the seismic image, resulting in high uncertainty in the salt interpretation. To reduce the uncertainties in salt interpretation, a multi- physics workflow is devised to integrate gravity data with the seismic measurements.

The multi-physics workflow employs a jointly collected suite of wide-azimuth, long-offset, broadband seismic data and potential field data. The process consists of conventional processing steps to enhance the salt related signal and full 3D seismogravity modeling. Velocity model building, petrophysical link estimation for domain conversion and gravity forward modeling are then used to interactively asses scenarios.

Integrated geophysical imaging allows the creation of earth models with better constrained velocity and density distributions, improved geometries and reduced uncertainties.

Technical Lunch continued on page 9.

Technical Lunch continued from page 8.

Biography:

Wilson Ibañez started his career in the oil & gas industry in 2008. He initially joined Ecopetrol for three years where his primary research interest was seismic anisotropy and velocity model building. He then moved to Saudi Arabia where he joined the Seismic Wave Analysis Research Group at King Abdullah University of Science and Technology (KAUST). Wilson earned his master's degree in Earth Science at KAUST in 2013 where, in collaboration with Professor Tariq Alkhalifah, completed his research on effective orthorhombic anisotropic models for wavefield extrapolation.

After completing his master's degree, Wilson joined the Earth Modeling Geoscientist's group at Schlumberger in 2013. Since then he has focused his attention on testing and applying state of the art earth model building workflows, including but not limited to advanced full waveform inversion techniques and seismic tomography integrated with geology, borehole data, rock physics, and potential fields.

His recent work has been focused on applying and integrating non-seismic methods to depth imaging workflows, allowing him to build a cycle of iterative model building updates that lead to better seismic imaging and more reliable prospect evaluations. □

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

Contact Lisa Buckner at: outreach@gshtx.org

To support OUTREACH:
https://my.reason2race.com/cause/gsh

Technical Breakfasts

Full-waveform Inversion for Salt: A Coming of Age

Register for Tech Breakfast North

Register for Tech Breakfast West

Speaker: Zhigang Zhang,
Senior Lead Researcher,
CGG

Zhigang Zhang

North

Tuesday, Sept. 3, 2019
7:00 – 8:30 a.m.

Sponsored by Anadarko Petroleum and Quantico Energy Solutions

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

West

Wednesday, Sept. 4, 2019
7:00 – 8:30 a.m.

Sponsored by Schlumberger and WesternGeco

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

Abstract:

Updating a velocity model with salt using full-waveform inversion (FWI) has been a very challenging task.

We proposed a time-lag cost function to minimize the amplitude discrepancies between real and synthetic data, and to make good use of low frequency signal to mitigate cycle-skipping. This addressed two key issues in the application of FWI for salt model updates.

We applied this algorithm to different data sets, including wide-azimuth (WAZ) and full-azimuth (FAZ) streamer data, as well as OBN data in areas with different salt complexities. In all cases, salt velocity models from FWI led to significantly improved subsalt images. We also demonstrated, with one FAZ streamer data example in Keathley Canyon, that we probably do not need to use very high frequency FWI for the purpose of subsalt imaging; or at least not before we can resolve the discrepancies that exist between real and synthetic data (random and coherent noise and the effect of the elastic earth, for example).

With all the examples seen so far, we believe that the combination of advanced FWI algorithms and appropriate data will bring a step-change to salt model building workflows and subsalt imaging.

Biography:

Zhigang Zhang received B.S. (2002) and M.S. (2005) degrees in Geophysics from Peking University, China, and a Ph.D. degree in Oceanography from the University of Rhode Island in 2010. He worked as a Post-Doctorate Fellow at Los Alamos National Laboratory, Earth and Environmental Sciences Division from 2010, and then joined CGG in 2013.

He currently serves as a Senior Lead Researcher in CGG's Houston office and works on a variety of topics, including signal processing and full-waveform inversion. □

Microseismic SIG

Microseismicity in Texas, Part 1:
Lessons Learned From More Than Two Years of Seismicity Reported Through TexNet for the State of Texas

Register for Microseismic

Dr Alexandros Savvaidis

Speaker: Dr Alexandros Savvaidis
Manager of the Texas Seismological Network (TexNet) and Seismology Research Team Lead,
Center for Integrated Seismicity Research (CISR) at the Bureau of Economic Geology (BEG), UT Austin

Thursday, Sept. 5, 2019
11:30 a.m. - 1:00 p.m.

Sponsored by MicroSeismic, Inc.

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

Abstract:

An increase in induced seismicity in the central U.S. since 2009 led to establishment of TexNet seismic-monitoring in Texas. Accurate, absolute seismic-event location is critical to TexNet, allowing association of seismicity with human activity. To achieve this, different velocity models and methods have been used to identify absolute locations. Following that, a probabilistic association has been established between seismicity and oil and gas operations in part of West Texas. This study indicates that most of the earthquake activity is likely caused by hydraulic stimulation rather than salt water disposal.

Biography:

Dr Alexandros Savvaidis is the Manager of the Texas Seismological Network (TexNet) and Seismology Research Team Lead at the Center for Integrated Seismicity Research (CISR) at the Bureau of Economic Geology (BEG) at UT Austin. Dr Savvaidis has more than 20 years' experience in Applied Geophysics and Seismology.

Prior to joining the BEG, he held the position of Senior Researcher at the Institute of Seismology and Earthquake Engineering at Thessaloniki, Greece. From 2008 until 2015 he was managing the largest Seismographic Network in Greece, numbering 100 real time accelerometers and 150 offline installations.

During his extensive career he has coordinated several collaborations with academic and industrial partners in multidisciplinary European funded projects. In 2008 and 2012 he was visiting researcher at the University Joseph Fourier in Grenoble, France and at the University of Potsdam in New York, USA respectively.

(Note: Part 2 of this series will be presented at the Unconventional SIG meeting on Oct 3 at TGS) □

Rock Physics SIG

Automated Facies Classification for Seismic Inversion

Register for Rock Physics

Dr. James Gunning

Speaker(s): Dr. James Gunning
Research Scientist, CSIRO,

Wednesday, Sept. 11, 2019
5:15 p.m. Refreshments
5:30 p.m. Presentation Begins
6:30 p.m. Adjourn

Sponsored by NER, CGG and Ikon Science

Location: CGG
10300 Town Park Dr.
Houston, TX 77072

Abstract:

We introduce an algorithm for simultaneous facies classification and the fitting of rock physics models from multivariate well log data. Special features of the methodology are designed to render it resilient to data outliers.

The algorithm is a robust and globalized variety of the expectation-maximization algorithm. Facies classifications are natural byproducts of the expectation step, and optimized rock physics models are produced by the maximization step. The practical advantages of the approach are illustrated using data from the Satyr-5 well, located in the Northern Carnarvon Basin, North West Shelf of Australia.

Outputs of the algorithm include facies labels and free parameters in the corresponding rock-physics models, which can be easily interpreted and directly used in downstream workflows such as facies-based seismic inversion.

Biography:

Twenty-two years' experience in the oil business involving reservoir characterization, spatial statistics, and the use of remote-sensed data. His professional accomplishments include (i) authoring the CSIRO 'Delivery' suite of open-source tools for Bayesian stochastic inversion, well-tie and wavelet extraction, and CSEM inversion, and (ii) a facies-elastic inversion code (Ji-Fi) for which Ikon Geosciences received the 2019 Queen's Award for Innovation.

Broader research interests are in spatial statistics, Bayesian methodologies, uncertainty quantification, data integration, discrete and continuous optimization, and inverse problems from seismic and other remote sensed data. □

Potential Fields SIG

How Magnetism Shaped Our View of Tamu Massif, the 'World's Largest Volcano'

Register for Potential Fields

William Sager

Speaker: William W. Sager
Professor, Department of Earth and Atmospheric Sciences
University of Houston

Thursday, Sept. 26, 2019
5:30 p.m. - 8:00 p.m.

Sponsored by CGG

NEW LOCATION:

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

Abstract:

Tamu Massif is a submarine volcanic mountain with an area nearly that of New Mexico. Of that, there is no doubt. It is the largest edifice in the Shatsky Rise oceanic plateau, located about 1000 miles east of Japan.

A quarter century ago, an interesting hypothesis was published, stating that oceanic plateaus formed from the voluminous, bulbous head of a starting mantle plume, which caused massive eruptions when the head rose to near the surface. A corollary was that oceanic plateaus are equivalent to continental flood basalts and that these eruptions built enormous volcanic piles. About the same time, I noted that the magnetic anomaly over Tamu Massif looks like a classic equatorial dipole, modeling the mountain as a reversely-polarized homogeneous body and concluding that it formed rapidly during a single polarity period. This result seemed to fit the plume head hypothesis. More than a decade later, ocean drilling cores and seismic reflection profiles were interpreted to show that Tamu Massif is a single, central volcano, formed from massive lava flows, further supporting the plume head idea. The idea of a single volcano, the size of New Mexico, spawned the "world's largest volcano" moniker and, with click-bait journalism, the finding went viral. Among nagging doubts brushed aside, magnetic anomalies told a contradictory tale. Linear magnetic anomalies have been traced through much of Shatsky Rise and surround Tamu Massif. The indication is that the volcano formed near a spreading ridge triple junction during the Late Cretaceous. Spreading ridges are huge linear volcanoes, so how did an enormous single volcano form nearby? I went back in 2015 to collect new magnetic data over Tamu Massif. The resulting magnetic anomaly map shows that Tamu Massif and nearby Ori Massif (also a large volcanic mountain) are characterized by linear magnetic anomalies, similar to those formed at mid-ocean ridges. Only seafloor spreading creates such anomalies, so the implication is that Tamu Massif, and indeed all of the Shatsky Rise plateau, formed by this process. Tamu Massif is not an enormous single volcano, but instead a swollen segment of the past mid-ocean ridge system.

Biography:

William Sager is a professor in the Department of Earth and Atmospheric Sciences at University of Houston. After graduating from Duke University with a BS in physics, he obtained his MS and PhD degrees in geology and geophysics from University of Hawaii in 1979 and 1983, respectively. For 29 years, he worked at Texas A&M University before moving to University of Houston in 2013. His research focuses on marine geology and geophysics, especially with regard to plate tectonics. Dr. Sager has published 135 journal articles, sailed on 44 research cruises, and mentored over 100 graduate students. □

SAINT ARNOLD

PATRON SAINT OF BREWERS

+

GEOPHYSICAL SOCIETY HOUSTON

= 2019-2020 GSH ICEBREAKER

6-8pm Thursday, 5 September 2019

St Arnold Brewery
2000 Lyons Ave
Houston, 77020

Register at www.gshtx.org

Mingle with industry colleagues and meet the GSH board while enjoying the finest local craft beers at this award-winning brewery. Tickets are available through the GSH website events tab. For more information or sponsorship opportunities, please contact the GSH office at 281.741.1624, Tony LaPierre at tony.lapierre@rpsgroup.com or 281-733-5281 Members $20 and Non-Members $40.

