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GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON
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The Epicenter of Geophysical Excellence

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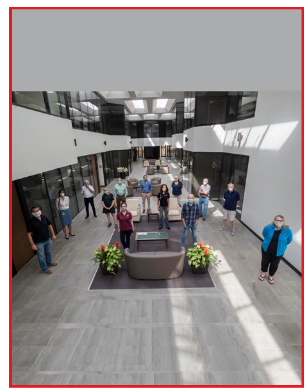

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To ensure your information reaches the GSH members in a timely manner, please note the following deadlines and plan accordingly. Please submit your articles and any questions to Alvaro Chaveste, editor, at AlvaroChaveste@hotmail.com

GSH JOURNAL DEADLINES

Dec 2020	**Oct 13**
Jan 2021	**Nov 14**
Feb 2021	**Dec 14**

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A Word from the Board

By Matt Blyth, First Vice President

The last time I wrote a *"Word from the Board"* article was back in the April edition of the Journal. Due to the lead times involved in generating the online Journal editions, the article was actually written in the world of February 2020 prior to COVID-19. What a change there has been since then! At the time I was 1st Vice President Elect and was just getting to terms with the GSH technical schedule of breakfast and lunch talks along with the SIG meetings and helping to organize the 2020 Spring Symposium, all of which came to a grinding halt in mid-March. Since then the GSH board has been adjusting our schedule, postponing events and trying to envisage what the future of the GSH technical offerings should be in light of both the COVID-19 restrictions on group events and the associated collapse of the oil and gas industry over the last two quarters. After initially attempting to postpone our usual events for a couple of months, it became clear that a different approach was needed.

In June we launched a series of (almost) weekly online technical presentations to ensure we provided ongoing technical content to our members. These presentations were well received and showed that online talks could attract both attention and attendance. The tech event series ran until the end of July and during our summer break we reconsidered the traditional GSH fall and spring technical schedule. In the past we maintained two breakfast presentations and three lunch presentations a month, which was a heavy schedule both for our presenters and the GSH staff and volunteers. In order to cover the larger geographical spread of Houston we were also holding these events at three locations – westside, downtown and northside. For various reasons, the northside events tended to be sparsely attended and frequently cancelled and the in-person attendance at the other events varied widely. With the new reality of our industry it was clear that the old schedule would be an over the top approach. So, the new fall technical schedule will feature (and by the time this journal is published you will already be aware of it) one breakfast talk and one lunch talk each month. Our initial idea was to launch this as a combined online and in-person event, with the option to participate in person for a lunch/breakfast or join online and view the presentation remotely.

Considering COVID-19 we wanted to be sure our members were ready for in-person events when the fall sessions would start in September. Therefore, in early August we launched a member survey to gauge people's thoughts on how we should deliver our events. The results overwhelmingly showed that our membership is not ready to return to in-person events but also that the idea of a hybrid online and in-person event is the future course for our technical talks. As such we decided to abandon the option of in-person events for the remainder of 2020 and to go online only for our breakfast and lunch talks. We still hope and plan to reintroduce the in-person content for our meetings when conditions allow, of course. We are planning what I hope is an engaging 2020/21 technical offering, with a wide variety of speakers from both the Houston area and outside. We are experimenting with different platforms to deliver the best experience for our attendees and these events remain free to our members. With that, the reality is the GSH has lost almost all of its major fundraising sources this year– from corporate sponsorship, to social events and of course the spring symposium. This leaves us in a difficult situation as we go forward into 2021. We will need to be creative in how we approach this problem and our recently launched commercial presentation offering is an aspect of this. If you have ideas on how we can approach this (or any other) problem, or if you would like to present at any of our events then please reach out, we would love to hear from you. Thank you and stay safe! □

From the Other Side

By Lee Lawyer

I received a note from Kevin Sherwood that started, "It is with great sadness…" and then continued, "that the Surprise Birthday Party was cancelled." Since John is within a year of my age, my first assumption was that John has passed away. This was several months ago. John Sherwood is alive and well in Houston. Many years ago, I met John at California Oil Field Research Company (COFRC) based in Southern California. Kevin (Son) asked a group to call or send an email on the exact birth date. That is the background. This surprise birthday Party from Kevin started an email chain. You may recognize a few names.

From Lee L: John, there is a rumor going around that you are "celebrating" your birthday tomorrow. Since I am your senior by a few years, I feel free to give you some good advice. QUIT CELEBRATING YOUR BIRTHDAYS. I remember the "good old days" at the lab. That was when Chevron was doing research. I never could quite understand what we were researching but it was good, especially the geochemistry guy! (Kidding).

From John Sherwood: Let me clear up one issue. I long ago decided against celebrations for my birthday. This must be my son tormenting me. If I am correct, you are 91 and not SO many years my senior. Somewhat close to Sven Treitel? I equated my birth date of March 29 1930 as a Geophysicist closest to the SEG birth on March 11 1930 but I recall finding Enders closer, at around March17(?) 1930. The days at the California Research Corporation were great. (I do not know what stunning intellect transformed CRC into the Chevron Oil Field Research Company!). I have been fortunate to work there and plead guilty to having only fun.

For instance, look back to the mid-1960s. I had devised the concept of CAM (Seismic Migration) and squeezing it onto an IBM 360 with 32K of memory, the only random access being a bank of about 14 tape drives. I truly wanted to program this myself but was about to travel to England for a couple of months. Also, I had been burdened (as you know, I am NOT a manager) with a number of colleagues to assist moving into digital seismic. What were they going to do in my absence? So, being a good company man, I spent a couple of weeks educating myself and Glenn Mackenzie, Fred Herkenhoff, Bill Miller, Harry Agger & Ron Taylor on CAM. We structured it into an appropriate number of subroutines, each with well-defined input and output. The Team allocated the subroutines between themselves and I departed for England happy to know that I would return to have fun examining the first ever (definitely first for Chevron) variable area, wiggle trace plots of migrated seismic data.

From Sven Treitel: John copied me his note to you. It is always good to have news about you (Lee), direct or indirect. We are all now members of an elite of geophysicists over 90, and I must tell you that just having passed 91 I outrank you, John, and Enders. On the other hand, Enders outranks all of us when judged in terms of closeness to SEG's founding date. It is all a matter of where you place the origin of your coordinate system.

From Enders Robinson: It is so good to hear from you. Thanks for the birthday greetings. Mine is March 18, 1930. I also have a total inability to type. Your reference to "bitter and British bangers" reminds me of a New Zealand friend who talked about "bangers and mash" of which I did not know and never asked. Now with the internet, all is clear. Where is "From the other side" when we need it? John's email would be perfect? TLE is not just the same without the golden observations of Lee.

From Kieran Thompson: I was flattered to be included in your (John's) e-mail chain. I too remember our first meeting in Denver, I seem to recall that you were presenting a paper on synthetic seismogram which, for some obscure reason, I seem to remember you describing it as a Victorian piece of equipment. Coincidently I was wondering how you were the other day and looked you up on the internet where I saw you were awarded The Maurice Ewing Medal (2008).

From Lee L: Great Scott! This is a reunion and a half. When someone agrees to be a subject in FTOS, I always tell them that I will make them famous. Ergo, I am going to make you guys more famous. I was recently called the "Old Guard" by the President of the GSH. Little did he know the company I was keeping. □

An exciting ***Live Webinar*** Sponsored by The GSH and The SEG

Borehole geophysics: Using rock properties, well logs, and all kinds of seismic methods

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Monday, Sept 28; Wednesday, Sept 30;
Monday, Oct 5; Wednesday, Oct 7, 2020
10:00 AM - 2:00 PM Central Time (USA)

By Dr. Robert Stewart

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GSH Technical Events

Technical Lunch

SP-wave Challenges for Shear-wave Petrophysical Applications

James Gaiser, Gaiser Geophysical Consulting

Abstract and Bio

Online presentation

October 21, 2020 - 11:00am-12:00pm CST

Register

Technical Breakfast

De-risking Drilling Hazards using Seismic Inversion Driven Fracture Pressure: A Case-study from the Permian Basin

Vishnu Pandey, CGG

Abstract and Bio

Online presentation

October 7, 2020 - 7:00-8:00am CST

Register

Unconventional SIG

Spatiotemporal Gyration
— A Tool for Completions Optimization

Vladimir Grechka, Senior Adviser, Borehole Seismic LLC

Abstract and Bio

Online presentation

October 1, 2020 - 11:30am-1:00pm CST

Register

GSH Gets Down to Business

Diffraction Imaging Case Studies from Around the World

Alexander Mihai Popovici, CEO, Z-Terra

Abstract and Bio

Online presentation

October 6, 2020 - 12:00-1:00pm CST

Register

Data Processing and Acquisition

Creating Conditioned Volumes, Attributes, and Stratal Domain Transformation Processes to Resolve Structure and Identify Stratigraphic Elements

Coerte Voorhies, EdgeSeis, LLC

Abstract and Bio

Online presentation

October 21, 2020 - 5:00-6:00pm CST

Register

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- An opportunity to win prizes for online engagement

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Welcome to
the Second HGS and EAGE Conference on Latin America Online

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WHY SHOULD YOU ATTEND?

