

May 2021



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# GSH Journal

GEOPHYSICAL SOCIETY OF HOUSTON  
Volume 11 • Number 9



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Time-frequency Masking Guided – Page 9**

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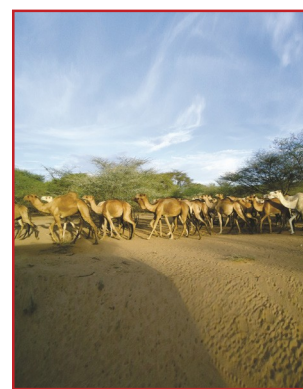
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A camel herd encountered during a seismic survey in the Middle East.

Photo courtesy of Global Geophysical.



## 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 [AlvaroChaveste@hotmail.com](mailto:AlvaroChaveste@hotmail.com)

### GSH JOURNAL DEADLINES

Sept 2021 ..... Jul 16

Oct 2021 ..... Aug 16

Nov 2021 ..... Sept 16

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# A Word from the Board

*Metamorphosis – Letting Go of the Old, Embracing the New* By Lucy Plant, Treasurer Elect



For many of us this month marks the one-year mark for working from home. Looking back on the last year it seems almost surreal, I remember the notification coming that we would be transitioning to working from home for the 'coming weeks' we had training sessions on working

from home, friendly reminders about cleaning and sanitization and with that we jumped in to a world of remote learning, zoom meetings and, for some of us, the daily juggle of suddenly having to home school our children (I don't know about you but I now have a whole new appreciation for what teachers do).

The past year has transformed nearly every aspect of our world seemingly overnight. Suddenly attending a client meeting in sweat pants and the unscheduled interruptions of pets/children/spouses became somewhat normal and through the lens of online meetings we got to see another side of our colleagues and clients seeing the person behind the position and building stronger connections.

Living through a global pandemic has presented an opportunity for many of us to reassess our priorities and evolve professionally, although not without its challenges, the opportunity to work from home has presented us with many benefits, for example, to attend zoom yoga sessions during our lunch hour, or carry out household chores whilst on a call to the more fundamental opportunity to spend more time with our children and spouses.

Companies are also evolving and as offices begin to reopen many employers, initially concerned about productivity rates with working from home, are now embracing flexibility offering hybrid work options. Digital transformation has gone from being a corporate buzz word to a key focus (don't forget to sign up for our GSH-SEG Spring Symposium on Apr 27-28 to hear from industry experts on how

they believe Machine Learning and AI will change our industry).

The GSH has also had to evolve. For a society such as ours the pandemic has presented several challenges. As a non-profit organization a lot of our operating costs are covered by monies generated from our luncheons and events and from corporate donations with the double whammy of a pandemic and commodity price crash these funds dried up quickly and we needed to adapt rapidly to our new virtual world hosting online events and virtual happy hours. Our GSH members have responded resoundingly positively to the flexibility offered by online meetings and, although we will hopefully restart in person meetings again soon, I believe the flexibility of online meetings will be here to stay.

This pandemic and the pressures that came with it highlighted areas for improvement within the society, our recent member survey provided important food for thought in respect to the continued direction and focus of the organization. We believe this pandemic and the challenges it presented can help the GSH metamorphose into a stronger organization, and, as a board, we are committed to ensuring the longevity of the GSH through innovation and creativity, and to ensure that we remain inclusive and representative of our members whilst also providing both technical and professional value to them.

Just as we are looking to evolve we are also seeing other societies evolve, I am sure many of you have seen the announcement that the SEG and American Association of Petroleum Geologists (AAPG) will be holding joint annual meetings in September the first time the two groups annual conventions have been held together since 1955. The combining of these two great events will foster greater interdisciplinary learning.

The COVID-19 pandemic has a large dark side, but it has presented many positives as well. As we let go of the old ways of doing things and embrace the new, we look forward to the new opportunities this presents both personally, professionally and as a society. □



# From the Other Side

By Lee Lawyer



Previously, I told you that I had finished my three training years on seismic crews and then went on to a year in the Gravity Section in Houston. After Gravity, I was sent to the Standard Oil Company of Texas's (SOTEX) office in Amarillo. I liked Amarillo; I was the second geophysicist amidst all those geologists. The other geophysicist did not

work, and he was my boss. This begins to sound like 'Interpreter Sam'. We discovered 120 million bbls OEG (Oil Equivalent Gas) and over twenty million bbls of oil both from my work (hear that Sam?). I was in Amarillo for about six years when the company closed the Amarillo office because of organizational changes (too bad Sam.) That was the last time any Oil or Gas was discovered on one of my interpretations. I was told that my next paycheck was waiting for me in Oklahoma City, which is the City where I grew up. I graduated from Oklahoma University, several miles south of my new downtown office. I had returned to my roots. We did not find a bbl of oil/gas in Oklahoma if you can believe that.

Things changed, I cannot recall when and where I was located (probably still in Amarillo) when a scout brought us information about a Phillips seismic crew out of Midland who was taking a shot every 750 feet. I'm not sure of that number but our normal shot separation was a lot longer than that. Phillips contract crew was Petty Geophysical. They were probably acquiring three-fold data, you know the rest of that story. Ken Gilliland, the Division Geophysicist in Oklahoma City for Chevron, was the first person in Chevron to really understand how significant that advancement was. Ken acquired a six-fold line in East Texas. When challenged by our Research group and other company geophysicists, his answer was direct, "Look at the new line and compare it to other lines in the area", the uplift spoke for itself.

I stayed five or six years in Oklahoma City, then off to Houston. My job there was on the staff of the Chief Geophysicist, Chuck Edwards. My stay

in Houston did not last long, a big reorganization sent me to Denver. The new organization covered two large Divisions, Rocky Mountain Division, and the Midcontinent Division. I started as Staff to the Chief Geophysicist, Joe Spencer but soon took over the Midcontinent Division. Are you getting tired and confused? Too many Chiefs in the kitchen? Chuck Edwards moved up to Chief Geophysicist of the corporation, we called him Super-Chief.