SHEARWATER ACTeQ rps

Predicted and Observed Shear on Pre-existing Faults During Hydraulic Fracture Stimulation

Mark D. Zoback and Jens-Erik Lund Snee, Stanford University Department of Geophysics

Summary

Multi-stage hydraulic fracturing increases production from extremely low-permeability unconventional reservoirs by simultaneously inducing slip on pre-existing fracture planes. Here we illustrate how the high pore pressure generated during hydraulic fracturing operations induces slip on pre-existing fractures and faults with a wide range of orientations, thus creating an interconnected permeable fracture network. We demonstrate the basic principles of stimulating slip on poorly oriented faults using the stress state for a horizontal well in the Barnett Shale where fracture orientation data are also available from an image log. We compare this analysis with independent fracture orientation data obtained from earthquake focal plane mechanisms. Using the stress data, we are able to determine which nodal plane slipped in each microseismic event. As the two analyses yield essentially identical results, they show the basic processes by which slip on planes of varied orientations occurs during hydraulic stimulation. We extend this analysis to address some misconceptions about the likelihood of slip on horizontal bedding planes and planes parallel and perpendicular to horizontal principal stress directions. Notably, we show that inducing slip on horizontal or sub-horizontal bedding planes is nearly impossible except in compressive (reverse to strike-slip/reverse) stress states ($S_{Hmax} \geq S_{hmin} \approx S_V$) or when ambient pore pressure is extremely high. The latter case results in very small differences in the magnitudes of the three principal stresses, regardless of the regional stress state.

Introduction

While it is generally accepted that the microseismic events that accompany multi-stage hydraulic fracturing in horizontal wells principally result from shear slip on pre-existing fractures and faults, the relationships among fracture orientation, the state of stress, and the pore pressure perturbation caused by hydraulic fracturing is often poorly understood. For example, questions are sometimes hotly debated regarding how slip occurs on planes with highly varied orientations, whether some microseismic events are associated with bedding

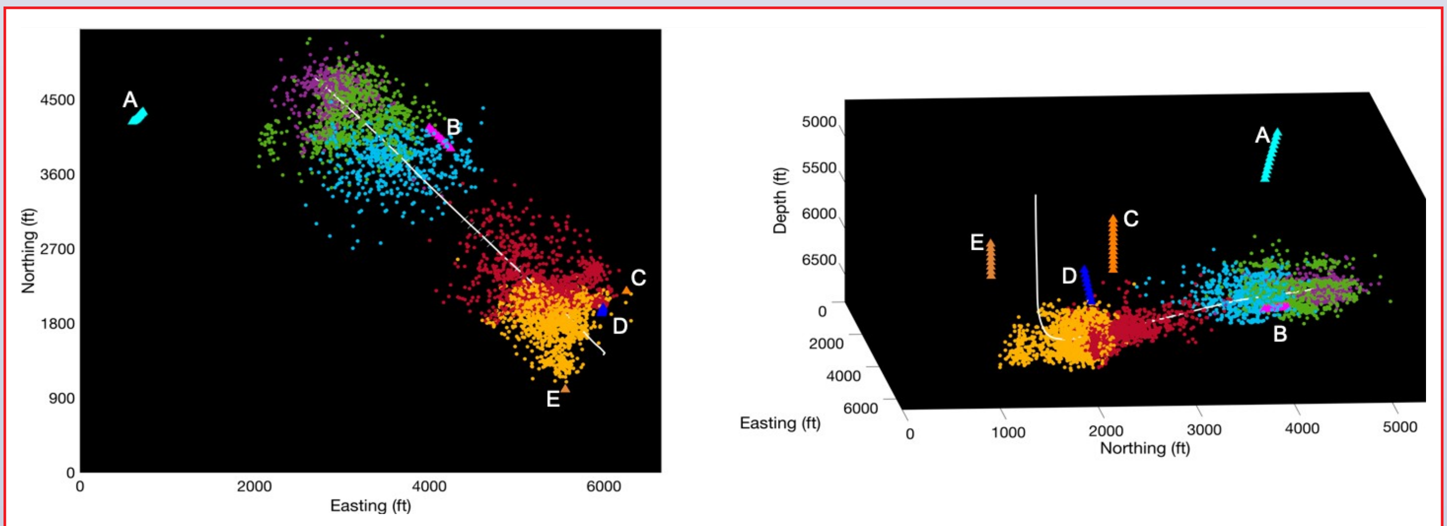


Figure 1: Perspective view of microseismic events generated during multistage hydraulic fracturing in the Barnett Shale. Dots are colored by stage number. Triangles labeled A–E represent the locations of seismometers in multiple down-hole monitoring arrays. Two arrays were active at a time during fracturing operations.

Technical Article continued on page 16.

Technical Article continued from page 15.

plane slip and/or opening mode deformation, and whether the subsurface fracture distributions can be characterized by orthogonal fracture sets aligned with current stress directions. In this paper, we investigate the relationships between the state of stress, slip on pre-existing fractures, and pore pressure using a unique dataset from the Barnett Shale that is illustrated in *Figure 1*. We then generalize this discussion to other stress states.

Summary of dataset

The microseismic dataset was acquired in a fairly routine manner. Twenty-level, 3-component seismometer arrays were sequentially deployed in 4 near-vertical wells and one horizontal well (labeled A–E in *Figure 1*), when 5 hydraulic fracturing stages were stimulated in the horizontal well shown. The microseismic events associated with each stage were recorded by at least two arrays. Although the relative locations of these events were poorly constrained (see Hakso and Zoback, 2017), Kuang et al. (2017) carried out a detailed analysis of the seismic waveforms to obtain focal plane mechanisms associated with each stage. Inversion of the focal plane mechanisms associated with each stage yielded very similar strike-slip/normal faulting stress states, with the maximum horizontal stress (S_{Hmax}) trending NE–SW. This stress state is essentially identical to that determined from hydraulic fracturing and other information (Hakso, 2017).

This dataset also includes orientations of pre-existing fractures measured with a Formation Microimager (FMI) image log run prior to stimulation. The orientations of pre-existing fractures are shown in the stereonets of *Figure 2*. Only one of the two nodal planes associated with each focal plane mechanism represents the orientation of the fault that actually slipped. The other nodal plane, the auxiliary plane, has no physical significance. Kuang et al. (2017) identified the active fault from the microseismic focal mechanisms by selecting the nodal plane with the higher Coulomb failure function *(CFF)*, representing the plane that would be most likely to slip in the ambient stress field, defined as:

$$CFF = \tau - \mu\sigma_n,$$

where τ and σ_n are the shear and effective normal stresses resolved on the fault, respectively, and μ is the fault's coefficient of friction. Having both the information about pre-existing faults from the image log as well as the planes that actually slipped, we can compare predictions of plane orientations that *should* slip with those that *actually* slipped as microseismic events.

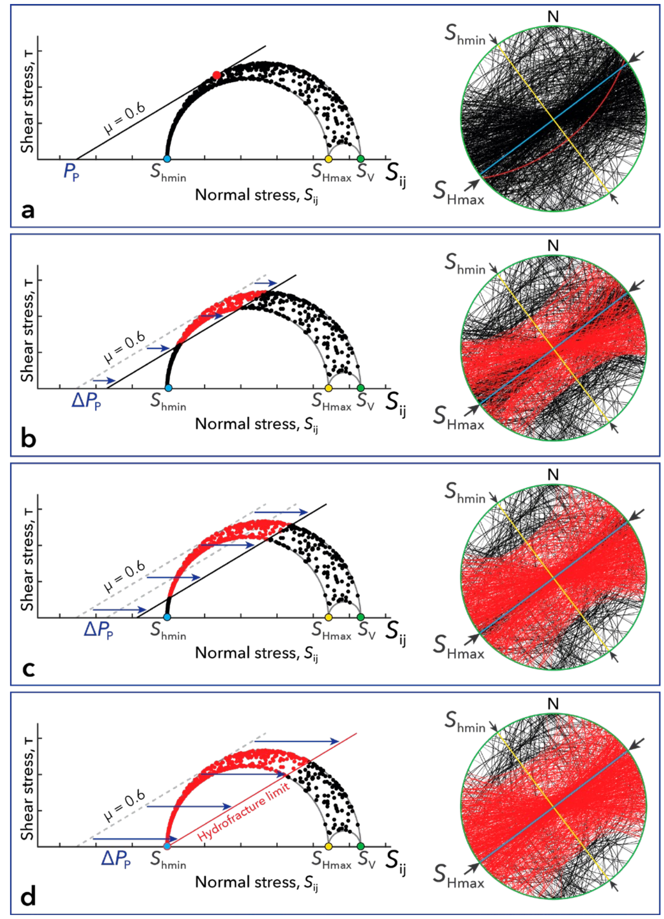


Figure 2: Mohr circles and stereonet plots illustrating the natural fractures measured in the FMI log that would be active at progressively increasing pore pressures during stimulation. a.–c. The number of fractures that will potentially fail in shear (red planes) increases as the pore pressure perturbation (ΔP_P) increases. d. The fractures that are expected to slip once P_P reaches the frac gradient ("Hydrofrac limit").

Kuang et al. (2017) report an S_{Hmax} orientation of N053°E based on an *in situ* measurement made in a nearby wellbore. This is consistent with several S_{Hmax} orientations measured *in situ* by Lund Snee and Zoback (2016) that range between N020°E–N055°E from within 30 km of the present study. Lund Snee and Zoback (2016) also mapped a normal/strike-slip faulting regime in this area, with

Technical Article continued on page 17.

Technical Article continued from page 16.

$S_V \geq S_{Hmax} > S_{hmin}$, where S_V is the vertical principal stress and S_{hmin} is the minimum horizontal principal stress. These *a priori* constraints are consistent with the results of stress inversions conducted by Kuang et al. (2017). Using their microseismic focal mechanisms, they found a normal/strike-slip faulting regime and an S_{Hmax} orientation of N060°E.