The HGS (Houston Geological Society) and EAGE (European Association of Geoscientists and Engineers) will host for the second time the Latin American conference that will take place in a fully virtual format, between the 1st and the 3rd of December 2020. On this occasion, the HGS/EAGE will bring an integral and exceptionally enriched conference on Latin America.

Since the last two decades, the Latin American region has faced continuous development in energy resources, which has opened to increased investment. In recent years, the oil and gas industry has significantly increased exploration and production activities in the southern Caribbean margin, the Andean foreland, Guyana-Suriname offshore, deep-water Brazil, Argentina and Uruguay offshore, unconventional exploration in Argentina and Colombia, and the opening of exploration areas on the Pacific margin of South America. All this makes the second HGS/EAGE Conference on Latin America a perfect setting to keep up with the latest in Petroleum Geoscience for Conventional and Unconventional E&P, Natural Resources and Ore Geology, Machine learning present and future role in exploration, Seismic Imaging in E&P, that in overall, contribute to open to constructive dialogues on energy integration and prosperity of the region.

The Technical Committee has prepared a flagship event that includes special sessions on the Caribbean Offshore and the Special Session on Venezuela "*Venezuela's Upstream to Downstream - Past, Present and Future*", oral presentations, and poster sessions that will be widely attended by academic and industry participants from the USA, Europe and Latin America.

We look forward to seeing you at the second Latin American conference hosted by the HGS/EAGE!

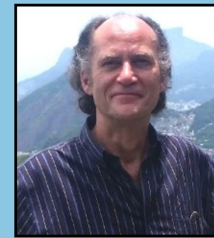
A Live Webinar!

Velocities, Imaging, and Waveform Inversion

The Evolution of Characterising the Earth's Subsurface

Featuring Dr. Ian F. Jones - ION Geophysical

November 9-11, 2020 9:00 am – 1:00 pm Houston Time



The course is designed for practising geoscientists and geoscience students who desire a better understanding of the principles and limitations of both current and emerging technologies involved in subsurface parameter estimation and imaging. The material is designed to help readers better understand how contemporary velocity estimation methods work, and what approximations are involved in obtaining computationally tractable solutions. The evolution of the industry's approaches to building earth models with ray tomography and full waveform inversion is covered, as are some of the emerging possibilities for replacing imaging techniques with direct subsurface parameter inversion methods. The approach will be mostly non-mathematical, concentrating on an intuitive understanding of the principles, demonstrating them via case histories.

This **12 hour course** can be taken 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**. **The Course Fee: $335!** With major discounts for Groups and Students. 1.2 CEU's are awarded.

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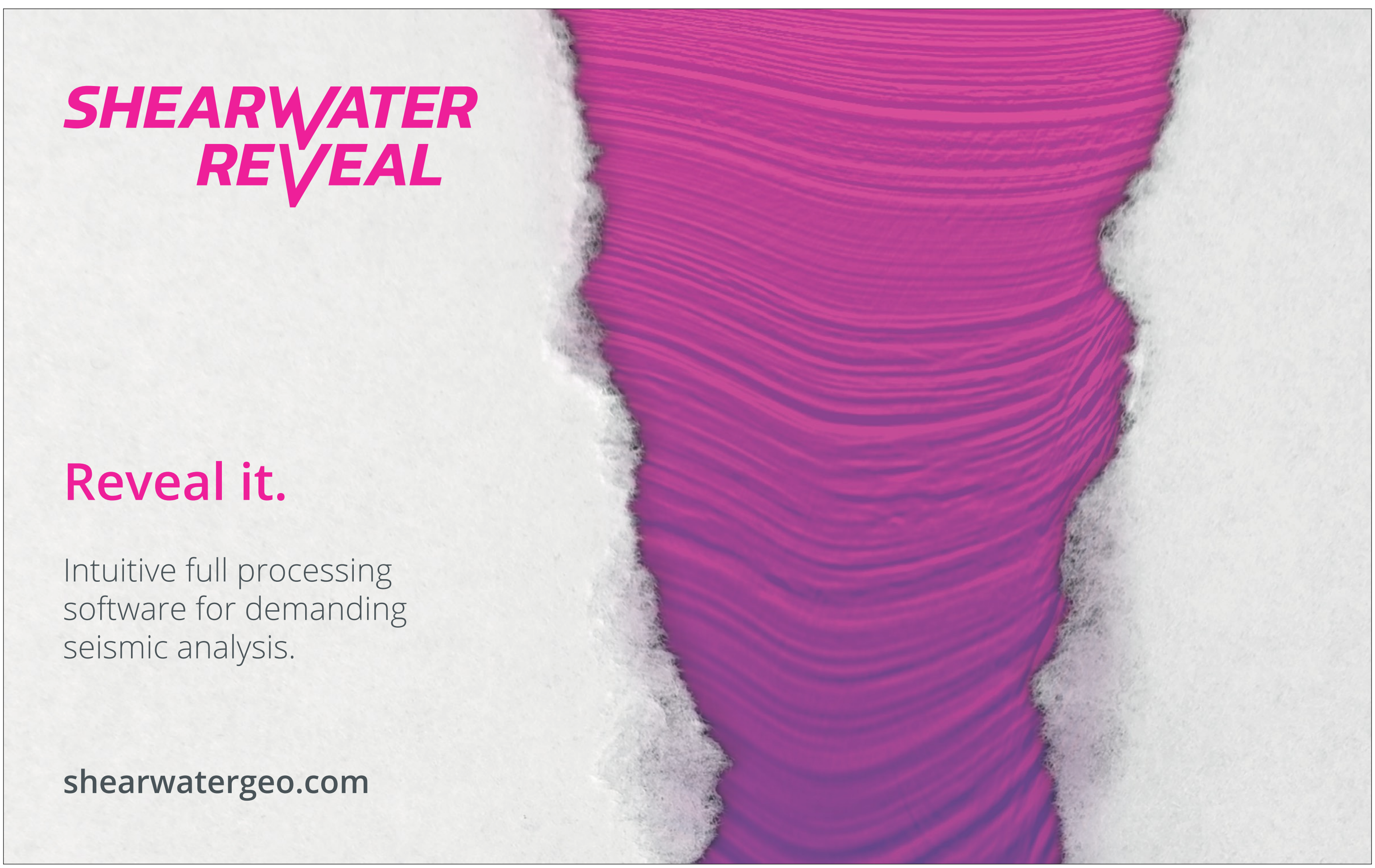

The First Active Seismic Experiment on Mars to Characterize the Shallow Subsurface Structure at the InSight Landing Site

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SUMMARY

In November 2018, the InSight lander successfully touched down in Elysium Planitia on Mars. Since then, two scientific instruments were deployed directly onto the surface of Mars: (1) SEIS, a package consisting of two three-component seismic sensors and (2) HP^3, a heat flow and physical properties package. HP^3 includes a self-hammering penetrator (mole) that hammers itself into the subsurface of Mars to a maximum depth of five meters. The mole hammering generates seismic signals that are recorded by SEIS and can be used to image the shallow subsurface just below the landing site. Even though not included in the level-one mission objectives, this opportunistic seismic experiment is, to the best of our knowledge, the first active seismic experiment ever conducted on a different planet. Here, we discuss the most important aspects of the implementations of this opportunistic experiment.

INTRODUCTION

The first extraterrestrial active seismic experiments were performed on the Moon by astronauts during the Apollo missions 14, 16 and 17 with the aim to map the elastic properties of the shallow lunar subsurface (Cooper et al., 1974). The lunar active seismic data show unexpectedly different characteristics to comparable data collected on Earth. Long-lasting reverberations are exhibited indicating low attenuation and intense scattering of seismic waves in the lunar crust. However, the active seismic data proved to be valuable for the characterization of the seismic properties of the shallow lunar subsurface (Sollberger et al., 2016). An alike but unplanned active source seismic experiment can be performed on Mars during the InSight (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) mission (Kedar et al., 2017; Golombek et al., 2018).

The InSight lander carried a seismometer (SEIS – Seismic Experiment for Interior Structure), a Heat-Flow and Physical Properties Package (c), and a geodetic instrument (RISE – Rotation and Interior Structure Experiment) (Banerdt et al., 2020). The overarching goals of the mission are to investigate the early formation processes of terrestrial planets by monitoring Mars' seismicity and determining the heat budget of the planet.

HP^3 and SEIS are directly placed on the surface of Mars as shown in *Figure 1*. The SEIS package

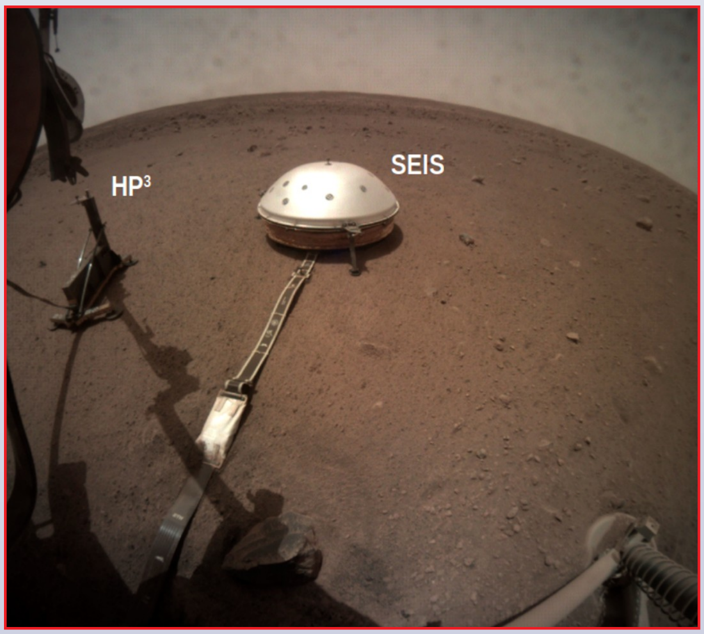

Figure 1: A picture taken from the InSight Context camera showing the seismometer (SEIS) and the Heat-Flow and Physical Properties Package (HP3), which are 1.1 meter apart from each other (Image credit: NASA/JPL-Caltech).