Another move came after five or six years in Denver, I was moved to San Francisco as Division Geophysicist of the Alaskan Division. Brrrrrrrr! I was officed in San Francisco though, not Alaska. Pete Diamond was my Chief Geophysicist. San Francisco was beautiful, my office was downtown, a few blocks up from the Ferry building which survived the great earthquake in 1906 and a few blocks down from the square. My house was many miles away in Walnut Creek and after another move or two, in Round Hill which was even further away from my office. Somewhere in there I moved to Chevron Overseas, COPI, to the same building on Market. I could spend the rest of the year explaining why San Francisco is so beautiful, but I will not. I strongly recommend that you visit there. (Bring big money if you plan to stay.) After San Francisco I went back to Houston, to stay.

I want to try to remember those Chief Geophysicists: Chuck Edwards, Joe Spenser, Pete Diamond, John Northwood, and then back to Chuck Edwards, the Super-Chief. I am kidding a little bit, but I liked all these very diverse Chiefs. Funny thing about John Northwood, he resigned from COPI at precisely the right time for me to become his replacement as General Chairman of the SEG Convention in San Francisco. Wow! Also, I became Chief Geophysicist of COPI. After a few glorious years as Chief Geophysicist of COPI, I was offered a Vice President position in Houston with Chevron Exploration and Production Services Co. Don't go away. After a year of two, I was offered the position of Super-Chief and I accepted. In the next ten years I reported to the E&P Director on the Chevron's Board of Directors. In order, Larry Funkhouser, Al Martini, and Bill Crain. That was top of my profession, no more rungs in the ladder. I retired in Houston in 1996 after nearly 39 years with Chevron. That was 25 years ago but I am still a doodlebugger at heart and soul. □





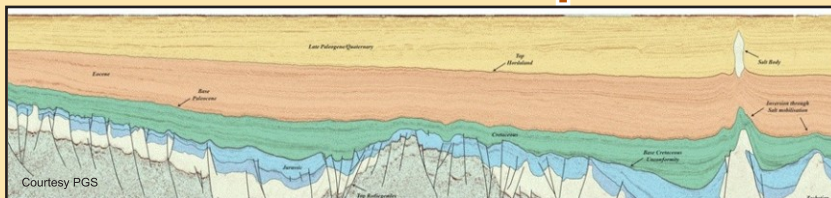
# A Live Webinar

Sponsored Jointly by the SEG and GSH



SOCIETY OF EXPLORATION  
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## Basic Seismic Interpretation



Four Half-days (9 AM - 1 PM Houston Time) May 25-28, 2021



Presented by  
**Don Herron & Bob Wegner**



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# GSH Technical Events



## Rock Physics SIG

*Elastic Waves in Unconsolidated Sands*

**Colin Sayers, University of Houston**

[Abstract and Bio](#)

Online presentation - May 5, 2021 - 12:00pm-1:00pm CST

[Register](#)



## Unconventional SIG

*Climate Change, the Energy Industry, and the Role of Carbon Capture Utilization and Storage*

**Ali Tura, Colorado School of Mines**

[Abstract and Bio](#)

Online presentation - May 6, 2021 - 11:00am-12:00pm CST

[Register](#)



## Data Processing & Acquisition SIG

TBA

**Speaker**

[Abstract and Bio](#)

Online presentation - May 11, 2021 - 5:00pm-6:00pm CST

[Register](#)



## Technical Breakfast

*Seismic Denoising using Structure-Similarity-Aware Stacked Denoising Autoencoder Networks*

**Wen Hu, Forland Geophysical Services**

[Abstract and Bio](#)

Online presentation - May 12, 2021 - 7:00am-8:00am CST

[Register](#)



## Data Science and Machine Learning SIG

*Applications of Machine Learning for Rapid Analysis of Distributed Acoustic Sensing Data Monitoring Hydraulic Fracturing*

**Richard Gibson, NanoSeis**

[Abstract and Bio](#)

Online presentation - May 12, 2021 - 11:00am-12:00pm CST

[Register](#)



## Technical Lunch

TBA

**Speaker**

[Abstract and Bio](#)

Online presentation - May 19, 2021 - 11:00am-12:00pm CST

[Register](#)



## Potential Fields SIG

*Fatiando a Terra: open-source tools for geophysics*

**Leonardo Uieda, Santiago Soler and Agustina Pesce**

[Abstract and Bio](#)

Online presentation  
May 20, 2021 - 4:00pm-5:00pm CST

[Register](#)



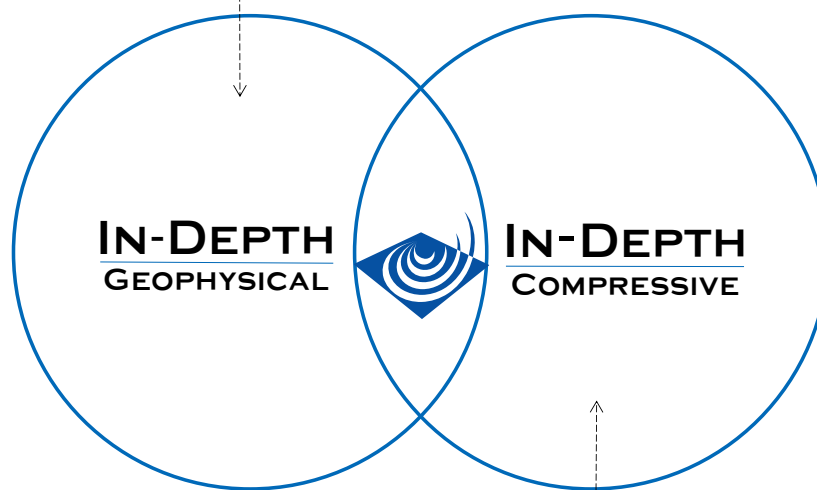
# *Annual Meeting and Year End Celebration*

Thursday, 27 May 2021



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# Seismic Data Enhancement and Targeted Noise Removal Using Time-frequency Masking Guided by Beamformed Data

Andrey Bakulin, Geophysics Technology, EXPEC Advanced Research Center, Saudi Aramco, Dmitry Neklyudov, Institute of Petroleum Geology and Geophysics SB RAS, Novosibirsk, Russia; Ilya Silvestrov, EXPEC Advanced Research Center, Saudi Aramco

## Summary

Land seismic data are often quite challenging for reliable seismic imaging. The mechanism responsible for difficulties in data processing may be identified as severe frequency-dependent phase and amplitude perturbations making events incomprehensible in multi-channel records. We present a new approach by combining nonlinear beamforming and time-frequency masking to compensate for such effects in two steps. First, we construct a crude signal “guide” using data-driven nonlinear beamforming. Second, we employ trace-by-trace time-frequency masking to repair damaged phase and amplitude. Phase masks are of paramount importance to heal the wavefield and make desired events coherent and trackable. Amplitude masks aim to suppress noise from the amplitude spectra. Introduced methods avoid smearing of amplitude information across channels and preserve frequency bandwidth of desired signals.