Predicted orientations of fractures that experienced shear failure

Figure 2 shows the orientations of fractures measured in the FMI log for the entire logged portion of the well in two ways. The plots on the left are Mohr diagrams normalized by the vertical stress, which illustrate the shear and normal stresses resolved on each plane in the measured stress state. The plots on the right are stereonets, which provide a geometrical view of the plane orientations in space. Hypothetical planes perpendicular to S_V, S_{Hmax}, and S_{hmin} are shown in green, yellow, and blue, respectively, for visualization purposes. Planes colored red represent fractures that are critically stressed (*CFF*≥0) under the pore pressure (P_P) and stress conditions shown in each plot.

Note that the Mohr diagrams shown here are presented in terms of total stress, rather than effective stress. Presentation in this way makes the intercept of the Coulomb frictional failure line with the abscissa equal to the ambient pore pressure. Ignoring poroelastic stress changes, which are likely to be quite small in relatively impermeable formations pressurized for short periods of time, we can thus evaluate the tendency for slip by simply displacing the friction line to the right to represent ever-increasing pore pressure. In general, the physical limit to the amount that pore pressure can be raised is the least principal stress.

Brittle rocks in the Earth's crust are critically stressed, meaning that the faults best oriented for slip within the ambient stress field are in a state of frictional equilibrium. Other ways of saying this are that the frictional strength of well-oriented faults limits stress magnitudes and/or that the shear stress on well-oriented faults are within one earthquake stress drop of frictional failure (Zoback et al., 2002). This condition is represented by the red plane shown in *Figure 2a*, which is the fracture measured in the image log that is best oriented for slip under the stress field constraints that we describe above. *Figure 2a* represents the stress and pore pressure conditions that exist prior to stimulation, assuming for visualization purposes (but not by necessity) that pore pressure is approximately hydrostatic and that the fracture best oriented for slip was exactly critically stressed (*CFF*=0) at the start of stimulation. *Figures 2b, 2c, and 2d* show cases during stimulation in which the fluid injection progressively increases until it reaches the frac gradient ($P_P \approx S_{hmin}$) in *Figure 2d* ("hydrofracture limit"). For illustration, we neglect "net pressure," the amount that the pressure exceeds the least principal stress during high-rate pumping of a viscous fluid. This is typically on the order of a few MPa (a few hundred psi).

As pressure increases, more and more poorly oriented planes begin to slip (the dots in the Mohr diagrams and planes in the stereonets change from black to red). This illustrates the critical importance of the process of shear stimulation during slickwater hydraulic fracturing. Many "old, dead" fractures and faults are stimulated in shear, become permeable, and their highly variable orientations result in an interconnected fracture network. Note that once the frac gradient is reached, the majority

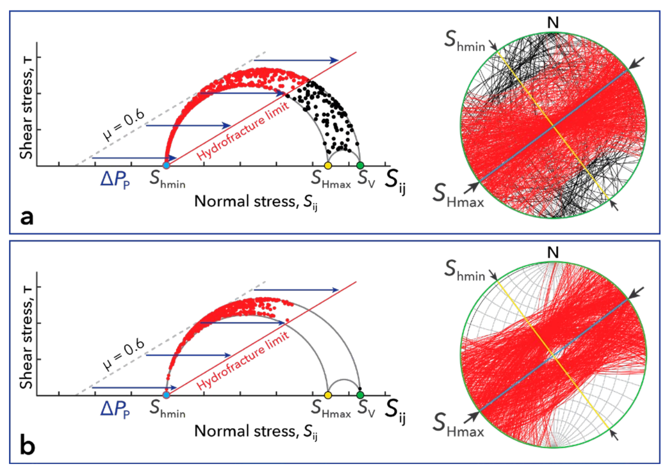


Figure 3: a. Plots showing the fractures identified in the FMI log. Planes colored red would be expected to slip during stimulation at pore pressures sufficient to propagate a hydraulic fracture. b. Plots of the orientations of planes that actually slipped during stimulation. These orientations were generated by sampling from a distribution of active faults from microseismic focal mechanisms with noise applied to represent orientation uncertainties.

Technical Article continued on page 18.

Technical Article continued from page 17.

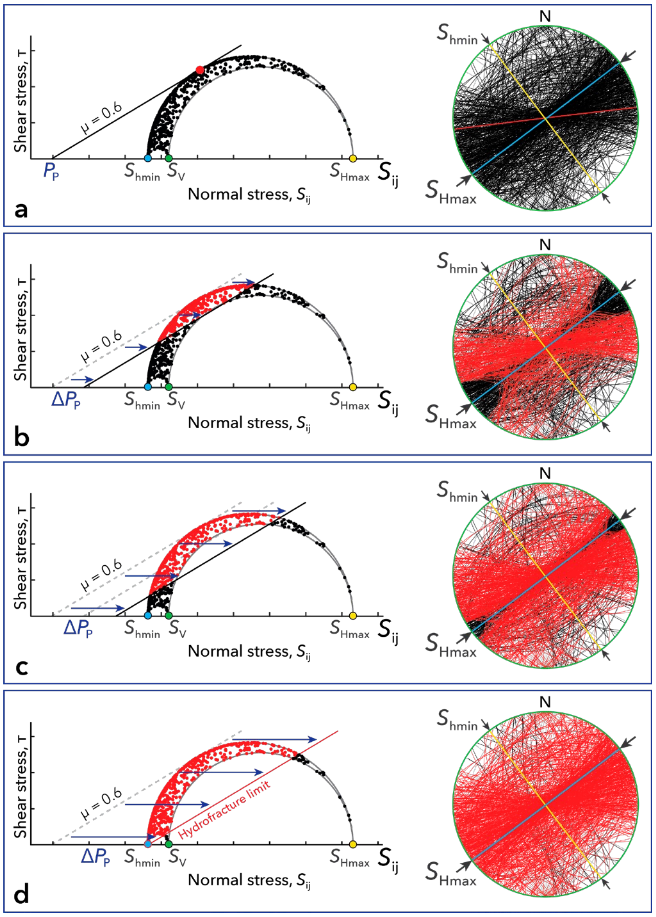


Figure 4: Mohr diagrams and stereonets showing which planes would be expected to slip if stimulation had instead occurred in a strike-slip/reverse faulting stress state.

of planes are expected to slip, but many will not; as explained below, these are the planes that are roughly perpendicular to the vertical stress (planes with low dip) or S_{Hmax} (planes with steep dip that strike NW–SE).

Comparison with orientations of fractures that slipped during stimulation

The discussion above is presented in the context of the actual stress state for the Barnett well, as well as fractures observed with an image log in the well. This said, it is only a heuristic discussion in that we offered no proof that those planes actually slipped. However, because we know the focal plane mechanisms of these events and the planes that slipped in the microearthquake sequence, we compare in *Figure 3* the planes we presumed to slip in *Figure 2d* with those that actually slipped. Note the overall consistency of *Figures 3a and 3b*. The planes shown in *Figure 3b* *did* slip and are quite similar to the planes *expected* to slip based on the available fault population seen in the image log.

Importance of the stress state

It is obvious that the nature of shear stimulation illustrated in the figures above is dependent on the orientations of the fractures and faults that are present, the stress state, and the fluid pressure perturbation. To illustrate the importance of the stress state, in *Figure 4* we revisit the case considered in *Figure 2*, keeping the everything the same except the stress state. Instead of a normal/strike-slip faulting stress state ($S_{hmin} \ll S_{Hmax} \approx S_V$) typical of the Fort Worth Basin, we consider a strike-slip/reverse faulting stress state representative of parts of the Appalachian and Alberta basins ($S_{hmin} \approx S_V \ll S_{Hmax}$). Coincidentally, the S_{Hmax} orientation in all three areas is approximately NE–SW. While there are many similarities between *Figures 2 and 4*, with moderate increases in pore pressure in *Figure 4b* only strike-slip faults (very steeply dipping faults striking ±30° from the S_{Hmax} direction) are made to slip. At higher pressures *(Figures 4c and 4d)*, slip is expected on many planes, some at very high angles to S_{Hmax} and some sub-horizontal.

Slip and opening on sub-horizontal bedding planes and near-vertical fractures striking sub-parallel to S_{Hmax}?

A number of publications hypothesize that slip and/or opening occur on sub-horizontal bedding planes and/or near-vertical fractures striking sub-parallel to the direction of S_{Hmax}. This is illustrated in *Figure 5*. At the left, a hypothetical focal plane mechanism is shown that implies either that dip slip (west side up) occurred on a near-vertical plane striking approximately N–S, or that slip occurred on an orthogonal horizontal (presumably bedding) plane (rock above the bedding plane moving to the east). This is illustrated in the cross-section in the center. The possibility of opening-mode deformation is shown schematically on the right. Of course, it is theoretically possible for both slip and opening to occur on the same plane.

Technical Article continued on page 19.

Technical Article continued from page 18.

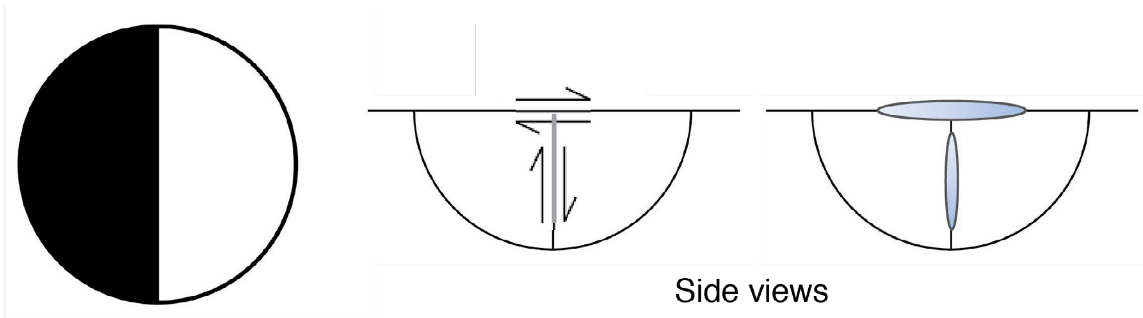


Figure 5: Illustration of the focal plane mechanism that would be produced by slip on a horizontal or vertical plane.