Technical Article continued on page 12.

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

Technical Article continued from page 11.

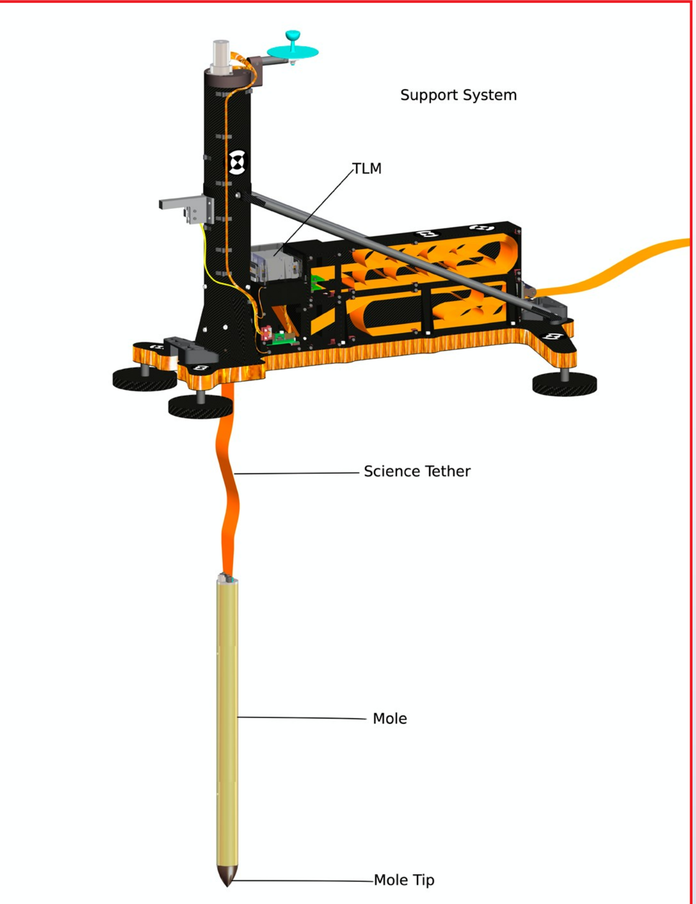

Figure 2: The HP³ instrument. The support system includes TLM, the science tether and the mole while deployed on the surface of Mars. After mole release, the mole will penetrate vertically down and the science tether will unroll. The TLM is reading out coding samples attached to the science tether to determine its absolute and relative distance (Figure modified from Spohn et al., 2018).

is used to monitor the intraplate seismic activity, localize potential events (marsquakes) and derive interior properties of the planet. In addition, SEIS measures the distinct seismic signals generated by the HP³ hammering, which is a supplementary experiment for the InSight mission not included in the original mission plans. Here, we present approaches to overcome various challenges associated with this opportunistic experiment.

THE HP³ MOLE

The HP³ instrument consists of the three main components illustrated in *Figure 2*: the support structure (placed on the surface), the science tether and the self-hammering mole. The mole contains thermometers as well as tilt sensors. The science tether connecting the mole to the support structure contains platinum resistance temperature detectors, and the support structure includes the tether length measurement system (TLM). The TLM uses optical sampling of position codes placed on the science tether to determine relative and absolute distances of the science tether as the mole penetrates into the subsurface. The tether distances together with the mole's tilt measurements are used to determine the absolute depth of the mole.

The HP³ experiment consists of two main operational phases: the penetration phase and the monitoring phase. During the penetration phase, the mole hammers at a rate of 0.1-1 mm per stroke for 0.5 - 4 h to reach a depth of 0.5 m for each hammer interval. When the desired depth for one interval has been reached, the HP³ switches to monitoring phase for two days to measure the thermal conductivity. Afterwards, the mole starts its next hammer interval. When the final depth has been reached, the long-term monitoring phase starts to measure the Martian temperature over the course of one Martian year (two Earth years).

THE SEIS PACKAGE

The SEIS package consists of a three-component very broad band (VBB) and a three-component short period seismometer (SP) working independently from each other (Lognonné et al., 2019). Both seismometers are mounted on a leveling system (LVL) to be able to level the instruments. InSight's SEIS device is protected by a wind and thermal shield (WTS) to reduce effects caused by wind and temperature. *Figure 1* shows how SEIS is covered by the WTS (white cover).

SEISMIC RECORDINGS OF HP³ HAMMERING

HP³ penetration was not originally conceptualized as an active seismic experiment during mission planning, and thus comes with a series of experimental difficulties. The main challenges that need to be overcome concern 1) to ensure a time link between HP³ as a source and SEIS recording (both HP³ and SEIS clocks operate independently) and 2) to achieve a temporal resolution to perform high-resolution imaging.

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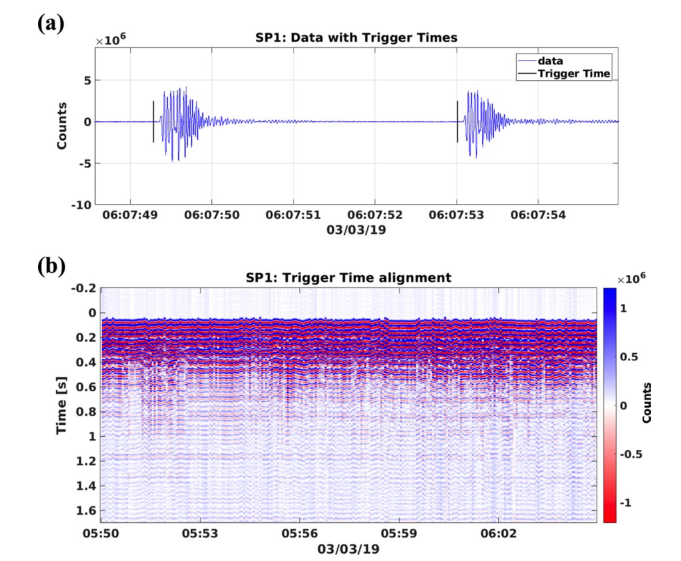

Figure 3: (a). A zoomed in version of the seismic data (solid blue line), where the solid black lines represent the interpolated trigger times of the mole on SEIS. (b). A receiver gather of a zoomed in version of the second hammer session performed on Mars. The zero time represents the trigger timing (solid black line a).

During one hammer session, thousands of hammer hits will be generated with each hit having its individual trigger time. A snippet of the recorded time series of the second hammer session including two hammer strokes with their corresponding trigger times is shown in *Figure 3a*. These trigger times are used to align the seismic data and arrange them as a common-receiver gather with time zero corresponding to the source (trigger) time of each trace *(Figure 3b)*. To correctly link the HP^3 recorded trigger times with the seismic records all clocks need to be transformed to the same base. The HP^3 and SEIS both run on different clocks that are occasionally synchronized with respect to the lander clock. A high-resolution analysis of the seismic data requires a synchronization of the source and recording clocks with a sub-millisecond accuracy. This is achieved by interpolation between exact time pairs that are only available once every few hours. Temperature variations can influence the time rate of the SEIS clock resulting in a non-linear behavior between these time pairs. The interpolation technique used here does take this into account.

When recording, the seismic data passes through a down-sampling flow resulting in the final data product at a sampling rate of 100 Hz. To avoid aliasing, the data are passed through a digital anti-aliasing FIR filter that only passes information below 50 Hz. However, the HP^3 mole is expected to generate seismic signals at frequencies much higher than 50 Hz.