## Introduction

Modern land seismic acquired with single sensors or small arrays requires significant prestack enhancement. Separating signal and noise appears to be an insurmountable challenge when reflections become broken up and invisible while scattered noise dominates. Local multidimensional stacking can successfully identify and enhance weak signals on prestack seismic data (Buzlukov and Landa, 2013; Bakulin et al. 2018). While massive multidimensional stacking methods summing hundreds and thousands of traces are efficient at finding events in the noisy original data, they are infrequently used in mainstream seismic processing because of undesired side effects: 1) Original amplitudes at each receiver point are biased (heavily averaged); 2) Data is overly smoothed and important local traveltimes or amplitudes features characterizing near surface or

subsurface are distorted; 3) higher frequencies are suppressed during beamforming/local stacking. Beamforming is often used to condition the data for deriving time processing parameters (Bakulin and Erickson, 2017), but distortions introduced by local stacking are typically considered as too severe for reliable quantitative analysis. Here we propose an alternative approach that uses massively beamformed data as a “signal guide” that “corrects” corrupted data but only to the extent required for conventional methods to work.

## Time-frequency masking guided by beamformed data

The propagation of seismic signals is a nonstationary process. As a consequence, desired signal estimation procedure is designed in the time-frequency (TF) domain using the short-time Fourier transform (STFT). It is useful to relate the “healing” procedure to time-frequency masking (TFM) from speech processing (Yilmaz and Rickard, 2004). While in the speech processing, there is usually “noisy speech” and approximately estimated “clean speech,” we replace them with the analogs of “noisy data”  $x(t)$  and “enhanced (beamformed) data”  $s(t)$ . The enhanced dataset from beamforming or local stacking represents our best estimate of the signal with a much higher signal-to-noise ratio but suffering from limitations above. We assume that the enhanced dataset retains identical structure and number of traces.

As in speech processing, our goal is to extract the best estimate of desired signals contained in  $x(t)$  using corresponding enhanced trace  $s(t)$  as a guide. Applying STFT to  $x(t)$  and  $s(t)$ , we obtain complex-valued time-frequency (TF) spectra of the traces  $X(k,l)$ ,  $S(k,l)$  with  $k, l$  representing the discrete frequency bin and time frame indices, respectively. The input signal in TF domain  $X(k,l)$  contains superposition of actual signal and noise. TFM

*Technical Article continued on page 10.*

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



provides an estimate of desired signal TF spectrum  $\hat{S}(k,l)$  as a multiplication

$$\hat{S}(k,l) = M(k,l) \cdot X(k,l). \quad (1)$$

In speech processing  $M(k,l)$  is typically a real-valued function,  $0 \leq M(k,l) \leq 1$  (Wang, 2008); however, a complex-valued TFM has also been recently introduced (Williamson and Wang, 2017). Clean speech (i.e., “signal”) and noise properties are required to design TFM. In contrast to seismic, in speech processing, a reliable estimate of the desired signal spectral distribution is usually available. We propose to utilize an enhanced dataset from local stacking as an analog of clean speech. Having a “guide” dataset from beamforming identical in the number of channels, we can perform single-channel TFM filtering where each “noisy trace” is subject to specialized TFM derived solely based on corresponding “enhanced trace” from beamforming, thus simplifying the processing sequence to trace-by-trace transformations.

### Phase corrections (phase-only TFM)

Bakulin et al. (2019) has demonstrated that phase plays an outsized role in restoring coherency of broken up reflections. Specifically, two phase methods were introduced. *Phase substitution*: We take the TF phase of the enhanced trace as our best estimate of the signal phase, whereas the amplitude spectrum remains untouched. TF spectrum of the desired signal trace is given as:

$$\hat{S}(k,l) = |X(k,l)| \exp[i\varphi_S(k,l)], \quad (2)$$

where  $|X(k,l)|$  is amplitude TF spectrum of original trace, and  $\varphi_S$  is the phase spectrum of the enhanced trace after beamforming. Phase substitution method can be considered as a special case of complex-valued phase-only TFM with

$$M(k,l) = \exp[i\{\varphi_S(k,l) - \varphi_x(k,l)\}], \quad (3)$$

as can be easily observed by substituting (3) into (1). Here  $\varphi_x$  and  $\varphi_S$  are phase spectra of original (“noisy”) and enhanced traces, respectively.

*Phase sign corrections*: We correct the phase of original data using phase sign-correction mask (PSM)

$$\begin{aligned} \hat{S}(k,l) &= X(k,l) \cdot PSM(k,l), \\ PSM(k,l) &= \text{sign}[\cos\{\varphi_S(k,l) - \varphi_x(k,l)\}]. \end{aligned} \quad (4)$$

If original and enhanced data are in phase (phase difference is less than  $\pm\pi/2$ ) at a specific frequency – then no correction is made ( $PSM = 1$ ). If they are out of phase (difference more than  $\pm\pi/2$ ), then phase at this frequency is flipped by  $\pm\pi/2$  ( $PSM = -1$ ).

Both methods represent specialized phase-only TFMs maintaining original amplitude information as well as higher frequencies without smearing across multiple channels. In this study, we introduce the next step of targeted noise removal by additional application of amplitude TFMs also guided by the same beamformed data.