Despite the heated discussions surrounding this topic, one can extend the analysis illustrated in *Figures 2–4* to address this. Recall that in terms of the Coulomb criterion, for slip to occur on a plane the *CFF* must increase to zero. Another way of saying this in terms of the Mohr diagrams shown above is that the point representing a potential slip plane must touch the frictional failure line. Similarly, for opening-mode deformation to occur, the effective normal stress on the fault must be less than zero. Another way of saying this is that a point representing a potential opening plane must be to the left of the intersection of the frictional failure line with the abscissa. *Figure 6* shows how these conditions might be met in the two stress states considered above in *Figures 2d and 4d*. For a normal/strike-slip faulting stress state, *Figure 6a* demonstrates that it is essentially impossible to cause either planes sub-parallel to gently-dipping bedding or normal to S_{Hmax} (the green and yellow circles, respectively) to slip (or open), even when pore pressure reaches the magnitude of the least principal stress. In a strict sense, this also true for planes sub-parallel to S_{hmin} (blue circle), recognizing that during hydraulic stimulation, the net pressure can be a few MPa (a few hundred psi) above the least principal stress. In terms of *Figure 6a*, the frictional failure line would shift slightly to the right, making it possible for both the slip criterion and opening mode criterion to be satisfied. Hence, in a normal/strike-slip stress environment, it is possible for both shear and opening of fractures and faults sub-parallel to hydraulic fractures when the pumping pressure slightly exceeds S_{hmin}. The situation is completely different in the strike-slip/reverse faulting stress state shown in *Figure 6b*. When net pressure results in pressures reaching values slightly in excess of S_{hmin}, it would be possible for opening and shear to occur on planes sub-parallel to hydraulic fractures, but slip might also occur on sub-horizontal planes, depending on the difference in the magnitude of S_{hmin} and S_v, and the magnitude of the net pressure. However, just like the normal/strike-slip stress state, it is essentially impossible for slip (or opening) to occur on planes approximately normal to S_{Hmax}.

Summary

The simple analyses presented here demonstrate the importance of prior constraints on the stress field and the orientation of pre-existing fractures and faults to estimate which planes can be made to slip during stimulation. Reliable predictions of the active fractures enable one to construct realistic discrete fracture network models and estimate the total stimulated rock value that might be accessed during hydraulic fracturing according to specified stimulation strategies. Such predictions can be fed into testable models and improved iteratively as additional data become available during continued operations to optimize the success of stimulation.

Technical Article continued on page 20.

Technical Article continued from page 19.

Acknowledgements

We thank Total for providing the data used in this analysis. This research was supported by the Stanford Natural Gas Initiative (NGI). □

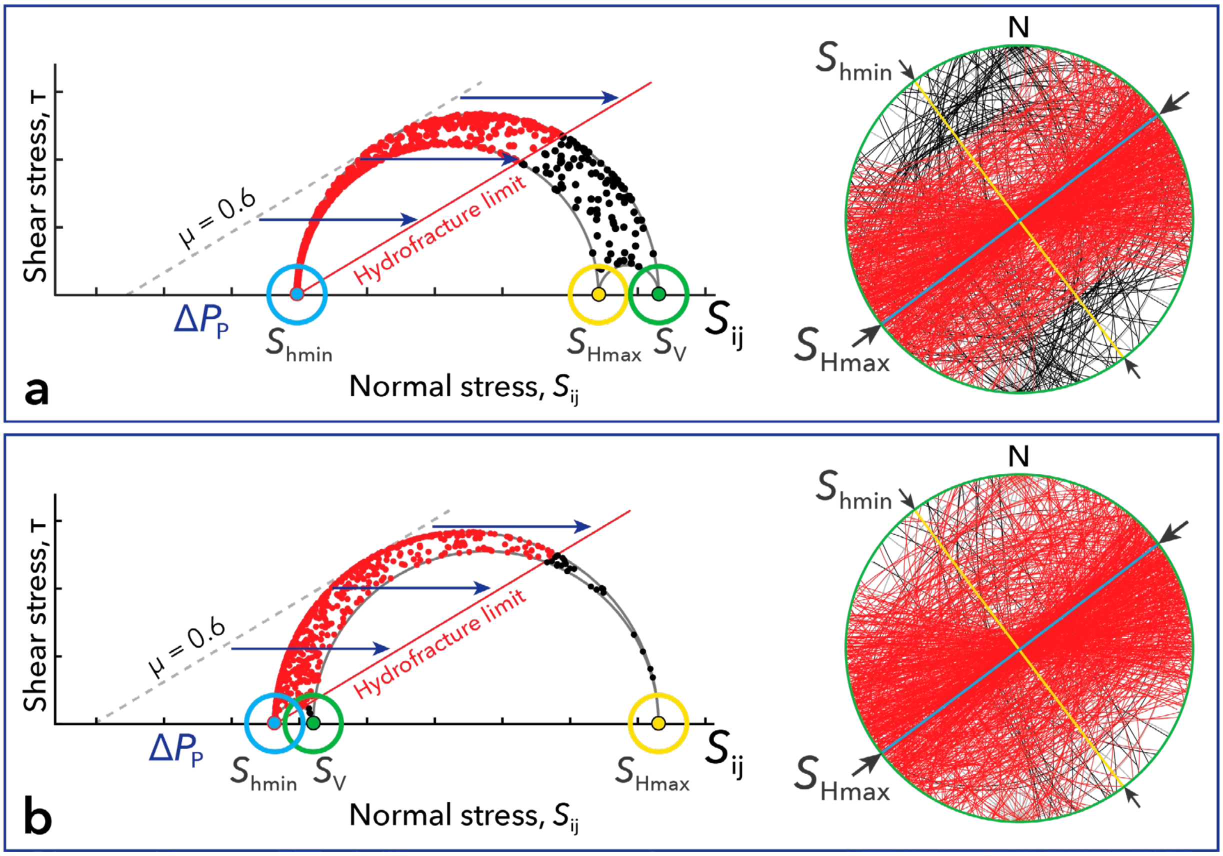


Figure 6: Evaluation of the tendency for shear slip or opening on planes normal to one of the principal stresses. Sub-horizontal bedding planes are illustrated by the green dot on left and the plane shown in green on the stereonet. Planes normal to S_{hmin} (sub-parallel to hydraulic fractures) are shown in blue and those normal to S_{Hmax} are shown in yellow. a. The normal/strike-slip stress state ($S_{hmin} \ll S_{Hmax} \approx S_V$) considered in Figure 2d. b. The strike-slip/reverse stress state considered in Figure 4d ($S_{hmin} \approx S_V \ll S_{Hmax}$).

References

Hakso, A., 2017, Analysis of microseismic multiplets in a hydraulic fracturing operation: Ph.D. thesis, Stanford University.

Hakso, A., and M.D. Zoback, 2017, Using multiplets as an independent assessment of relative microseismic location uncertainty: The Leading Edge, 36, no. 10, 829–836, doi:10.1190/tle36100829.1.

Kuang, W., M.D. Zoback, and J. Zhang, 2017, Estimating geomechanical parameters from microseismic plane focal mechanisms recorded during multistage hydraulic fracturing: Geophysics, 82, no. 1, KS1–KS11, doi:10.1190/GEO2015-0691.1.

Lund Snee, J.-E., and M.D. Zoback, 2016, State of stress in Texas: Implications for induced seismicity: Geophysical Research Letters, 43, 10,208–10,214, doi:10.1002/2016GL070974.

Zoback, M.D., J. Townend, and B. Grollimund, 2002, Steady-state failure equilibrium and deformation of intraplate lithosphere: International Geology Review, 44, 383–401.

Permalink: https://doi.org/10.1190/segam2018-2991018.1

Save the date!

GSH – HGS

JOINT SOCIETY DINNER

Plates to Prospects: Integration of data at multiple scales to enhance exploration, with insights from the deepwater fold and thrust belts offshore Northeastern México

Dr. Carl Watkins

CGG GeoSolutions

OCTOBER 7TH, 2019

NORRIS CONFERENCE CENTERS

HOUSTON/CITYCENTRE

Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 25.

We appreciate our

Corporate Members

Apache

ConocoPhillips

Fairfield Geotechnologies

Seitel

In-Depth

TGS

For more information about becoming a Corporate Member, go to GSHTX.org

GSH Outreach

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

The Alief STEM Student Conference - Career & College Exploration Expo was held on Saturday, April 13, 2019 at the HCC Alief Campus - West Houston Institute. Huw James and Lisa Buckner hosted an exhibit booth and spoke to over a hundred of the, mostly middle school, students attending the event. They listened intently to our short presentation on seismic waves in order to receive a coiled toy spring.

On April 26, 2019 Mac Hooton, Mike McCardle and Judy Schulenberg attended Career Day at Ridgemont Elementary in the Fort Bend Independent School District. Ridgemont includes PreK through 5th grade. Their enthusiasm and energy are contagious. The students were very excited to see Mr. Hooton's rock and mineral collection, to hear about where he collected many of his samples, and to learn about some of their potential uses. They were especially excited to be able to touch and hold the samples. Mr. Hooton also demonstrated how seismic signals are produced using an app on his cell phone which shows wavelets in 3D. He first showed the students how hitting the table can produce a wavelet that can be seen on the phone, and then explained the importance of energy in each of the three dimensions. The students had great fun banging all over the top, edge, and end of the table to produce their own signals. Mike McCardle and Judy Schulenberg expanded on Mr. Hooton's seismic wavelet demonstration by showing the students sample geophones and explaining how they were used to record the data. Using visual aids, we discussed how the earth is like a Tootsie Pop, and how seismic is used to find oil and gas.

2019 Gustavia Pearls - Jagadish Maddiboyina and Mac Hooton

Energy Venture Camp - Lisa Buckner

Students also enjoyed our "Drilling for Oil" game, where we buried a can of black shoe polish (oil field) in a plastic tub decorated with salt domes and formations painted on the sides filled with kitty litter. On the surface of the sediment, we simulated a shipwreck to represent an archeological site, and we added a small coral reef complete with Nemo to show that oil and gas companies must be mindful of preserving the environment. The students used unsharpened pencils to drill for the oil; those who were successful came out with black polish on the end. We gave away 125 GSH toy springs and pencil drilling rigs.

Angela Gibson, our school contact, was especially grateful for our attendance. She explained that being from a disadvantaged area, the students rarely if ever, are exposed to STEM programs, and how important it is to "plant those seeds" early. We were both pleased and humbled to have the opportunity to reach out to their community. Ms. Gibson intends to invite GSH back again next year.

Outreach continued on page 24.

Outreach continued from page 23.

Gustavia Pearls - Lisa Buckner and Jagadish Maddiboyina

Gustavia Pearls - Mac Hooton

On Thursday, June 6, 2019 Lisa Buckner gave a "Careers in Geoscience" presentation at the EnergyVenture Camp at San Jacinto College. The one-week summer STEM camp is open to students (ages 12-14) and is offered a total of six times across their three campuses; each session with about 25 students. The camps are meant to bring awareness of the wide variety of careers in the energy industry through fun hands-on activities, a plant tour, and career presentations given by a process technologist, an engineer, and a geoscientist. To find out more visit https://www.sanjac.edu/energy-venture-camp

GSH participated at the Gustavia Pearls Women's Outreach STEM Festival for the first time on Saturday, June 8, 2019. The event was held in the gymnasium of the Houston Parks J. Robinson Sr. Community Center near I-10 and I-610 East Loop. Hands-on activity exhibit booths included drones, robots, rockets, NASA, Ghost Busters, GSH and more. The GSH booth was composed of two tables that had the led animated

Outreach continued on page 25.