To record information >50 Hz of the hammering signals, we designed a new FIR filter (in the following referred to as the "spike filter") that is uploaded to the lander and filters the seismic

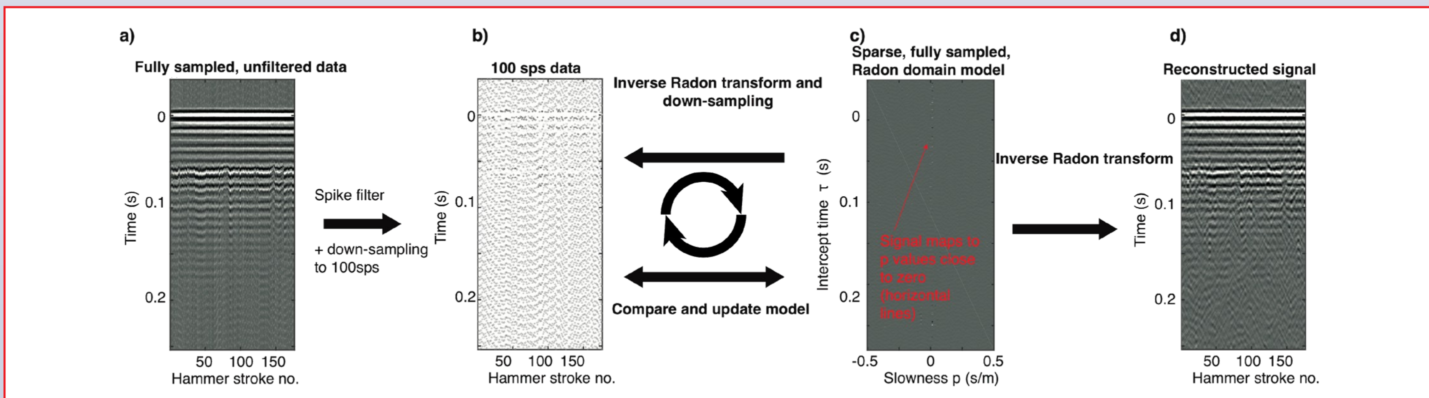

Figure 4: Illustration of the reconstruction algorithm used to recover the high-frequency information from fully aliased seismic data recorded during HP3 hammering. The example is from an actual analogue field experiment conducted in the Nevada desert with a spare model of the mole. a) Input seismic data before passing through the on-board down-sampling flow. b) Aliased data down-sampled to 100 Hz aligned to the hammering time. Note the quasi-random subsampling of the common-receiver gather. c) Sparse, fully-sampled Radon model of the data. d) Reconstructed signal.

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data during mole hammering. The spike filter has a flat frequency response and thus passes all the information contained in the hammering signal. As a consequence, the down-linked data is aliased. The signals need to be reconstructed to recover the high frequency information.

We developed a compressed sensing inspired algorithm (e.g. Donoho, 2006; Candes et al., 2006) that allows to accurately recover the high-frequency signals beyond the nominal Nyquist frequency of 50 Hz (Sollberger et al., 2020). Compressed sensing allows the recovery of sparse signals way beyond the Nyquist limit. The concept of the reconstruction algorithm is illustrated in *Figure 4*. Our reconstruction algorithm exploits the fact that the hammering signal of the mole is highly repeatable. Thousands of very similar signals are recorded as the mole slowly penetrates into the regolith. As a result, the data show a linear structure when arranged in a common-receiver gather with each hammer stroke aligned with respect to the hammer time *(Figure 4a)*.

HP[3] time samples are not identical to the time samples on SEIS. Each of the repeated signals is sub-sampled differently *(Figure 4b)*. This is an ideal prerequisite for compressed sensing. Due to the linear structure, the data has a sparse representation in the Radon transform domain. Instead of the conventional Radon transform, we use the so-called deconvolutive Radon transform (Gholami, 2017), which allows for an even sparser representation of the signal. Each linear event in the 2D data is effectively compressed to a point in the deconvolutive Radon domain *(Figure 4)*. Reconstruction is then achieved by finding the sparsest model (the model with smallest L1-norm) that fits the aliased data. This is achieved by solving a basis pursuit de-noising problem (BPDN). The reconstructed, up-sampled signal can then simply be found in the time domain by applying the inverse deconvolutive Radon transform to the best-fitting Radon-domain model parameters *(Figure 4)*.

SEISMIC-DATA PROCESSING

The reconstructed, up-sampled seismic data and accurate trigger times enable a high resolution analysis of the data. First-arrival P-wave travel times and the seismic waveforms are used for seismic tomography and reflection processing, respectively.

In order to test the imaging potential of the HP[3]-SEIS active seismic experiment, we demonstrate the processing on a synthetic dataset. We used finite-difference modeling to generate a synthetic dataset using the petrophysical model of the shallow Martian subsurface (B. Knapmeyer-Endrun, personal communication). We then picked the first-arriving P-wave travel times and applied a non-linear seismic travel time tomography based on Bayesian inference, which allows to quantify uncertainties. The method that we applied is the reversible jump Markov chain Monte Carlo (rj-MCMC) algorithm which allows the model space to be trans-dimensional. The parameterization of the model space is defined using Voronoi cells (Okabe et al., 2009). This allows four different perturbations to the model for each iteration step of the Markov chain (Bodin and Sambridge, 2009). Three of those perturbations imply a change in the parameterization: a “birth” step creates a new Voronoi cell, a “death” step removes a Voronoi cell and a “move” step rearranges the Voronoi cells. The fourth possible perturbation is a velocity step, which proposes a velocity parameter and does not influence the parameterization. The forward problem of the first-arrival travel time computation is solved using the Fast Marching method (Rawlinson and Sambridge, 2004).

Figure 5a represents the posterior density functions (PDFs) in 1D and 2D of the rj-MCMC applied to the picked travel times. The use of only one single seismic station limits the ability to resolve structural details in high resolution. However, *Figure 5a* shows that smooth trends in vertical and lateral velocity variations can be successfully recovered.

To obtain a more detailed model of the subsurface, we plan to additionally analyze potential reflections from subsurface interfaces. The basis for our seismic reflection analysis is the observation that the acquisition of the data with the HP[3] mole at depth and SEIS at the surface closely resembles a reverse vertical seismic profile experiment. First, the seismic data is separated into up- and down-going wavefields using f-k filtering. Then, a corridor

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stack is constructed by summing the energy within a selected window starting from the first-break curve of the predominately multiple-free upgoing wavefield. *Figure 5b* represents the result of a corridor stack applied on the synthetic data. The recovered reflections at 3 m and at 5 m closely correlate with interfaces in the model. Based on the synthetic results of the seismic tomography and reflection techniques, we are confident to resolve preliminary structures of the shallow Martian subsurface.

CONCLUSION

The penetration of the HP^3 mole into the subsurface of Mars down to a depth of 5 m generates seismic signals recorded by SEIS. Here, we show that we are able to analyze real Martian data using an interpolation technique to solve timing synchronization issues and a reconstruction method to accurately recover high-frequencies from the down-linked aliased signals. Based on representative synthetic data we show that the distinct seismic signals generated by the mole can be used to image the shallow subsurface (at least) down to the final depth of 5 m.

The interested reader is referred to Banerdt et al. (2020), Lognonne et al. (2020) and Giardini et al. (2020) for more information on the InSight mission, investigations of the Martian near-surface structure and seismicity.

ACKNOWLEDGMENTS

The authors acknowledge the scientific discussion and inputs from all SEIS and InSight team members who have focused their activity on scientific preparation of the SEIS data analysis phase and preparation of interdisciplinary investigations. We acknowledge NASA, CNES, partner agencies and Institutions (UKSA, SSO, DLR ; JPL, IPGP-CNRS, ETHZ, IC, MPS-MPG) and the operators of JPL, SISMOC, MSDS, IRIS- DMC and PDS for providing SEED SEIS data (https://doi.org/10.18715/SEIS.INSIGHT.XB_2016). The design, building of and research into the HP^3 has been supported by the German Aerospace Center (DLR), by NASA, the OAW, and the Polish Academy of Science. The Swiss co-authors were partially supported by the ETH research grant ETH-06 17-2. □