### Targeted noise suppression with amplitude TFM

TFM are widely used for single-channel enhancement of noisy speech signals. Amplitude TFM applies a simple real-valued function, which is close to 1 in a “signal dominance” region of the TF spectrum and close to 0 in a “noise dominance” area. One of the most popular “soft amplitude” based TFM is the so-called Ideal Rationale Mask (IRM). One possible realization of IRM is defined as:

$$IRM(k,l) = \sqrt{\frac{|S_{est}(k,l)|^2}{|S_{est}(k,l)|^2 + |N_{est}(k,l)|^2}}, \quad (5)$$

where  $|S_{est}(k,l)|^2$  and  $|N_{est}(k,l)|^2$  are estimates of desired signal and noise power spectra, respectively. In speech processing the noise power TF spectrum is estimated using established methods such as minimal statistic (MS) approach (Martin, 2001). After that, the clean speech power spectrum is estimated by spectral subtraction. In seismic exploration, we have little a priori information about the real behavior of the noise power spectrum. Noise and desired signals in seismic data do not necessarily satisfy the assumptions of the MS approach or other methods widely used in speech processing. Also, one usually deals with broadband sources, i.e., with signals which have useful components within the entire frequency band (2-100 Hz), so models of “colored” uncorrelated noise are not very useful. Instead, we can rely on some rough signal estimation obtained as a result of a data enhancement based on local stacking (beamforming) procedure. This information

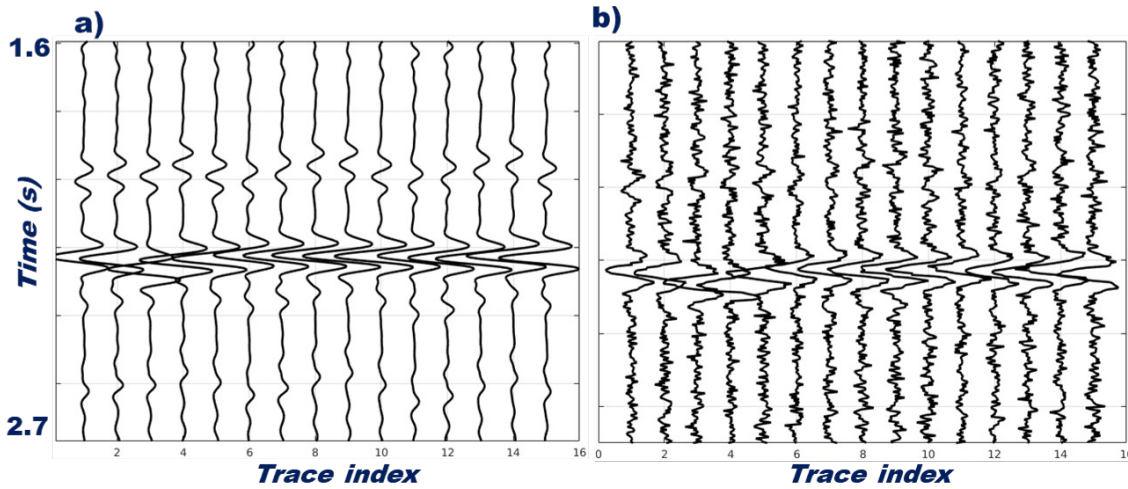


Figure 1: (a) Ensemble of original 15 traces. Reference trace has index 1. (b) The same ensemble contaminated by white gaussian noise (SNR=-2dB)

may be used to construct “Seismic IRM” utilizing the following scheme.

1. Original trace  $x(t)$  and a “guide” trace  $s(t)$  are normalized by their energy  $Q_1 = \sum x^2(t)$ ,  $Q_2 = \sum s^2(t)$ , so we further deal with the traces  $x_n(t) = x(t)/Q_1$  and  $s_n(t) = s(t)/Q_2$ .
2. STFT is applied to  $x_n(t)$ ,  $s_n(t)$ .
3. Phase correction mask, PSM is calculated using expressions (3) or (4).
4. “Signal intersection” power spectrum is calculated as  

$$|SI(k,l)|^2 = \min \{|X(k,l)|^2, |S(k,l)|^2\}$$
at each point  $k, l$ .
5. Noise power spectrum is estimated by spectral subtraction  

$$|N_{est}(k,l)|^2 = |X(k,l)|^2 - |SI(k,l)|^2.$$
6. Normalized “enhanced” trace power spectrum is used as an estimation of the “signal,”  $|S_{est}(k,l)|^2 = |S(k,l)|^2$ .
7. Estimated IRM is applied together with the phase correction masks (3) or (4)  

$$\hat{S}(k,l) = X(k,l) \cdot PSM(k,l) \cdot IRM(k,l).$$
8. After inverse STFT, the obtained trace is renormalized by the energy of the original trace  $Q_1$ , i.e.  $\hat{S}(t) = Q_1 * ISTFT[\hat{S}(k,l)]$ .

We emphasize that the most essential and nontrivial item in the whole procedure is how noise and signal power spectra are estimated. We described here only one of the many possibilities.

### Synthetic example: noisy ensemble from elastic model

We demonstrate the performance of phase and amplitude TFM’s on synthetic elastic data calculated for the 3D SEG/EAGE Overthrust model using land acquisition geometry. **Figure 1** shows an ensemble of 15 traces formed in the receiver domain before and after adding moderate white Gaussian noise (WGN) with SNR  $\sim -2$ dB. Our objective is to compare and contrast three different methods of estimating the original (noise-free) reference trace (first in the ensemble) from the noisy ensemble: conventional local stacking (with intra-array statics), phase correction method, and combined phase and amplitude TFM. We refer to the stacked trace as a “pilot” trace, and this “pilot” will be used for TFM constructions. **Figures 2 and 3** demonstrate that the pilot trace is deviating from the original trace due to time shifts and uncompensated phase variations of waveforms in the original ensemble. The pilot trace has SNR  $\sim 5.1$  dB in comparison with the reference noise-free trace. Here we treat the direct difference of output traces and known reference trace as “noise” in SNR calculation. Corrected trace after phase corrections is shown in **Figure 2b** (SNR  $\sim 2.2$ dB). It has better restoration of amplitudes