K-12 Outreach Volunteers Needed

Saturday, September 21, 2019   9:00 AM – 1:00 PM

STEM/Nova Day at Houston Museum of Natural Science

Earth Science Week 2019 Theme: "Geoscience is for Everyone"

Please help GSH educate children & families about geophysics and geology through fun and easy hands-on activities at our exhibit booths. Easy instructions will be provided for all volunteers.

Saturday, October 12, 2019   11:00 AM – 3:00 PM

Earth Science Celebration at Houston Museum of Natural Science

http://www.hmns.org or http://www.hgs.org

Lunch will be provided for all volunteers by the event coordinators.

Saturday, October 19, 2019   11:00 AM – 4:00 PM

Energy Day Festival at Sam Houston Park (downtown)

http://energydayfestival.org/houston

Contact Lisa Buckner at **outreach@gshtx.org** to volunteer at any event.
Come play with us!

Outreach continued from page 24.

Gustavia Pearls - Mac Hooton

seismic acquisition survey poster, the "Drilling for Oil" game, a coiled toy spring seismic wave motion demo, the cell phone Vibration Meter app, and Mac Hooton's rock and mineral samples. Our booth was located next to the very popular robots and drones booths. We gave away 84 GSH toy springs. Thank you to the GSH Outreach volunteers: Mac Hooton, Huw James, and Jagadish Maddiboyina. □

The Mystery Item on page 22 is a portable magnetometer.

U of H Wavelets

SEG Wavelets Compete in Regional SEG Challenge Bowl

By Matthew Storey

Students ready to begin the SEG Challenge Bowl at the GSH-SEG Spring Symposium.

On April 16th, SEG Wavelets competed in the Regional Challenge Bowl at the GSH-SEG Spring Symposium. The Challenge Bowl was hosted by Dr. Peter Duncan from MicroSeismic, Inc. and featured five teams of two students from different universities such as UH, UT, and OU. In total there were two teams from UH, two teams from OU, and one team from UT. The game was a hit and involved many rounds of questions related to geology, geophysics, geodesy, geochemistry, astronomy, and SEG history. The Symposium's honorees, Dan Hampson and Dr. Brian Russell, chimed in on the fun early on as a team playing against the students. As the game progressed, teams were eliminated and after a close battle between UH and OU, UH ultimately came

Group photo after the SEG Challenge Bowl at the GSH-SEG Spring Symposium.

Wavelets continued on page 27.

Wavelets continued from page 26.

out victorious. The winners, Manuel Paez-Reyes and Boming Wu, received an expense-paid trip to compete in the finals at the 2019 Annual SEG Meeting in San Antonio, TX.

In late April, SEG Wavelets held new officer elections for the upcoming school year. A new president, vice-president, treasurer, secretary, social chair, and webmaster were elected. Our goals are even higher for this upcoming year, but the students' and the university's best interests will remain a top priority. In 2018, SEG Wavelets was recognized by SEG as a **Summit-Level** organization for our outstanding engagement. We were ranked 1st in the United States for "**Best SEG Student Chapter**" and 3rd world-wide. We want to keep surpassing those high expectations and are always eager to host educational talks, short courses and workshops, field trips, outreach activities, and socials. Please visit us at our new website (www.segwavelets.uh.edu) for more information on how to get involved and follow us on LinkedIn! □

UH Winners of the Regional SEG Challenge Bowl. Manuel Paez-Reyes (left) and Boming Wu (right).

Geoscience Center

The History of Geophysics By Bill Gafford

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

Various early gravity meters and pictures

Earlier this year I wrote about some of the displays of artifacts and items from the GSH Museum Collection that are located around Houston and in Austin. Over the summer there have been some changes in some of the displays. The items that had been at the Bullock Texas State History Museum in Austin since 2000, have been returned to us since there are some renovations and changes being made to some of the display areas at the Museum. These items or others may be included in future exhibits there at some later date. Most of the items are from the 1920's and illustrate the beginning of seismic recording by the Petty family. We will look for another display location for these vintage instruments.

The SEG Iverson Collection of gravity instruments has been relocated from CGG to Bell Geospace in north Houston. The instruments were on display at the SEG offices in Tulsa until the SEG Geoscience Center was closed in 2009. They were then moved to Fugro Gravity and Magnetic Services, and later to CGG. The GSH is the custodian of this collection and the items from the collection that are not on display are now stored at the Geoscience Center. Pictures of the display in the new location at Bell Geospace are included with this article.

The following information provides some background about the Iverson collection:

Mr. Robert M. "Ivy" Iverson had a long career working with gravity instruments. In

Borehole gravimeter and controller

Geoscience Center continued on page 30.

Geoscience Center continued from page 30.

the 1950's he worked on a project for global standardization of gravity measurements at submilligal precision. For this work he used Gulf Oil Company pendulums on all continents of the world. He was involved with testing of newly designed gravimeters and worked with almost all the designers and manufacturers of gravimeters. In the early 1960's he began working for the U. S. Army Map Service to set up a global gravity database which would be used in certain military programs. By the time he left the AMS in 1970, he had coordinated many joint programs of gravity surveys which resulted in an unprecedented database of gravity information. In 1970 he co-founded Entech, which led to his involvement in developing airborne gravimetry.

During his career, Ivy collected a large variety of gravity instruments, many of which had been discarded or taken out of service; he enjoyed restoring and rebuilding these instruments. His collection spanned the era from torsion balances and pendulums, to metal spring gravimeters including LaCoste-Romberg, Maeder, Humble, Frost, North American, and then several instruments with quartz glass elements, including Mott-Smith, Worden, Atlas, and Worldwide models. The collection also includes many instrument parts, documents, manuals, correspondence, and drawings which provide a history of the development of gravimetry. Portions of the collection had been on display at Virginia Tech University for more than 20 years and were purchased from Mr. Iverson by the SEG in 2003 after a fund-raising campaign directed by Guy Flanagan. The Iverson Collection has been described as "the finest gravity meter collection in the world." Some of the items have been on display at the Smithsonian Museum in Washington. □

Our most recent quarterly Living Legends Doodlebugger social event was held on Wednesday morning August 7. These events are open to everyone and provide a time to visit with some of the Legends in our industry and see some of our more interesting geoscience artifacts. Light snacks, coffee, soft drinks, and water are provided. □

Early gravity meters and pictures

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

19th ANNUAL GSH SALTWATER FISHING TOURNAMENT

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

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

Cash Fish Pots and Captains Meeting!

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

EARLY REGISTRATION OPTIONS

(prior to Sept. 27th)

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

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

REGISTRATION OPTIONS OFFER LIMITED SPACES ON PROFESSIONALLY GUIDED BOATS

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

For information contact: Nathan Lenz Nathaniel.lenz@tgs.com C: 281-468-5459

2019 Inaugural

GSH FALL FORUM

The Business of UNCONVENTIONALS and the Role for Geophysics

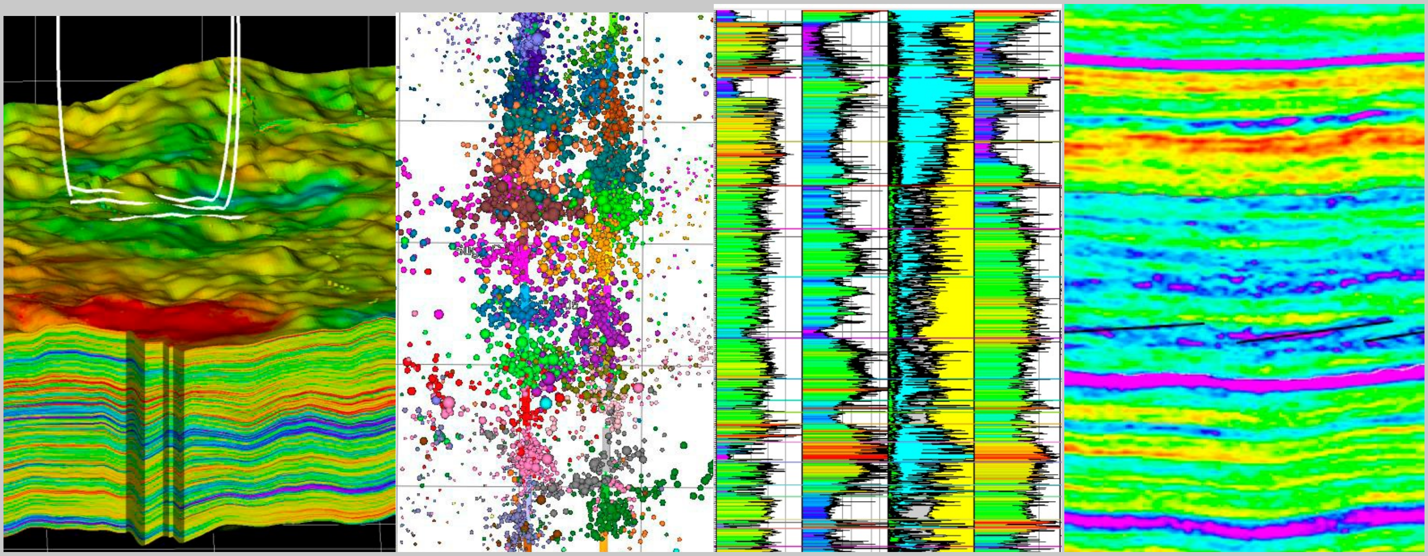
November 1, 2019

Norris Conference Center, Houston, TX

Exploring How Geophysics Is Used In Unconventional Resource Plays

- The business of unconventionals (how to survive/be successful/competitive)
- How is investor pressure for free cash flow affecting the market?
- How do we demonstrate the value of geophysics in unconventional plays?
- What Earth Science technical disciplines are relevant in unconventionals?
- How should universities and YPs prepare for the future in this field?