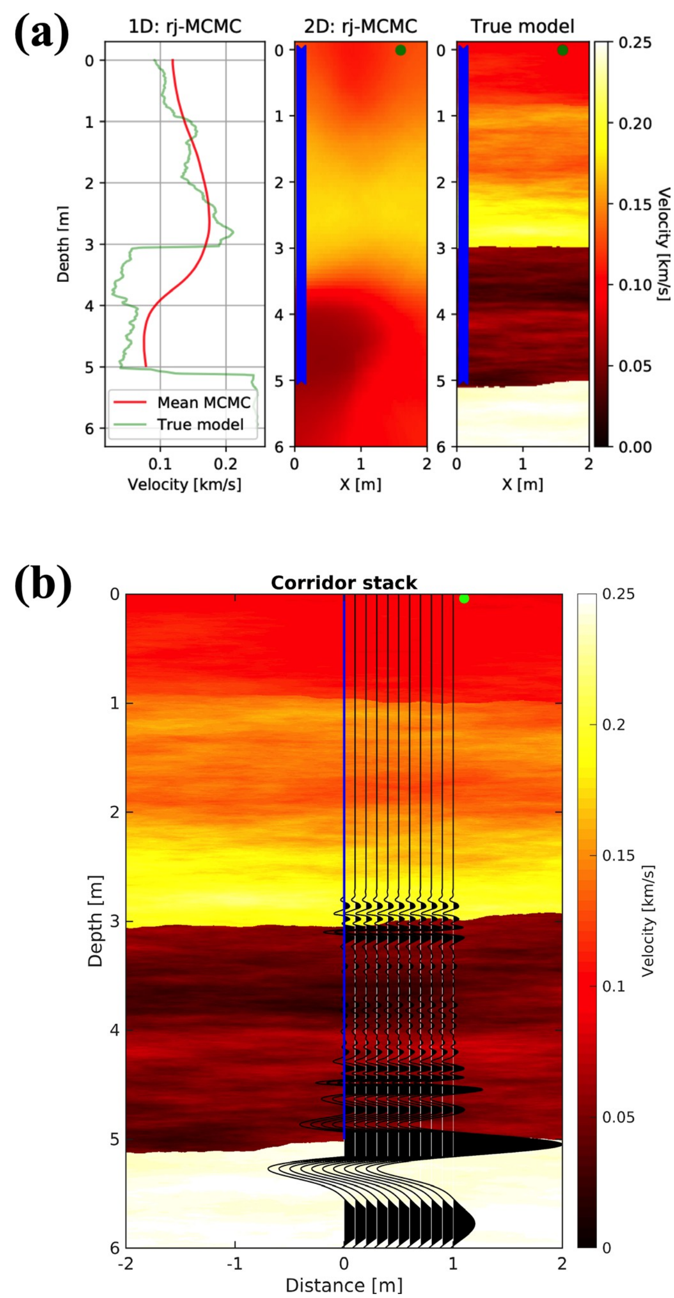

Figure 5: (a). 2D representation of the true model (right) and the posterior density functions (PDFs) on the left and middle after 100,000 iterations of the rj-MCMC in 1D and 2D, respectively. The blue solid line represents the hammer strokes of the mole (receivers) and the green dot symbolizes SEIS (source). (b). The same velocity model as shown in (a) used for reflection imaging. The black wiggles represent the corridor stack trace repeatedly shown for better visualization. The blue solid line represents the hammer strokes of the mole (receivers) and the green dot symbolizes SEIS (source).

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Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 26.

GSH Outreach

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

Earth Science Week, Oct. 11-17, 2020

About Earth Science Week - http://www.earthsciweek.org/about-esw
Since October 1998, the American Geosciences Institute has organized this national and international event to help the public gain a better understanding and appreciation for the Earth Sciences and to encourage stewardship of the Earth. This year's Earth Science Week will be held from October 11-17, 2020 and will celebrate the theme "Earth Materials in Our Lives." This year's event, the 23rd annual Earth Science Week celebration, will focus on the ways that Earth materials impact humans — and the ways human activity impacts these materials — in the 21st century.

Earth Science Week 2020 learning resources and activities will engage young people and others in exploring the relationship between Earth materials and people. This year's theme will promote public understanding of geoscience and stewardship of the planet, especially in terms of these raw materials.

You can order the 2020 Earth Science Week Toolkit - Earth Materials in Our Lives at https://www.earthsciweek.org/materials

There are a large number of geoscience activities to do with your kids. These are cataloged by subject and grade level at https://www.earthsciweek.org/classroom-activities This is where I found the Exploring for Petroleum - Modeling an Oil Reserve and Cupcake Core Sampling classroom activities, which we have done with students and educators. If you have enjoyed baking a lot during the pandemic, you will really enjoy the Cupcake Core Sampling. Other fun and edible activities are Chocolate Rock Cycle and Cookie Mining.

The Houston Geological Society is offering a virtual experience October 11 – 17 in celebration of Earth Science Week. They will provide links to videos, field trips, etc. that engage young people and others in exploring the relationship between Earth materials and people. Each day of Earth Science week will focus on a different geoscience. For more information, go to https://www.hgs.org/earth-science-outreach

Energy Day Festival - Saturday, Oct. 17, 2020 - Cancelled due to the COVID-19. More information about Energy Day can be found at https://energydayfestival.org/houston/

Have fun while staying safe! □

U of H Wavelets

The 2020-2021 SEG Wavelets

By Faith Walton and Michael Martinez

As COVID-19 swept across the world during 2020, organizations everywhere had to adapt quickly and efficiently - the SEG Wavelets at the University of Houston was no exception. New officer elections and the transition between administrations were conducted remotely, forcing officers to build trust and camaraderie through virtual meetings. Additionally, the Wavelets have had to adjust or postpone our plans for key semester events and socials to ensure the safety of those who attend. Planning these events is not an easy feat, especially in COVID-19 times. However, the SEG Wavelets are taking this opportunity to expand club accessibility with attendees that could not physically attend in the past. We also see this challenge as an opportunity to lean into the digital working world and collaborate with others.

In preparation for the 2020 job fair season, the SEG Wavelets will host a Zoom Resume Workshop Webinar featuring guest speakers Tanya Farirayi and Donah Justice from Earth and Atmospheric Sciences Career Services to help undergraduate students with their resume and interview skills. Additionally, the SEG Women's Network offers resume review services to all SEG members, which is a great reason to join your local SEG student chapter, the Wavelets. Throughout the fall, the Wavelets will host five to seven industry guest speakers via Zoom webinars. These webinars will range in topics from early career advice, exploration in the Gulf of Mexico, basin modeling in the Permian Basin, and applications of machine learning in the geosciences.

As for the future, the SEG Wavelets is postponing two significant events until the Spring 2021 semester. First, we plan on hosting our traditional Fall semester software bootcamps sometime after Spring Break or after finals in May. These software bootcamps expose undergraduate and graduate students to industry-standard software, which helps students interview for jobs and gives them software skills to complete more advanced research projects. We are also looking to push our Winter Holiday Party to the Spring semester and instead host a Spring Fling social event. Keep in mind that these two future events are pending the status of the COVID-19 numbers in the Houston area. We will not ask our members to take on health risks for social events.

To keep up with the latest SEG Wavelets news, follow us on our LinkedIn and Facebook at "SEG Wavelets" to keep up to date with our activities this academic year. Join SEG today at the local level with the Wavelets and the national level following our site's instructions. □

GSH Movie Time

Now Showing

Arctic Data Collection*

Early GSI crews were pioneers, not just pioneering the new technology of reflection seismology, but pioneers operating in hostile corners of the world; places where simple survival was a mark of achievement, even more so when coupled with collection of valuable seismic data.

Years of arctic experience gave GSI much knowledge about operating in extreme cold weather. Engineering teams worked hand in hand with field operations personnel to overcome the data collection gathering problems caused by harsh weather conditions. The result was to have well-trained personnel, new equipment technology, survey automation techniques, advanced logistical support technology and improved data collection and processing techniques. These innovations enabled GSI to be consistent in acquiring large amounts of high-quality data in the short arctic season.

*** GSI vintage videos courtesy of Schlumberger – WesternGeco**

Tutorial Nuggets
By Mike Graul

Can this be the Wrap Up on Inversion for Fracturing ?

Probably not, but let's give it a try, so we can start tutorizing on subjects that are murky to you, but of course fully understood by your neighborhood Guru .

The Tutored

So what have we learned so far?

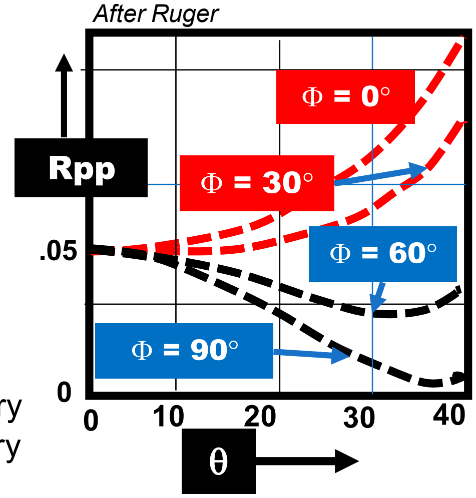
If you figure that out, let me know !

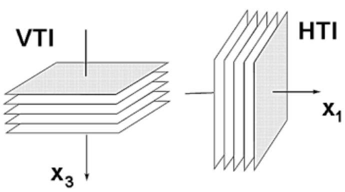
Guru in Tutorial Mode

The Guru (mildly incensed): I'll do the teaching around here. And this time, **LISTEN.**

At the right is the basic notion at work here, namely that in the presence of anisotropy the **S** to **R** azimuth will influence **AVA** behavior. This manifests itself for this **HTI** model as a dramatic variation in gradient with Φ, the azimuth angle. Note that the red dashed curves exhibit a positive gradient indicating that they are travelling ⊥ to the fracturing azimuth (Φsym) while the blue curves are close to || to the fracture azimuth (Φiso). In this case, **Φiso = 90°**, while **Φsym = 0°**. This might just be valuable information to someone in the exploration and drilling game.

After Ruger





Note that these two models are very similar with the axes of symmetry (**X_1 and X_3**) orthogonal.

A recent paper by **Lynn** and **Goodway** in *Interpretation*, reveals still another juicy concept, the idea that the near vertical incidence angle (θ = 0°) may be displaced from the convergence we see in the **Ruger** model, above, due to what might be called the anisotropic behavior of **porosity.**

Co-Conspirators

What??!!

Angry **Anisotropists** respond. Many call for **beheading** – the standard penalty for **Seismic Heresy**

A startled **Heloise** quickly walked back the assertion with her PR spokesman saying, "Dr Lynn merely meant that waves travelling **perpendicular** to the **faces of the penny-shaped** aligned fracturing would **perceive** a greater **porosity** than those traveling parallel to the alignments. Isn't that why we prefer drilling in that orientation? Dr Lynn would like to talk about something else now. Anything else." **Bill Goodway**, noted **LMR**ist, declined comment.