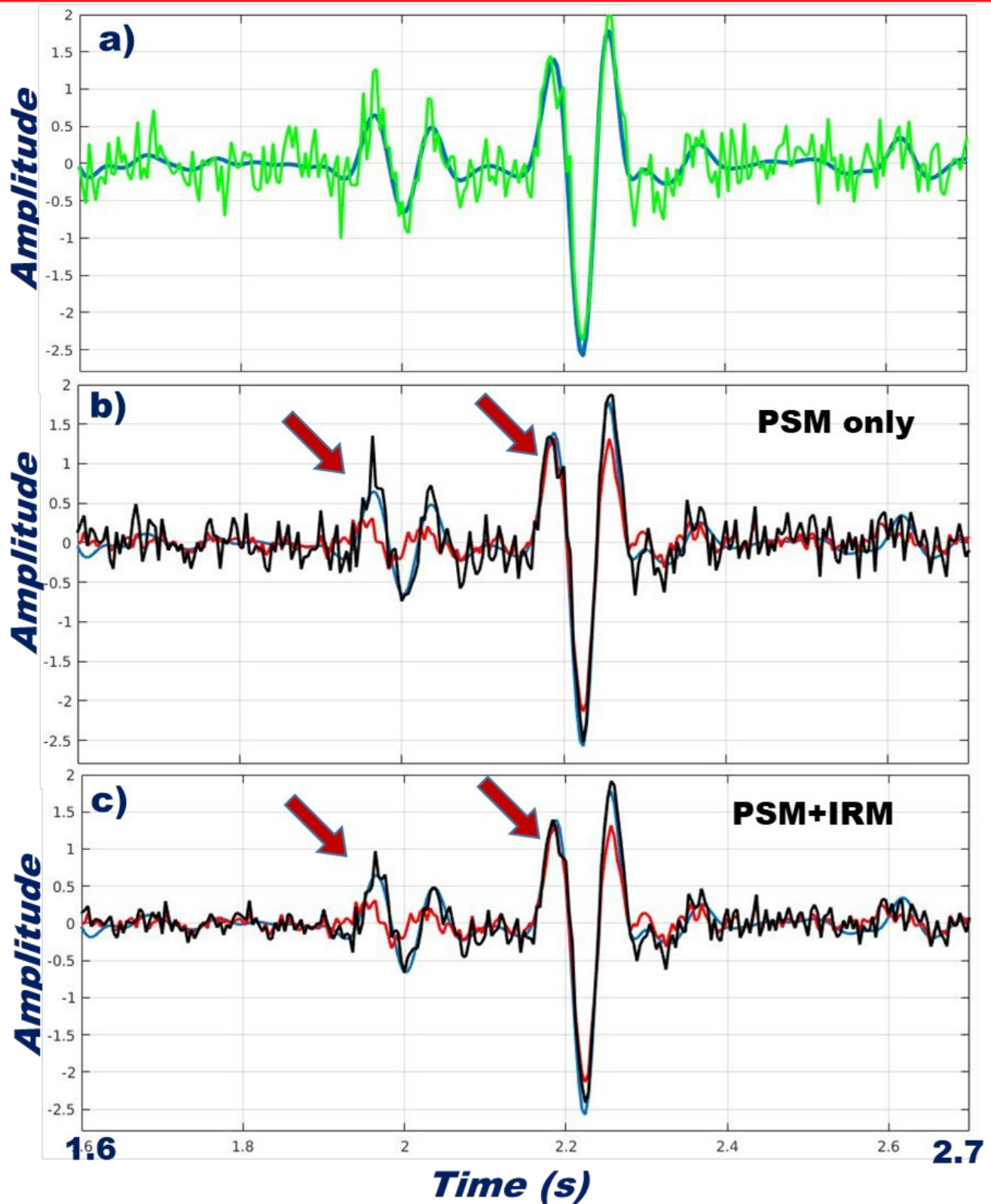
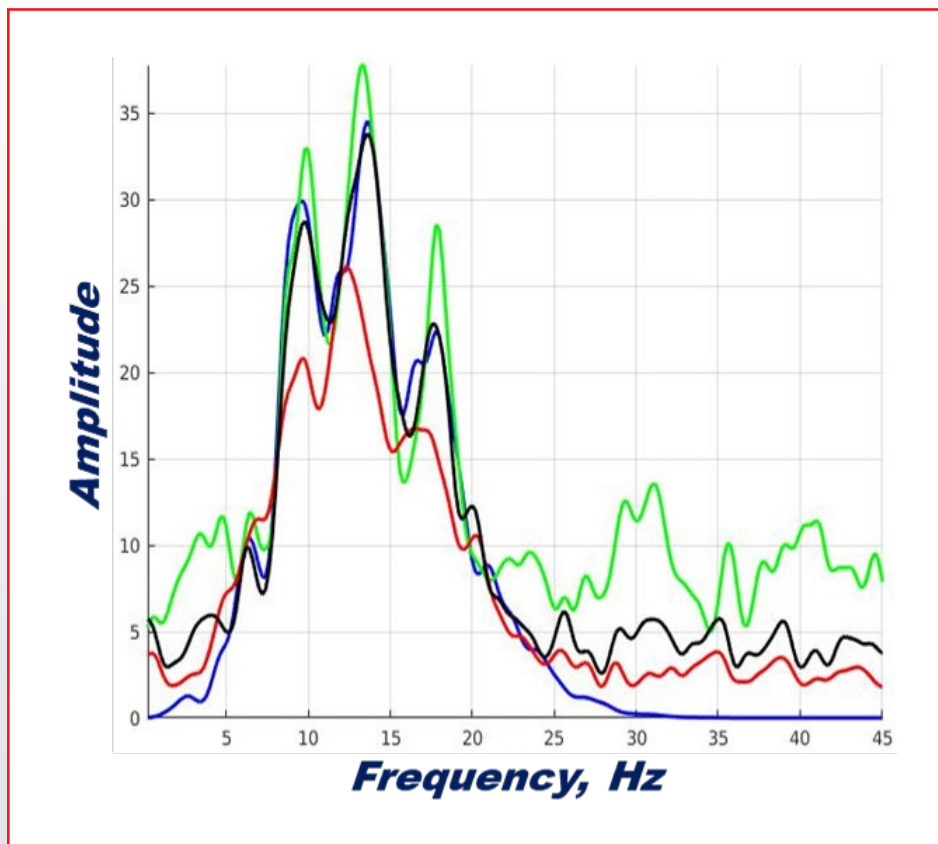


Figure 2: (a) Comparison of reference trace (blue) and its noisy counterpart (green, SNR is -2dB); (b) Comparison of reference noise-free trace (blue) with a trace after stacking (red, SNR=5.1 dB) and the output trace after phase correction (black, SNR = 2.2 dB); (c) Comparison of the reference trace (blue) with a trace after stacking and the output trace after phase corrections + IRM (black, SNR=6.4dB).