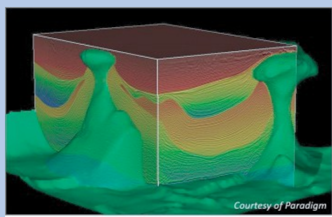
Includes a panel discussion by some of the leaders in the industry

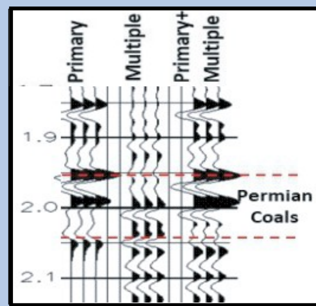


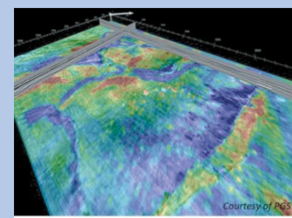
For Registration, Sponsorship & Booth info, call the GSH @ 281-741-1624 or visit gshtx.org

The GSH - SEG Webinar Series is Online

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







Title	**Presenter**
Seismic Modeling, Migration, and Inversion	Bee Bednar
Beyond AVO to Quantitative Inversion Interpretation QII	Bill Goodway
Affordable S-Wave Reflection Seismology	Bob Hardage
Simplifying and Lowering the Cost of S-Wave Reflection Seismology	Bob Hardage
Carbonate Essentials	Chris Liner
Basic Seismic Interpretation	Don Herron & Bob Wegner
Basics and UPDATES on Anisotropy: Azimuthal P-P for better Imaging, Fractures & Stress Analysis Acquisition, Processing & Interpretation	Dr. Heloise Lynn
Geophysical Signal Processing 101	Enders A. Robinson & Sven Treitel
Seismic Amplitude 20/20: An Update and Forecast	Fred Hilterman & Mike Graul
Extracting Geology from Seismic Data	Fred Schroeder
Applied Azimuthal Anisotropy-Azimuthal 3D P-P Seismic: Why Bother?	Dr. Heloise Lynn
Understanding Seismic Anisotropy in Exploration and Exploitation	Leon Thomsen
An Introduction to Borehole Acoustics	Matthew Blyth
Topics in Land Seismic Data Acquisition, Processing, and Inversion	Oz Yilmaz
Everything You Always Wanted to Know about Microseismic Monitoring	Peter Duncan
Full-Wave Seismic Exploration: Acquisition, Analysis, & Applications	Rob Stewart
Introduction to Applied Depth Imaging	Ruben D. Martinez
The Interpreter's Guide to Depth Imaging	Scott MacKay
Machine Learning Essentials for Seismic Interpretation	Tom Smith

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

SOCIETY OF EXPLORATION GEOPHYSICISTS


GEOPHYSICAL SOCIETY HOUSTON
2019 GSH Tennis Tournament
SAVE THE DATE
Friday November 8, 2019

A Conversation With... *Manika Prasad*

By Lee Lawyer

Dr. Manika Prasad is a Professor at Colorado School of Mines and holds a PhD in geophysics from the University of Kiel in Germany. Her focus is on Rock Physics. With some humor, She directs the Center for rock Abuse and discusses crushing rocks. She currently is the Distinguished Instructor Short Course. (LCL)

India is sort of a mystical place to many of us. Perhaps it would be more familiar if there was more oil and gas exploration going on there. I was surprised and pleased to see the latest edition of TLE, showing the geology and potential of oil and gas in India. It was great. For the first time, I saw the full extent of the Decan Trap.

That is just one of the areas of flood basalts. The Decan traps are one of the largest ones (over 2 km thick large regions of southwestern India. The Columbia River Basalts in the US is another flood basalt.

It is very difficult to get usable seismic data over the one in the US. I hate basalts near the surface.

But they are fantastic to go hiking in!

I can cede that. Your early life was in Bombay?

I grew up in Bombay. My early college work was in Bombay. I studied the Deacon Basalts and the type of volcanism that followed it. I remember learning about a'a and pahoehoe lava flows from my geology professor (Prof. Sethna) – Hawai'ian words that sounded magical.

This will probably be more about me than you but my readership is forgiving. I decided I didn't know much about India. I acquired a book on its history. Wow. Many, many small 'principalities', each separately governed, changing frequently. I read the book but I still don't know much about the history of India. I finally divided India's history into three parts, before the British, during the British, and after the British. That was the best I could do. You weren't there during the British rule?

Manika Prasad

That is correct.

Never the less, India is a fascinating place. I have never been there. We had a license on the west side, off shore from the Bombay High. Drilled two very dry holes. I didn't go out there for that.

Those were science holes. There is never a dry hole.

Tell that to Management, Professor. Let's journey over into your current position.

I am a professor of geophysics. I used to be in Petroleum Engineering and just as we speak, I re-joined geophysics after about ten years in Petroleum Engineering.

Can you describe your course work at Mines?

I teach Petrophysics and Rock Physics. It's between geology-geophysics and Petroleum Department. That is how I can be housed in either one. The Rock Physics part is more geophysics. It is about physical wave phenomena, propagation, electrical flow and fluid flow.

I notice you received an award for a paper on the subject was correlating permeability and

Interview continued on page 38.

Interview continued from page 37.

Frozen Clear Creek

velocity using a flow zone indicator. What is a flow zone indicator?

You take all of the flow geometry information that you don't understand and cannot measure easily, and define it as a hydraulic unit and say that if all pores in a hydraulic unit have similar geometry, their permeability can be tied to porosity. Now since we have "defined" pore geometry, we can better relate velocity to porosity using the geometry information. The hydraulic unit works as a descriptor for the geometry of the pore space.

Let's back up a little. Your history after you graduated from St. Xavier's College in Bombay, you moved to the University of Kiel, in Germany, where you received your Masters degree and a PhD in geology in 1990. I looked up Kiel. It is located in the connection between Germany and Denmark. How did you select Kiel?

I applied to several places where they offered Marine Geology. One of the places offered me admission was the Technical University of Berlin. I had no idea of general locations. So, I took out a map. Berlin had no ocean next to it. Not very scenic. Kiel came closest to my "requirements" so I selected Kiel.

Masters and Doctorate there?

Right. Sometime during my geology course work, I realized that I missed math and physics a lot. In those days, geology was not as quantitate as it is now. I was missing the math and physics aspects of the course work and research work. After a course on plate tectonics in the geophysics program, I asked to be switched to geophysics. I did two MS theses - one in geology and one in geophysics. And then switched completely to geophysics for Doctorate.

Geophysics doesn't take you very far from the rocks. What happened after you finished your PhD. When did your first go to Hawaii?

I first went back to India in 1990 to the Institute of Geomagnetism, where we did field work, Geomagnetic surveys, in Gujarat and in Uttarakhand. And then I applied elsewhere because I wanted to be doing more rock physics and more applied seismic work rather than geomagnetics. Two offers, one from Reading, England and one from Hawaii.

Stop for a minute on 'Geomagnetics'. What does that mean?

We were mapping the magnetic field and induced electro-magnetic field for various surveys.

Remnant magnetism? Is that what you were looking for?

Induced magnetism. We were studying the subsurface in order to map the structure and any faults in the region.

The whole field of electrical and magnetism is obscure to most geophysicists. Most never use it but there are a few groups out there that do.

Interview continued on page 39.

Interview continued from page 38.

Mud Queen

The big thing is that all of those types of studies don't require the large amount of machinery that seismic does. Easier to do, which means you don't need so much equipment. Doesn't cost as much. The other thing is that all of these methods are inversion based where seismic data gives you reflectors.

I am thinking of the language requirements in your many travels. India used English, I assume. The University of Kiel was either German or Danish. Hawaii uses English except for Aha and Pahoiho.

In India, English was one of the official languages. If you are studying the STEM fields, a majority of times, you will learn in English. I had learnt German before going to Kiel, and I had read a lot in German but they don't speak like that. Someone suggested that I read something like the National Enquirer in German to learn to speak it and understand it.

I believe that a requirement for PhD in the US was German and another language. German was the scientific language and French the diplomatic one. That was a while back. Not sure what it is today.

In those days, one has to pass a German language test to study in German universities.

Rock physics has become more and more important. You were selected to give the Distinguished Instructure Short Course. That is a lot of work. You are required to have an extensive text book and then travel all over the world giving the course. Writing the text must take time.

It takes a while. It is never complete because it is an evolving field. And since it is for people who are not doing it, you must include basics and that takes a little rethinking. You must scale back and present material so that people can actually follow through and do it.

What is the title of the course?

The title is Physics and Mechanics of Rocks, a practical approach.

Do you talk about rocks as they were formed or as they currently exist?

As they currently exist.

You don't look at diagenesis?

We do look at how diagenesis affects the rock but not how diagenesis takes place.

That is a subtle distinction. You teach at Colorado School of Mines. How long have you taught there?

I joined in 2004 and taught since 2005, almost 14years.

Do you plan to stay?

Sure. It is a nice school, a nice setting. I have a fantastic pool of students and people I work with.

Your field is so specialized, I don't think that you will be affected by the changes we see today. The

Interview continued on page 40.

Interview continued from page 39.

Copper Mountain Resort, CO

switch to unconventional methods has caused less seismic acquisition.

I agree. Rock Physics is a niche field. But, it is becoming more and more main stream. A few years back at the SEG Annual Meeting we would have only one or two sessions. That has changed. Now we have rock physics sessions on all days as well as poster sessions. That shows that more people are finding the value of doing it and more are actually using it. But it is still niche field.

People are spending a great deal of time and effort trying to convert our seismic data to Rock Physics terms. Do you feel they will be successful?

You find people converting impedance volumes into porosity volumes. Those are possible with some of the models we can generate. That is being done today. It is not out of the ordinary. Our challenge is to put more finesse into those porosity models. That is where we need better processed seismic data and more integration between rock physics and seismic.

There may be a better way to approach the question. Suppose we acquire and process perfect seismic data, no noise, perfect parameter selection, and so forth. Do we have the band width to convert that data to a rock physics level? There is some doubt that that is possible. Not me! I have lived through too many changes that couldn't have been predicted to be a skeptic. But are reaching a little too far?

If we define the problem and then acquire the seismic data and process the data to solve that particular problem rather than taking generic seismic data and then try to make our way into rock properties. In other words, we need to go the other way. We need to define the problem and then acquire the best seismic data necessary to solve that particular problem.

Interview continued on page 41.

Interview continued from page 40.

We do acquire data assuming that if we follow general design parameters, we will have the solutions we seek. Our design parameters have changed a lot over the years. It would be interesting if we could approach it as you describe. Perhaps we need to start a new era of experimentation. Do you see anything on the horizon that could improve our ability to get more definition?

They are looking at optic fiber. That promises to have much higher sensitivity. But we need to get a handle on the noise. It picks up everything. At the moment we don't have much coverage using fiber optics. We could use fiber optics to connect an array of acoustic sensors. We can use induced seismicity as a source. That will give us added definition.