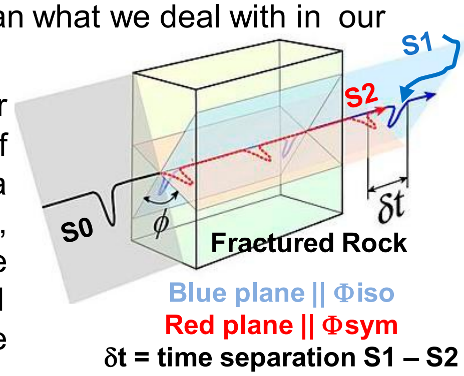
Tutorial Nuggets continued on page 22.

Tutorial Nuggets continued from page 21.

Curious

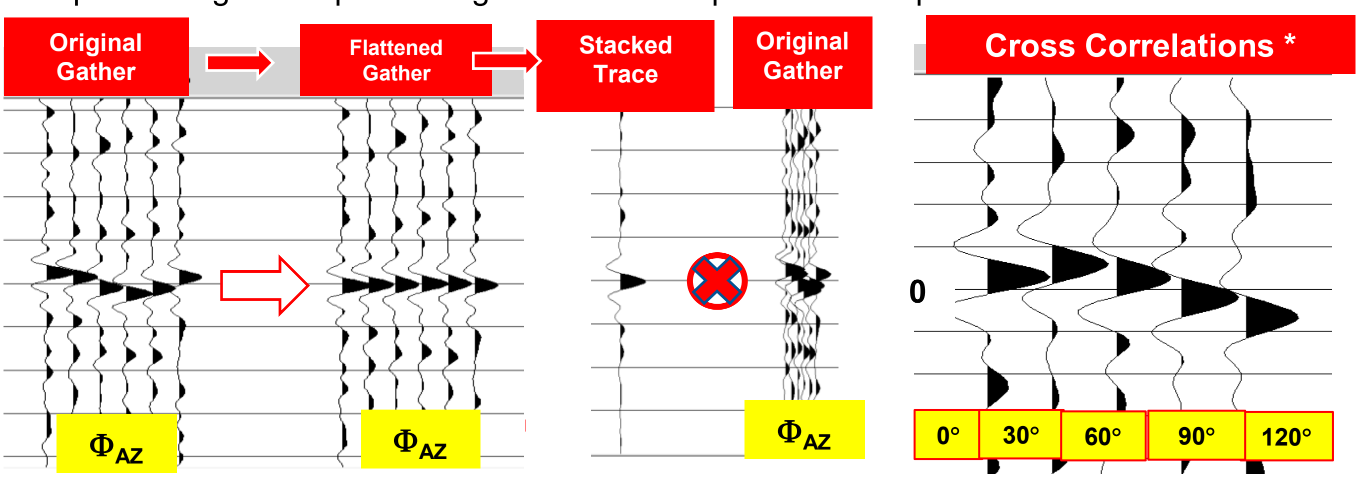
In medicine, as in general research, 2nd opinions are welcome. Is there a way of confirming your PP inversion technique – a second opinion, so to speak?

Doctor, it is a pleasure to have you enter this discussion, despite your busy schedule doing obviously more vital functions than what we deal with in our relatively trivial practice.



Yes, indeed, we do have a back-up plan. Some even consider it to be more reliable. Time will tell. It's based on the concept of **S-wave splitting**, which arises when an S-wave impacts a fractured layer (the block at the right). The incident S–wavelet, **S0**, is **polarized** into **orthogonal planes**, paralleling the **Isometry** and **Symmetry** orientations, respectively, labelled **S1** and **S2** in the cartoon. **S1** represents the "Fast Vs" while the **S2**, perpendicular to the fracturing, is the "Slow Vs" causing a time separation, **δt**, when the S-waves emerge from the fractured rock. It is this time difference we will use to determine the azimuth of fracture orientation, Φiso. The magnitude of the δt is used to estimate of the anisotropic parameter, **γ = (S1 – S2)/S1.**

The processing technique leading to the desired quantities is depicted below.



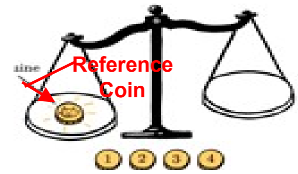
The first panel, original gather is an **azimuthal gather** depicting an event immediately below a fracture rock. An automated process is used to **align** the event times differences around the approximate average arrival times (2nd panel). The azimuthal traces are then **stacked** to form a **stacked trace** with the appropriate wavelet shape and improved **S/N**. This trace is then cross-correlated, ⊗ with each of the original Φ_{AZ} traces, over a short time zone, to determine the Φ_{ISO}, Φ_{SYM}, and **δt**. Here, those values would be **30°**, **120°**, and **.013 ms**, respectively.

Where, you ask, did the Shear data come from? Directly from the **Hardage Theorem**, which tells us that an old legacy **"P-wave"** data set has hidden within it an abundance of S to P **converted wave** (**SvP**). All you have to do is find a competent processor to extract it from its ubiquitous, but obscured, presence in your 3D. Folks, this stuff works.

Tutorial Nuggets continued on page 23.

The October Puzzle

This one is reminiscent of the earlier Nugget puzzles*, but sneakier.



Chris Egger, GSH Treasurer, Has been asked to have 4 Duncans minted for 20-21 President Peter, who uses these as his tipping supply for the ever-frugal President's Fall travel season. Chris, as usual, turns to the GSH Mint, housed in the Kathy & Karen Bar and Grill back room. When Treasurer picks up the Duncans, he is devastated by a note he finds next to the coins (apparently written by a counterfeiter, which suggests that one of the identical coins is not real. Acting swiftly, our fast thinking money man, knowing fake coins do not weigh the same as the real Duncan, he acquires the services of the **GSH Balance Scale**, and a **Reference Duncan,** guaranteed to be real. Time is of the essence, so help Chris find the **minimum number of weighings** to determine **(A)** whether there a Fake Duncan among the newly minted four; **(B)** if there is a fake, which coin is it; and **(C)** is it heavier or lighter.

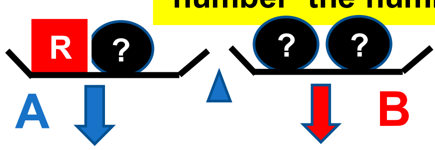
As a **bonus question**, suppose the former miserly Peter asks for **13 namesake coins** be minted. Apply the same clues and rules, What now is the minimum number of weighings?

Solutions: First some clues, keys and definitions. The coins**: Reference** (valid Duncan) = R
Labelled Coins – their potential or real weight (after a weighing trial) : **Heavy** = H
Light = L ;**Unknown** (Unproven Duncan or potential counterfeit) = ?

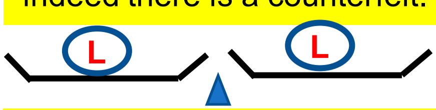
? ? ? ? R

1st Problem: 4 coins and a reference. In order to minimize the number the number of weighings, the trial before the last must reduce the unknowns with labels to 3 or the unknowns without labels to 1.That is done by choosing the first weighing as shown.

Weighing 1



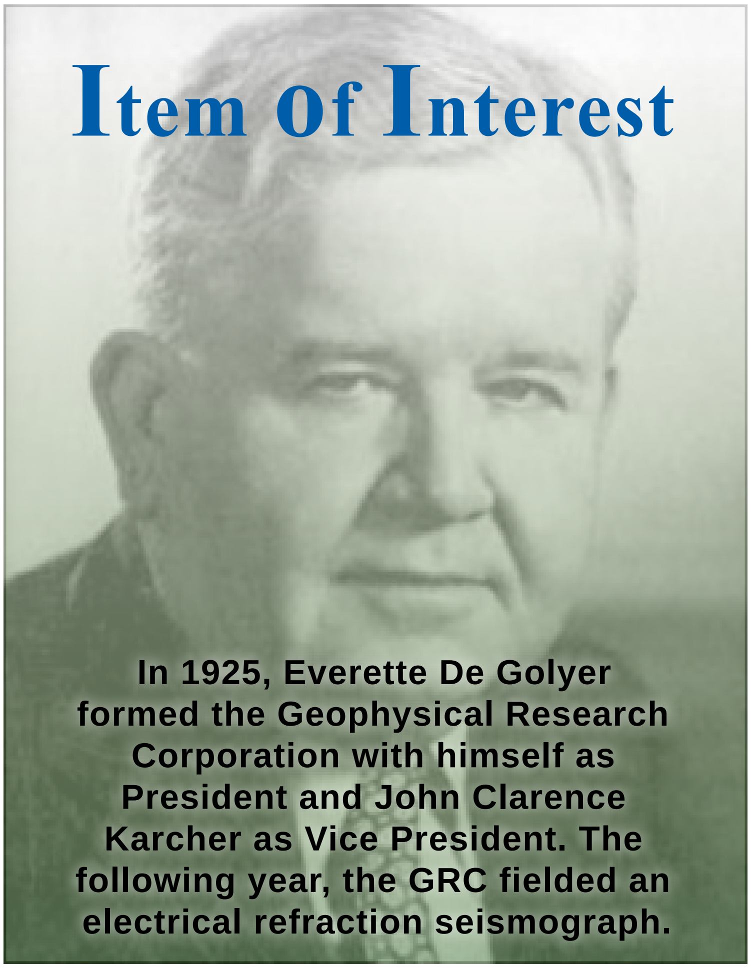
Three things can happen. (**A**) The left pan goes down so either the unknown (**?**) on the left is heavy (**H**) or one of the 2 unknowns on the right pan is **light** (**L**) compared to the **R**. (**B**) The right pan goes down and the left goes up which means the counterfeit is either one of the two on the right pan to be labelled **H**, or it's the unknown on the left to be labelled **L**. (**C**) The third possibility is that the **pans balance**, indicating that the remaining unknown (**?**) is our culprit, if indeed there is a counterfeit.