**Figure 3: Comparison of amplitude spectra of input and output traces: reference trace (blue); reference trace with noise (green); trace obtained by (red); trace after phase corrections + IRM (black).**

of weak reflections (marked by arrows), but the random amplitude noise remains unsuppressed. The trace produced by a combination of phase corrections with amplitude TFM has visible reduction in noise level (SNR = 6.4dB), more accurate peak signal amplitudes, whereas coherent arrivals remain properly positioned. **Figure 3** confirms that conventional stacking reduced amplitude spectra too much (hitting both noise and signal), whereas the combination of phase and amplitude TFM provides a most accurate estimate of noise-free spectra, efficiently harvesting information from the entire ensemble.

### Single-sensor data example from a desert environment

An example of common-midpoint (CMP) gather from a challenging 2D land single sensor dataset acquired in a desert environment is shown in **Figure 4a**. Original data was partially stacked

within offset bins 100 m. This dataset has already been passed through a standard processing flow of noise suppression and is ready for imaging. Nevertheless, data remains noisy with target reflections being barely visible, especially at the near offsets and later times. **Figure 4b** shows the same CMP gather after enhancement using nonlinear beamforming or NLBF (Bakulin et al., 2018) with summation apertures of 100 m x 100 m. Approximately 150 neighboring traces are used in the local summation to enhance each original trace. After the enhancement, the reflections are easily recognizable in the whole offset range. The high-frequency content of the signals is suppressed due to suboptimal stacking (averaged amplitude spectra of the gathers are overlaid on the figures). Using beamformed data as a “guide” and applying phase substitution method (**Figure 4c**), reflections remain visible in the entire offset

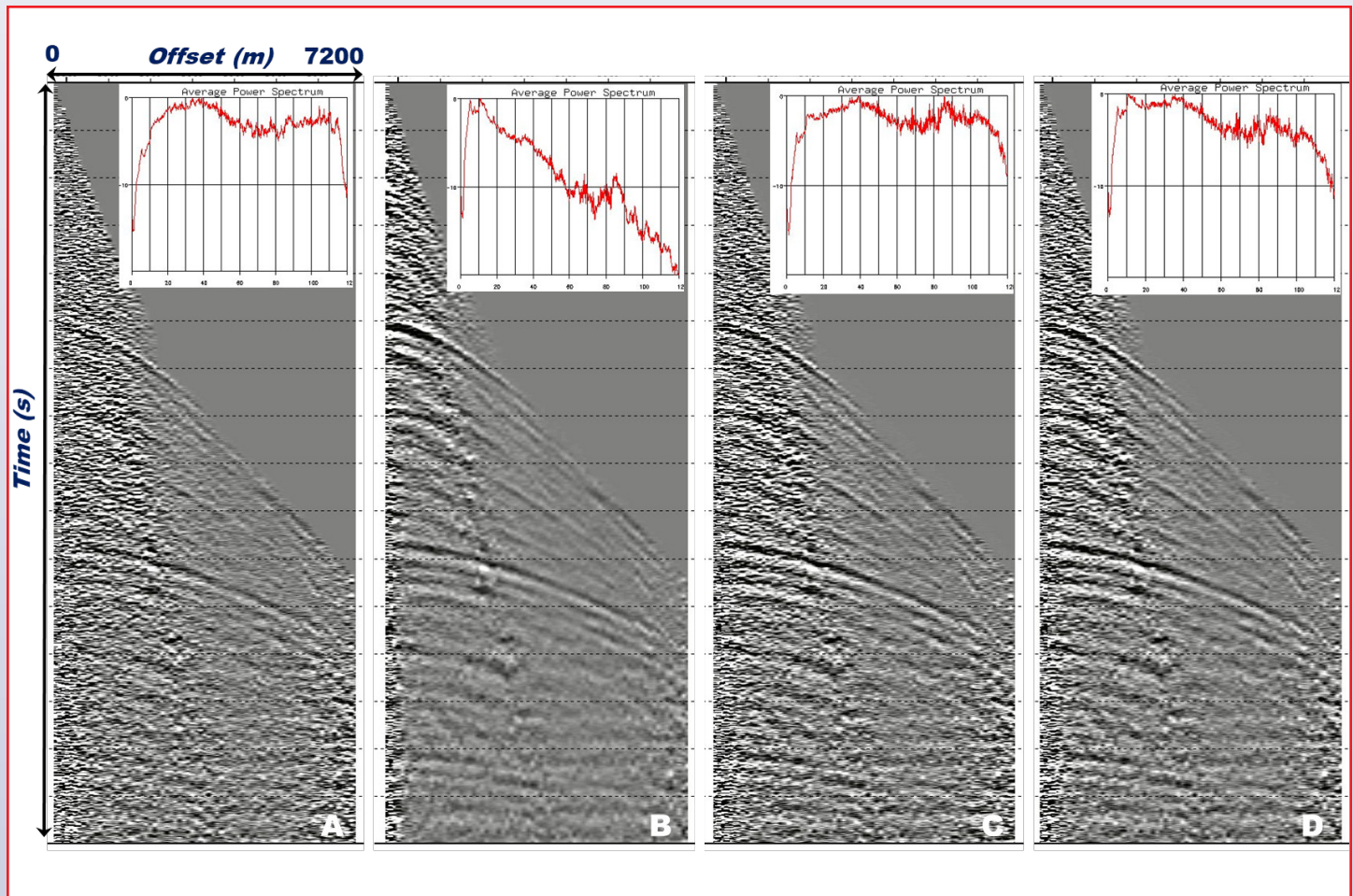
range without oversmoothing and with higher frequencies preserved. Application of amplitude TFM reveals better low frequencies (10 Hz) and also suppresses higher-frequency noise (60-100 Hz), leading to a more natural roll-off (**Figure 4d**). Computed amplitude spectra validate that introduced corrections led to the preservation of higher frequencies in the data. A comparison of stacks reveals that while the NLBF image (**Figure 5b**) has better event correlation at the middle frequencies, both TFM images possess finer spatial and temporal details (**Figure 5c, d**). Besides, amplitude TFM shows a visible reduction of non-geologic high-frequency noise (**Figure 5d**). The fact that higher frequencies are surviving after stacking suggests that we gained additional signals on prestack records that coherently added up during the imaging step. We conclude that the combination of phase and amplitude TFM provides clear uplift in prestack and post-stack images obtained with challenging single-sensor data.