Consider how much of the seismic pulse we use. Mostly we use the acoustic part of it. Also, consider that we use offset to determine fluid content. We have come a long way. Our rock physics associates need to continue to challenge us.

I realize we are straying into fields that are not covered in rock physics. We geophysicists, need to keep experimenting. We need objectives that were not reachable in past years. You need to define the problem and demand solutions. Rock physics are an integral part of our technology.

For a final question, if you could give advice to a young new professional, what would it be?

I would tell them to find mentors in all walks of life. People you learn from are your mentors. Prize them.

Very good. Thank you very much for putting up with me. I enjoyed our conversation. (LCL) □

Doodlebugger Diary

My Experience as the Mobil Oil Technical Lead for the Exploration of the Madre de Dios Basin, Peru
Part 2: Exploring the Las Piedras Block (1996-1999)

By Nancy House

In Part 1 I described the exploration and eventual drilling of the Candamo 1X on a giant overthrust anticline in the Tambopata Block (Figure 1). This block later became the Bajua Sonene National Park. There were large dry gas reserves in this area but they were not economically competitive with Camisea to the north and numerous large anticlinal traps discovered in southern Bolivia and the northern Argentina foothills. In Part 2 I will describe our exploration efforts in Las Piedras.

The foothills block (Tambopata) and the foreland block (Las Piedras) were carved out of a Technical Evaluation Agreement (TEA) covering most of the Madre de Dios Basin that was signed in 1994 *(Figure 1)*. The terms of each block were extremely aggressive calling for completion of 600 and 800 miles of 2D seismic respectively. The blocks were huge, 1 million hectares or 3.8 million acres each.

The terms of the contract called for the seismic to be completed and evaluated within 24 months and either a well proposed or 25% of the acreage dropped. The development contract stipulations continued for a term of five years during which the partners would keep any productive fields with the appropriate split to the government. With such aggressive terms no time could be lost in waiting for processing or recovering from errors. The operations were complex, dangerous and in extremely sensitive areas.

The environmental impact assessments performed in the early stages of Mobil's involvement in Peru took over two years to complete, and the actions to mitigate any potential impact were robust. In the foothills block the primary concern was biodiversity, and there Mobil provided a grant for Conservation International to study the flora and fauna along the seismic lines to catalogue species and suggest best practices for reforesting the helipads. There were

Figure 1: Sedimentary basins of Peru showing the Camisea discovery and Exploration Blocks 78 (Las Piedras) and 76 (Tambopata). From http://www.perupetro.com.pe/wps/portal/corporativo/PerupetroSite/informacion%20al%20inversionista/¿por qué invertir en el perú-/!ut/p/z1/

botanists, and biologists studying the monkeys, river otters, parrots, and bats. There were vampire bats that carried rabies along with fruit bats that spread

Doodlebugger continued on page 44.

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

Doodlebugger continued from page 43.

Figure 2: Dr. Glenn Shepard (left) and an environmental monitor (right), walking back to the base camp along the Las Piedras River.

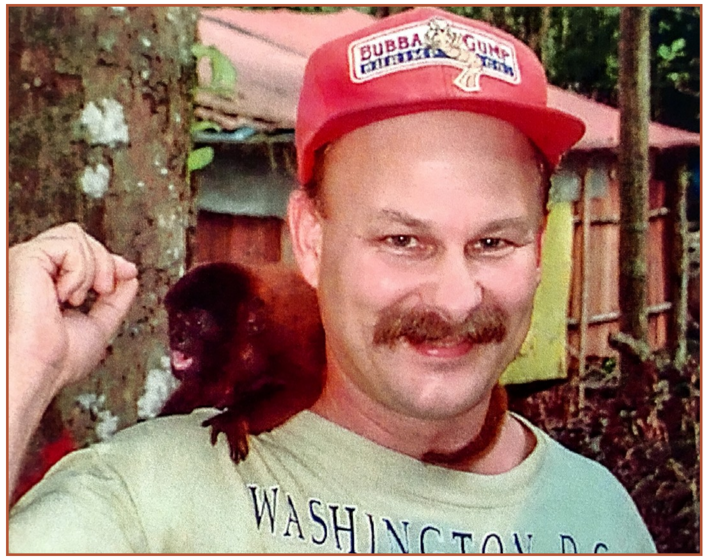


Figure 3: Seismic processor John Hefti posing with a small monkey. According to John, the monkey was left behind by the main pack so the camp adopted him during their stay.

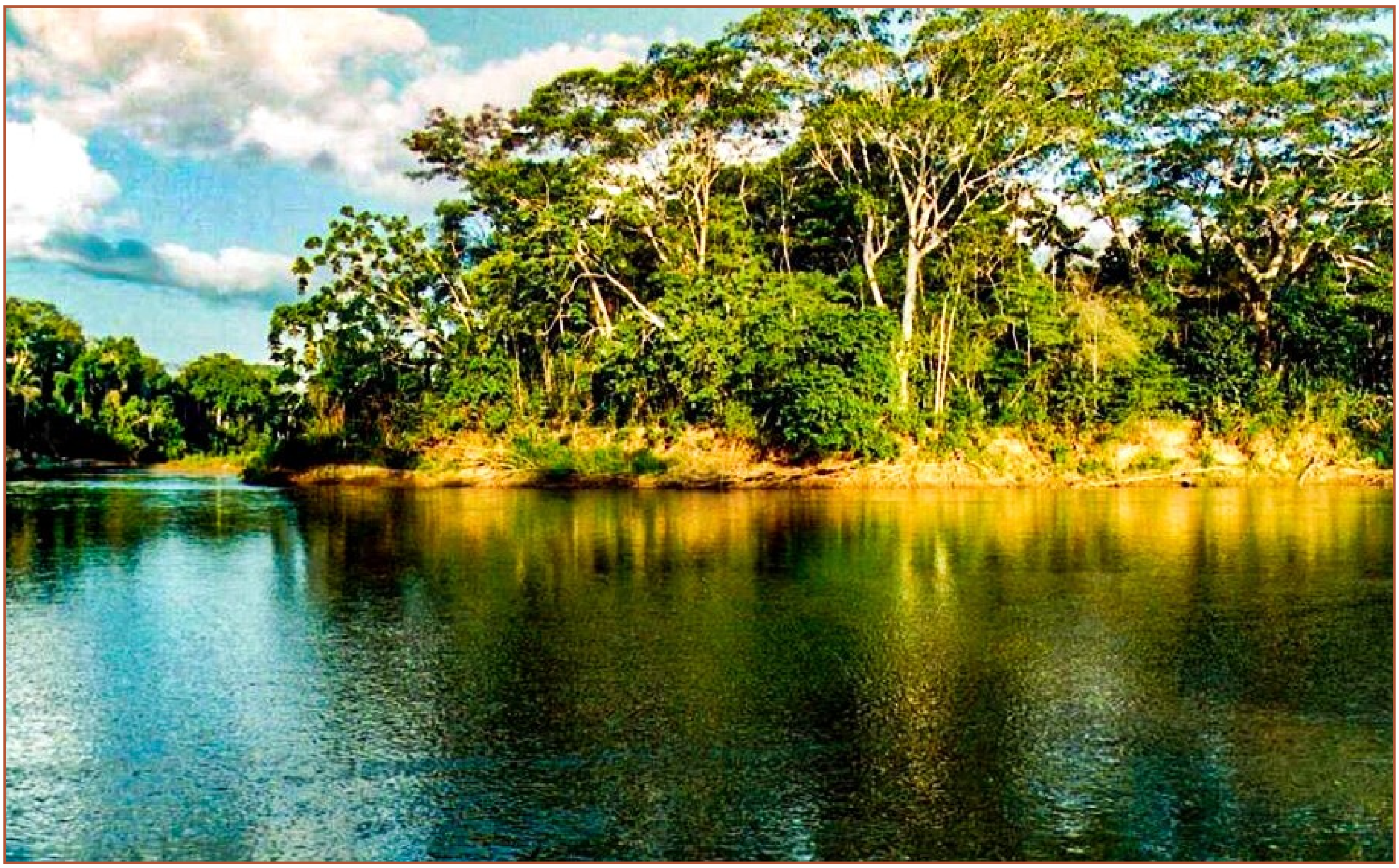


Figure 4: Las Piedras River looking out from the base camp on our first day near sundown.

Doodlebugger continued on page 45.

Doodlebugger continued from page 44.

Figure 5: Topo the camp pig. He is actually a peccary, who are essentially the pigs of the forest. This little guy was left behind by his pack so the camp adopted him and dressed him in a shirt with his name on it and a collar so he wouldn't get lost.

seeds throughout the rainforest. Environmental monitors were continually present during all operations.

In the foreland block in addition to flora and fauna to care for, there was the presence of 'voluntarily isolated natives'; indigenous people who had escaped deeper and deeper into the jungle to avoid first the Incas, then the Spaniards and finally the rubber traders of the early 1900's. An anthropologist by the name of Dr. Glen Shepard was invited to assist the operations due to the fact he was an expert in these native peoples and could advise us on the best means of avoidance[1][2].

Dr. Shepard first provided GPS coordinates of farmed areas of the Machiguenga and other indigenous tribes in nearby Manu Park. Then Mobil's remote sensing geologist, Jonathan Pershouse, scoured Landsat images for potential farmed areas within the Las Piedras Block in advance of the initiation of operations. Dr. Shepard then flew over those areas to determine if there were active farms in the block *(Figure 2)*.

Since we were so remote and had significant time constraints, field processing of the daily records was done at both sites (Tambopata and Los Piedras). As

Figure 6: Trips to the shower were always an adventure. Here an anteater greets a visitor to the showers.

we arrived at the Los Piedras base camp following a 40-minute helicopter ride from the jungle airstrip service in Manu Park, the field processor, John Hefti, was in the process rotating out at the conclusion of his stint (Figure 3). John was working as a field processor with Image Geophysical and was processing the raw Las Piedras data as it came in from the field. One of my objectives was to get fully briefed by John on what he was finding before he left. Another processing company, Excel

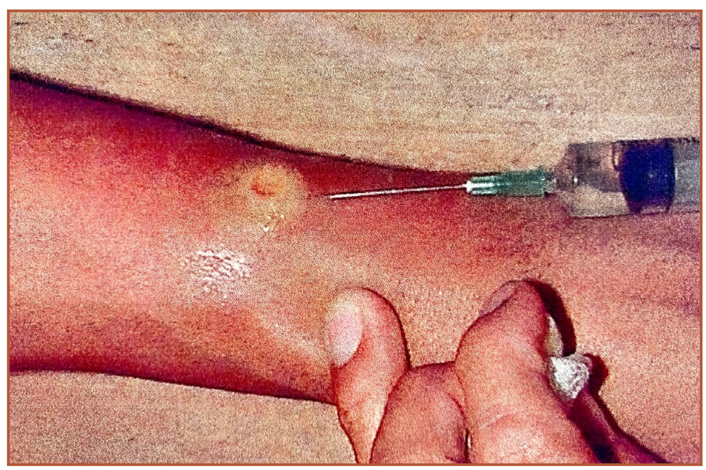


Figure 7: One of the Camp workers being treated for leishmaniosis, a skin wasting disease caused by bites from sandflies.