For either situation **A** or **B**, the configuration of the final trial is shown at the left, with the two possible **L's** weighed against each other. If either goes up, he's our **bad guy**. If they balance, it must be the one we labelled **H** from the first weighing. For case **C** the Unknown (**?**) is weighed against a reference (**R**). Any **imbalance** gives us the **weight** and **identity.** A **balance** says there is **no counterfeit.**

Now, the Bonus Puzzle presents some special problems, but the same principles apply, We did the 12-unknowns problem* back in December of 2015 (or Page 139 Book 2) in 3 weighings. Will that work for 13? We'll allow you an extra month for that solution.

Item of Interest



In 1925, Everette De Golyer formed the Geophysical Research Corporation with himself as President and John Clarence Karcher as Vice President. The following year, the GRC fielded an electrical refraction seismograph.

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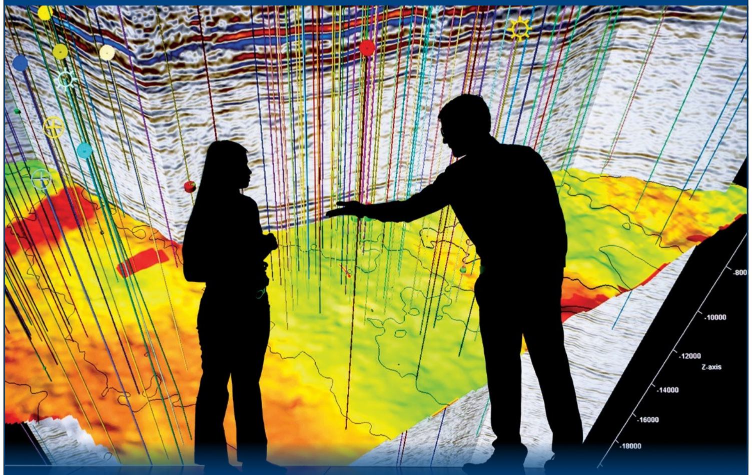

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The Mystery Item on page 17 is a

Thyssen Gravity Meter from the 1930's and probably is the first field gravity meter.

It was donated to GSH Geoscience Center by Seismos.

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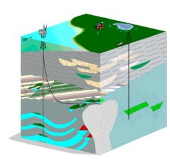

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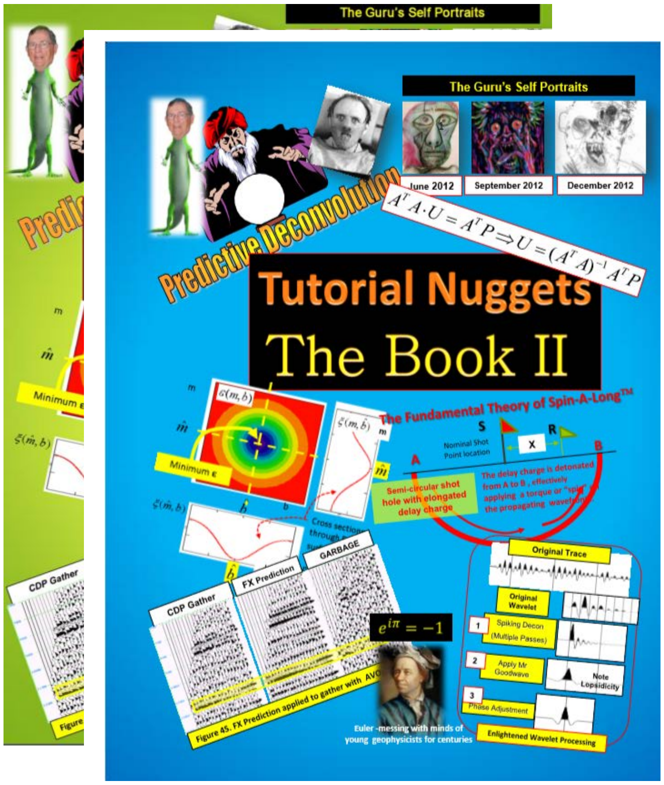

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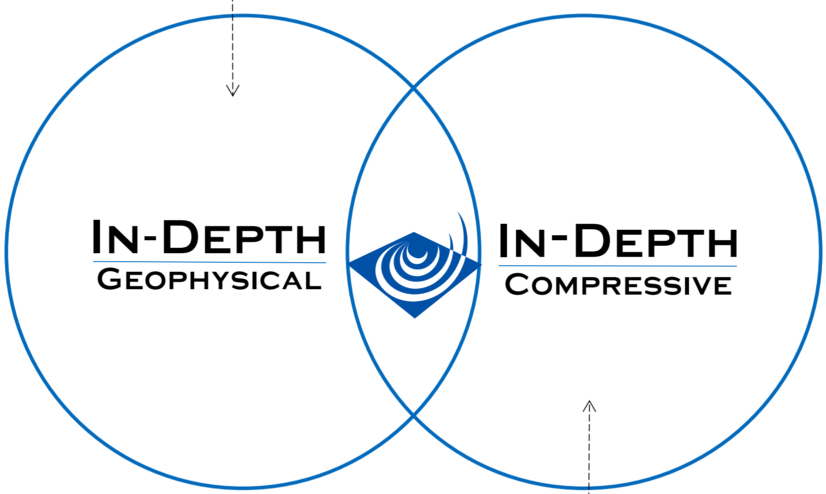

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Doodlebugger Diary

The Wild West: Adventures on the M/V Western Gulf in the Gulf of Mexico, 1979-1982

Part 2: Operations Aboard a Seismic Vessel (Part 1 of 2)

By Scott Singleton

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. Since early 2018, I have been recounting my own experiences and encourage those of you with experiences of your own to contribute. Your fellow industry professionals would love to hear your stories. I've had a lot of great comments about Nancy House's 3-part series on her Peruvian jungle experiences in the 1990's.

Last fall, I started reprinting early 1980's articles from the GSI Shotpoints that can be found at http://gsinet.us/. In March, I shifted to reprints of Western Geophysical Profile articles that are repositoried at https://seg.org/Publications/Journals/Western-Profile.

My current series recounts my time on Western Geophysical's Party 76. Part 1 was published in September's Journal.

When I first started my doodlebugging career for Western Geophysical in the Gulf of Mexico, their fleet mostly consisted of four smaller 'Green Meanies' *(M/V Western Gulf, Western Reef, Western Crest, and Western Geo II)*. These vessels had 90' hulls with an extra 10' section built onto their stern to make the deck section a total of 100' long. There also were two larger (135') Green Meanies in the GOM – the *M/V Western Cay and Western Cape (Figure 1)*. Western of course had many vessels at that time, most of which were larger than the GOM vessels, and these were positioned around the world. Their larger size enabled them to hold more supplies onboard, which enabled them to stay at sea for longer periods of time. This of course enabled more efficient operations, but in some parts of the world there was no other choice. In some places, to supply a seismic boat meant flying everything in from outside the country, which as you can imagine was quite expensive.

So, the little boats worked the domestic scene in the GOM. Their small size meant they were relatively cheap to operate. The downside to this was they could not hold many supplies, and we had a regular work schedule

Figure 1: The big and small brothers: The M/V Western Cape and M/V Western Gulf at the Western Geophysical dock on Pelican Island, Galveston in 1980. They are parked outboard of one of the other smaller 'Green Meanies', partially visible on the far-left side.

Doodlebugger continued on page 32.

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 31.