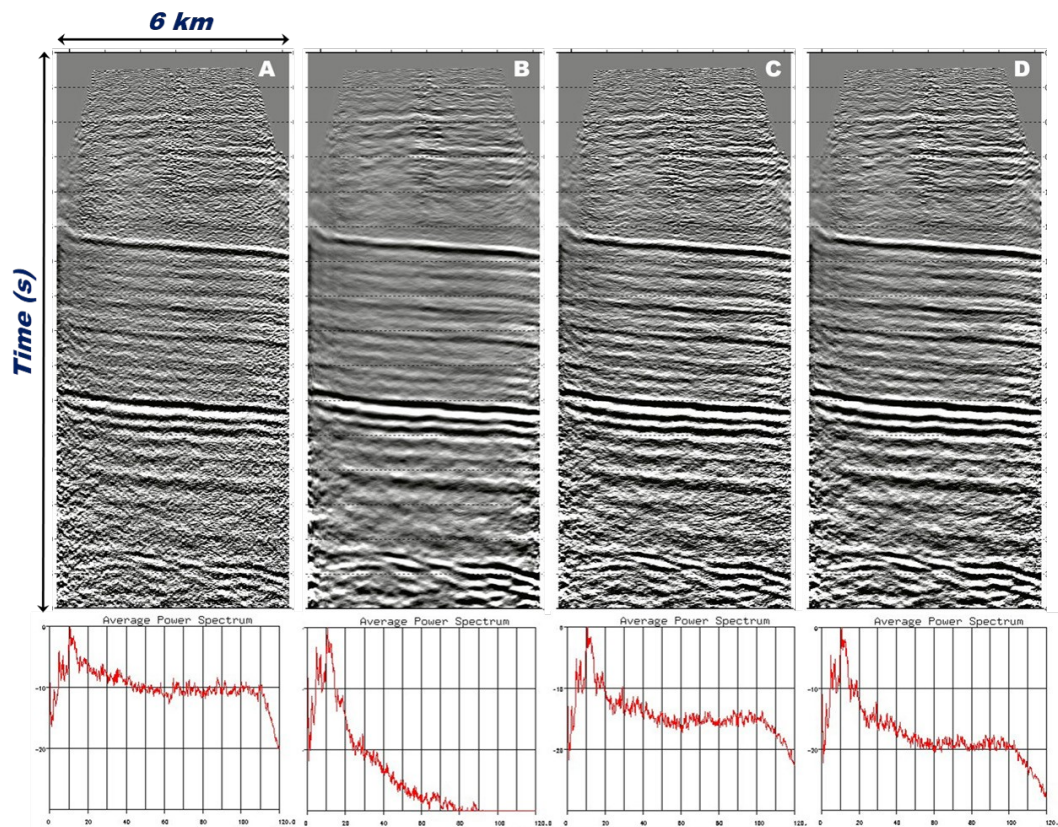
## Conclusions

We present a new approach that can perform delicate seismic data enhancement. We utilize massive beamforming with large apertures to uncover hidden reflectors. Such enhanced data forms a “guide” multi-channel dataset with the same number of traces serving as an approximate “signal model”. We exploit this “guide” to correct original data using specially designed time-frequency masking analogous to speech processing. We demonstrate that frequency-dependent phase corrections are crucial to restoring the coherency of broken up reflectors. Amplitude TFM masks are designed to attack noise. As before, “guide” dataset traces are used to design targeted

amplitude masks surgically knocking noise in places of domination while not touching areas with signals. Examples from synthetic and real seismic data validate the effectiveness of new methods. Corrected multi-channel gathers become acceptable for conventional processing by existing methods. Described TFM masking with the “guide” can also be considered an alternative to existing signal processing techniques that are often rather brute-force and limited in guidance and precision. Time-frequency masking guided by beamformed data opens a new avenue for multi-channel signal processing. We presented some initial designs for phase and amplitude masks, whereas the new methods pave the way for new possibilities in data enhancement and targeted noise removal. □



**Figure 4:** Real data example showing prestack CMP gathers obtained with different approaches: (a) Original data after conventional processing; (b) data after nonlinear beamforming; (c) data after phase substitution; (d) data after phase correction. While nonlinear beamforming (b) greatly improves coherence and continuity, observe loss of higher frequencies and oversmoothed character. In contrast, new methods (c) and (d) deliver significant improvement avoiding oversmoothing, preserving higher frequencies.



**Figure 5:** Real data example showing stack sections (bottom) corresponding to the gather presented in Figure 4: (a) Stack obtained with original data; (b) stack obtained with the data after nonlinear beamforming; (c) stack of the data after phase substitution; (d) data after phase correction + IRM. Corresponding averaged amplitude spectra are shown below stacks.

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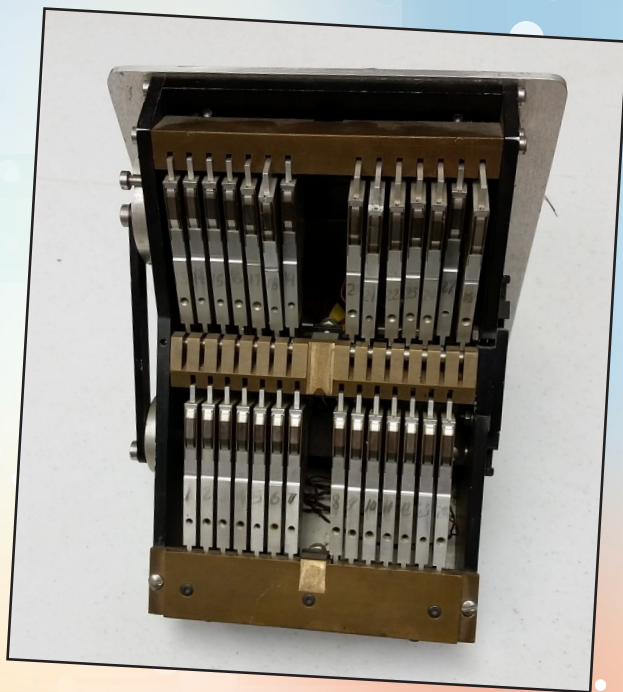
Permalink: <https://doi.org/10.1190/segam2020-3420095.1>



## Mystery Item

*This is a geophysical item...*

*Do you know what it is?*



*This month's answer on page 28.*

# Apache

EXPLORING WHAT'S POSSIBLE



# Geoscience Center

## *The History of Geophysics* By Bill Gafford

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



Some of the Legends inspecting artifacts.