Doodlebugger continued on page 46.

Doodlebugger continued from page 45.

Geophysical, was doing field processing of the foothills (Tambopata) data in the small village of Mazuco, a gold mining town like many in the old west of the US.

We disembarked and looked around and got settled *(Figure 4)*. There had just been a large rain even though it was the dry season and the river rose washing away a family of baby caiman (alligators) on the riverbanks. The river was beautiful, and we took a quick trip up with the onsite anthropologist. We were introduced to Topo, the camp pig (actually a peccary) that was left behind by his pack *(Figure 5)*. I slept wonderfully to the sound of tree frogs and howler monkeys, although I wasn't too sure about the family of tarantulas that peaked out of their holes at night.

The men had warm showers although you could never be sure what you'd find in there *(Figure 6)*. Unfortunately, diversity and equality had not quite made it into the forest in the 1990's and I had to shower in the infirmary for privacy. They were cold (but what is really that cold in the rainforest?), and I had to go through the infirmary to get there. Fortunately, no one on the crew was suffering from the tropical disease leishmaniosis when I had to go through, although this did occur *(Figure 7)*. To prevent this the camp veterans slept inside tents with mosquito netting which kept all sorts of biting insects at bay. Another highly recommended practice was liberally slathering repellent over your entire body every day after taking a shower.

Figure 9: View from base camp toward the river showing the raised walkways and the helicopter landing pads.

Figure 8: The infirmary at base camp being completed. Note the raised walkways.

The base camp was built from a few trees that had to be cut, with raised wooden walkways to all the tents and buildings *(Figure 8)* and out to the helipad *(Figure 9)*. It was rumored that Grant Geophysical spent nearly a million dollars just building the base camp. There was an air conditioned trailer for seismic processing, a pilot's quarter, the dining hall, infirmary, and sleeping quarters.

Having arrived at the base camp and been introduced to the crew onsite we were ready to get started with operations. This was the most exciting part of the trip because I had already spent time getting the Candamo 1X exploration well drilled on the Tambopata Block (described in Part 1) and was chomping at the bit to see what the Las Piedras Block had to offer. Tomorrow we would set off to accompany the field crew on their shot lines and start to see this new area reveal its secrets.

Next month: Part 3: The Secrets of Las Piedras, Peru

REFERENCES

1. https://www.documentarystorm.com/spirits-rainforest/

2. http://rainforestflow.org/dr.-glenn-shepard.html □

Join or Renew NOW

GSH Membership year
begins July 1st

For $60/year

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

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 Sanvido at 281-741-1624 for your multi-year renewal.

NEW AD SIZES For 2019!

AD FORMAT FOR ADVERTISERS

- Ads should be submitted as full color, print-ready, high-resolution pdf, tif, eps, Illustrator, or PhotoShop files.
- Do NOT submit ads as Word documents, PowerPoint, or Excel files.
- Avoid clip art and Internet images. All submissions should be to size and at least 300 dpi.
- Send a URL or email address for a hyperlink.
- All issues are permanently archived on the GSH website @ www.gshtx.org

AD SIZE DIMENSIONS

Full Page	8" w x 10.25" h
Half Page - horizontal	8" w x 5" h
Half Page - vertical	3.875" w x 10.25" h
Quarter Page - vertical	3.875" w x 5" h
Quarter Page - horizontal	8" w x 2.375" h
Eighth Page	3.875" w x 2.375" h

BUSINESS CARD ADS

- Submit a full color digital file and a link to a URL or email address
- 10 issues (September to June)
- **For mid-year additions, we will prorate the remaining months and add it to a full year**

MEDIA BUNDLES AVAILABLE

- **Please visit the GSH website for details**

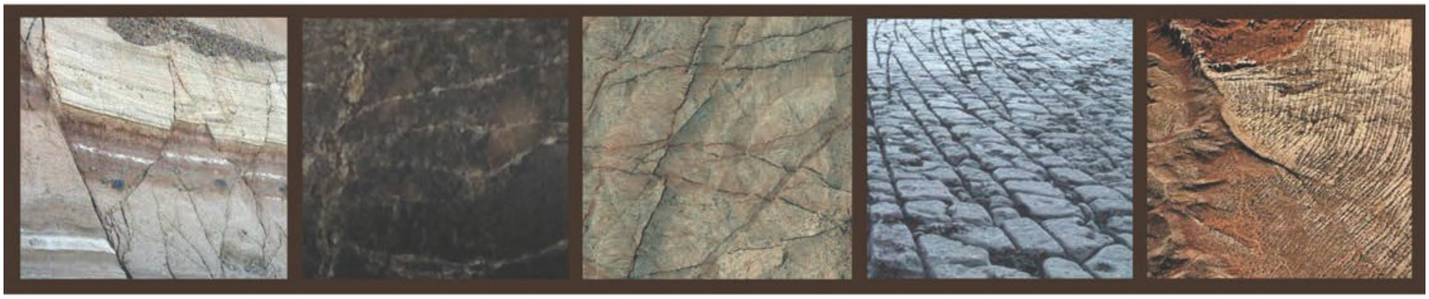
JOURNAL BANNER ADS

Color, linked to a URL or email address – Appears in rotation above every page while The Journal is open. Size: 2500px wide x 60px high, jpg or png accepted.

Applied Geoscience Conference

November 6-7, 2019

SOUTHWESTERN ENERGY • 10000 Energy Drive • Spring, TX 77389



Applied Geomechanics: Through the Life Cycle of the Field

Day 1 AM Session 1 – Accessing Targets Faster with Safer Wellbores

Day 1 PM Session 2 – Optimizing Completion Footprint and Stimulations Design

Day 2 AM Session 3 – Post Stimulation Diagnostics and Monitoring

Day 2 PM Session 4 – Extending the Life of the Field: Production, Refracturing, and EOR

University Poster Session both days.

This Fourth Applied Geoscience Geomechanics Conference (since 2013) by an industry expert committee provides the highest value through invited subject matter experts.

Cost structure

Early Bird: April 1 – June 30, 2019

HGS member $300.00

Non-member $375.00

General registration: July 1 – November 5, 2019

HGS member $400.00

Non-member $455.00

HGS student member $75.00

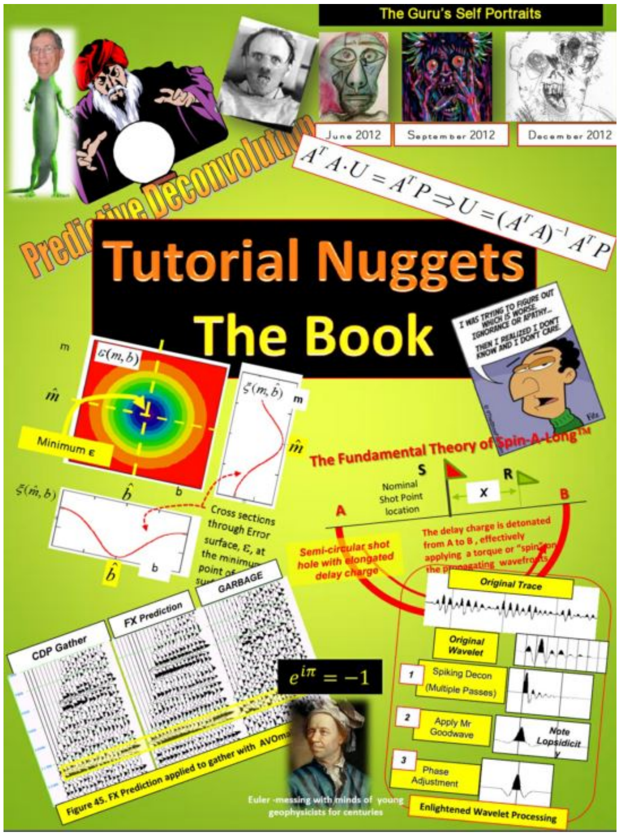
Note: Unemployed HGS members contact the office for discount

For more information please visit www.hgs.org or contact the HGS office: office@hgs.org

swn Southwestern Energy®

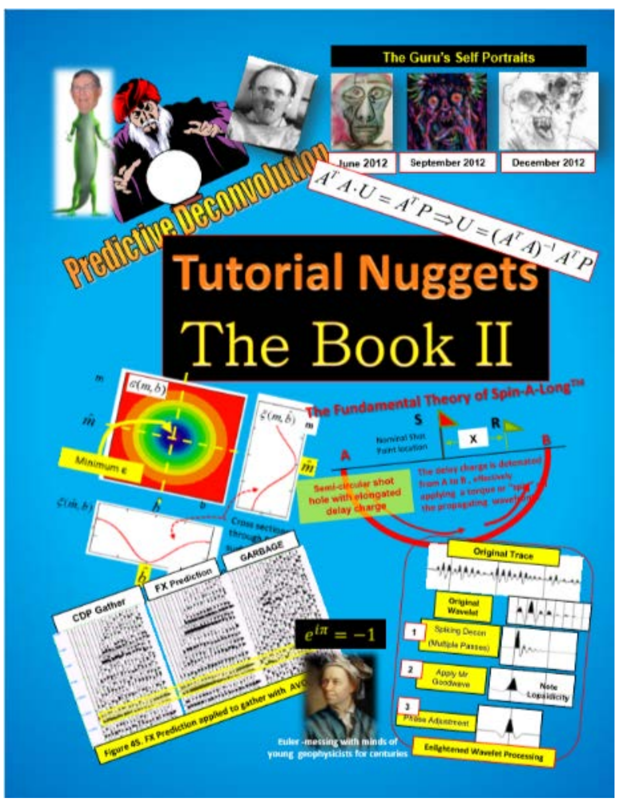
BAKER HUGHES a GE company

devon



Tutorial Nuggets The Book

Over 200 pages of information, formulas and humor!



Tutorial Nuggets The Book II

ORDER at
www.gshtx.org
Proceeds will be used to further scholarships, student memberships, educational outreach, and other activities of the Society.

The GSH is a 501(c)3 organization.

MEMBER PRICE $75