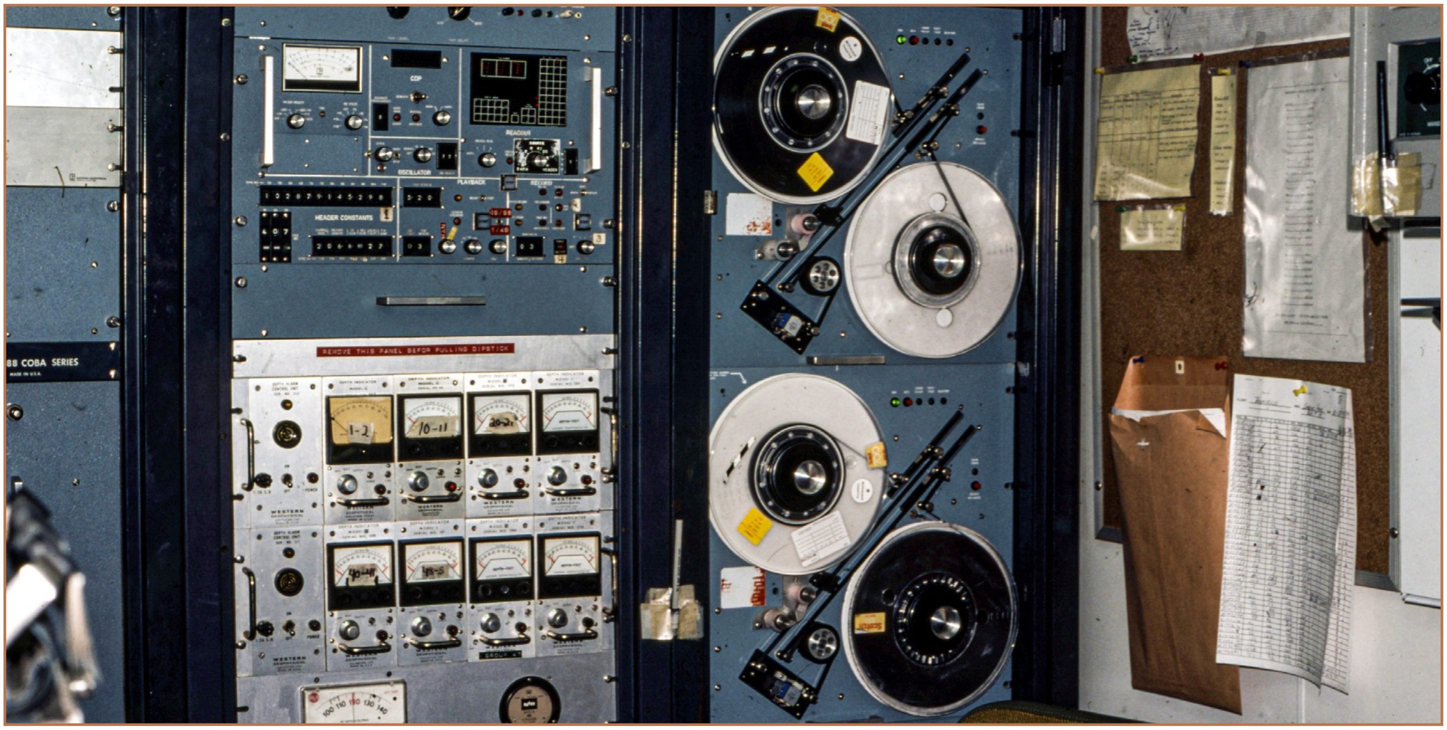

Figure 2: Two banks of the Western Geophysical LRS-888 COBA recording system. The upper left panel contains controls for various recording and playback parameters, including streamer test controls. The lower left panel contains depth gauges for portions of the streamer that have birds (depth control devices). The right bank was our two tape drives loaded with 3M Black Watch 700 tapes. The top drive is almost finished recording; the bottom drive is fresh and will take over when the top drive runs out of tape. On the top of the corkboard, to the right, is a section of shot readout where I labeled the various components of the record. I would post different things on this board, including stack sections that I had interpreted, to teach the crew the science behind the work we were doing. The fathometer is partially visible on the far right.

of 14 days on and 7 days off. During the off time, everyone would go home, and the boat stayed at the dock. Our salaries were based on an 80-hour base over a 2-week period. When we were onboard, we worked 12-hour shifts so you could make up your base in 1.5 weeks. Everything past that was overtime at 1.5 times your base salary.

The smaller ships had a basic configuration that consisted of the bridge (wheelhouse) up front on the second level, followed aft by the navigator's room and then the galley (where food was served and was essentially the only place on the boat where people could congregate indoors). Below that were the bunk rooms. Aft of that was the geophysical instrument room (the 'doghouse'). On top of the doghouse was the energy source operations room (the 'shoot shack') that was inhabited by 'gunners'. The stern of the boat was called the 'back deck' (my father, who served in the navy in WWII kept telling me it was the 'stern deck', but that obviously was too formal of a name for us doodlebuggers). The back deck is where we did all of our streamer work. This area was covered with an awning, on top of which we stored our spare streamer sections. Below all of that was the engine room. I'll describe the doghouse and the seismic source (the 'guns') in this episode and the remainder next month.

The Doghouse – The recording room crew had only a few things they had to do once a line started. They had to change tapes, print off a camera record of a shot every 10 shots to make sure all of the streamer traces were within recording specs, and monitor the cable depth, issuing commands to the 'birds' if needed ('birds' are streamer depth control devices that were attached to the streamers at specified intervals; they are called birds because they

Doodlebugger continued on page 33

Doodlebugger continued from page 32.

control streamer depth by moving wings located on either side of the streamer).

The recording system we used was a Western Geophysical system called the LRS-888 COBA Series. All signal came in from the streamer as analog via small wires and was converted in the recording system (via an A/D converter) to digital signal prior to being recorded on 3M 700 Black Watch reel-to-reel tapes *(Figure 2)*. The streamers were typically 2 miles long and consisted of 48 traces. Each trace was 220' long with one trace per streamer section. The streamer sections were sheathed with a thick, soft plastic called a 'jacket' that protected the wires and hydrophone transducers from sea water. The streamer section was filled with a 'cable oil' which was an odorless, high-flashpoint kerosene with no aromatic content that was non-conductive.

The Guns – The acoustic source we used was called Aquapulse. It was a trademarked method devised by Western. In this system oxygen and propane were fed by hoses into each 'gun', which was a cylindrical device girded by a steel frame and covered by a thick rubber boot *(Figure 3)*. This device had a sparker inside of it that ignited the flammable mixture. The boot acted to contain the explosion and was very effective at dramatically reducing the bubble pulse emanating from the explosion. The burned air was vented to the water slowly, as a stream of bubbles that in themselves had minimal acoustic signature.

This methodology was effective at producing a clean seismic signature. The downside was its limited energy output. In an attempt to counteract this deficiency, strings of Aquapulse guns were strung together to form an array. There were typically two guns per set, with four sets per boat, each set deployed away from the vessel via an outrigger *(Figure 3)*, thus forming a rectangular source array. Another method of increasing total energy was taking multiple shots at each CDP location. This of course could not be done if the vessel was operating in normal streamer mode, but our small boats often were deployed in shallow water to conduct 'back down and drag' operations. This was where we weighted the streamer down with chains and while shooting a line the vessel would pull up to a shot location, stop the boat and back down for about 30 seconds to let the streamer settle on the seafloor. We would then proceed to fire off 4 shots, each recorded with an 8-second record, before starting the engines and pulling up to the next CDP location.

As an epitaph for the Aquapulse technique it should be noted that this method and several others like it all became extinct when Bolt Technology Corp. perfected their high-volume air guns in the 1980's. They did this by designing arrays of air guns that varied in cubic inches of released air from large to small. When all of these air guns fired off at once, the sum energy was huge, but more importantly, the different air guns all had their own frequency characteristics and bubble pulses, so that the sum total was a broadband energy signature and whose bubble pulse was significantly mitigated via destructive interference.

Next Month: Part 3: Operations Aboard a Seismic Vessel (Part 2 of 2) □

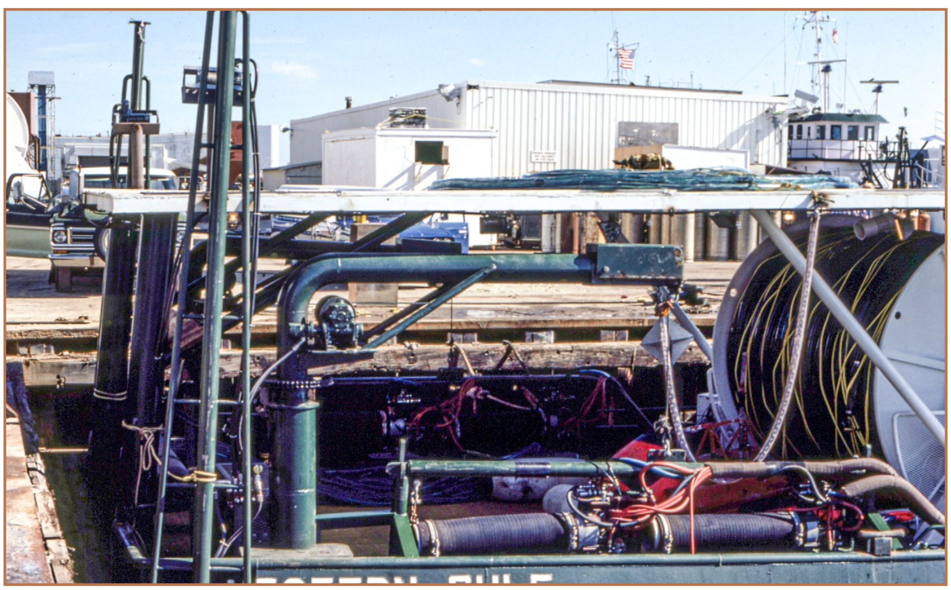

Figure 3: The back deck of the M/V Western Gulf showing the streamer reel and one of the 2-gun Aquapulse arrays. Another gun array is partially visible on the far side of the back deck. Spare streamer sections can be seen on the awning over the back deck. This picture was taken at the Western Geophysical dock on Pelican Island in 1980. On the far-right side of the photo, the superstructure of one of the larger 'Green Meanie' boats can be seen and a second mast behind it.