Story time with the Legends.

Our next Living Legends **Doodlebugger social event** will be held on **Wednesday, May 12** at the Geoscience Center. These events are open to everyone and provide a time to visit with old friends and share tales of the oil patch as well as

experiences after retirement. Retired or nearly retired doodlebuggers, and their spouses are invited, as well as anyone who is interested in visiting our Geoscience Center. This is a chance to visit with some of the Legends in our industry and see some of our more

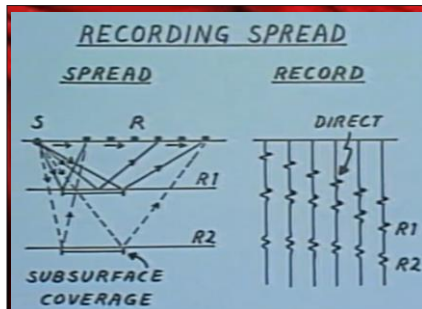
interesting geoscience artifacts and some of the Mystery Items that have been featured in the GSH Journals. This is a free event and no reservation is needed and parking is free. Light snacks, coffee, soft drinks, and water will be provided. Because of Covid 19, we will require masks and proper precautions and expect those attending will assume any risk of contracting the coronavirus. We believe most attendees will have had an opportunity to be vaccinated. Pictures from past Living Legend Doodlebugger events are included with this article.

We continue to receive donations of books, periodicals, and geoscience artifacts and have duplicates of some books and periodicals that are free for visitors. These include textbooks, training manuals, workshop notes, and a variety of geoscience related SEG and AAPG publications. If you are interested in a particular geoscience specialty or want to expand your general knowledge, we probably have educational publications that will fit your need in our library.

Volunteers are always needed to help research some of our older instruments and artifacts and organize our storage shelves. There is also a need for signs with descriptions of how the instruments were used and how they fit into an acquisition or interpretation process. We are always interested in finding new locations where some items from our museum collection can be put on display and help educate the public. □

The Geoscience Center has been mostly closed due to the Covid-19 restrictions with only a few volunteers at a time, but we are slowly opening again. Usually there is someone there on Wednesday mornings from 9:00 until noon or by appointment and visitors are always welcome. Please contact me at: [geogaf@hal-pc.org](mailto:geogaf@hal-pc.org) or by phone at: 281-370-3264 for more information.





## GSH Movie Time

### Now Showing Processing Overview – Part I\*

Lecture by John Wardel – 1982



This is the first of two lectures which give an overview of the processing of seismic reflection data. In the previous two lectures we went over how seismic energy travels through the earth, how it is reflected from interfaces between different types of rocks, and how these reflections advance and produce other type of events that are recorded on the seismic traces.

In this, and a lecture to follow, we will look at how those seismic traces are processed to produce a seismic cross-section which gives a representation of the geologic structures in the earth below the line of seismic data.

Click on red ticket to view movie



\* GSI vintage videos courtesy of Schlumberger – WesternGeco



*“Cutting advertising to save money  
is like stopping a clock to save time.”  
- Henry Ford*

## GSH Media Kits

## Item Of Interest

The Geophysical Engineering Company was formed in 1920 with the backing of Dr. William P. Haseman, Frank Buttram, Dr. Irving Perrine, the Ramsey brothers and D. W. Ohern. It was headquartered in Oklahoma City. J. Clarence Karcher □



GSH



Legacy



The GSH has been honored in the past to have received substantial support from members who have designated such at their passing. We are now beginning an official GSH Charitable Bequest Program and we would like to invite you to participate. This GSH program can help provide financial stability for the GSH, allow for long term planning of the society and allow you to honor your years in the geophysical profession. You will be recognized for your participation in this program on a Legacy of Geophysics page on the GSH website unless you choose to remain anonymous.

There are a variety of ways to participate. Some are listed below. There may be tax advantages to you in some situations, but you will need to consult your personal tax advisor for that determination as GSH cannot provide tax advice. Charitable bequests that are undesignated will be used for the general operating expenses of the GSH. Bequests may be designated for specific programs such as Scholarships, the Geoscience Center, Outreach, or others.

Some of the options for participation are:

- Gifts can be made by beneficiary, partial beneficiary, or contingent beneficiary designation in a retirement account, a certificate of deposit, a bank or brokerage account, or a life insurance policy.
- Gifts can be made through wills or trusts. You can designate a specific dollar amount, a particular asset, or a percentage of your estate.
- Gifts can be made through your IRA if you are over the age of 70 ½, and your gift can count toward your Required Minimum Distribution and be excluded from your gross income.
- Gifts can be made with stock or in cash.

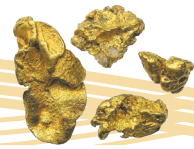
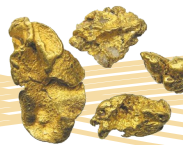
If this program is of interest to you, your attorney or financial advisor can provide more information and the appropriate forms. If you would like to know more about how such a bequest could benefit the GSH please contact the office at 281-741-1624 or by email: [karen@gshtx.org](mailto:karen@gshtx.org). We would like you to let us know if you have made such a bequest so that you may be properly recognized by the society.

I hope many of you will see a gift of this nature as a meaningful way to celebrate what geophysics and the local community have meant to you. Please consider a lasting gift to the GSH.

With warmest regards,

GSH President 2020-2021





## Stein's Paradox [In Honor of 2021 Baseball]

In 1955, **Charles Stein** of Stanford, discovered a **statistical paradox** that that once again shook the cloistered community inside the Academic Association of Statistical **Frequentists**, pictured below. This angry group was still reeling from the **Bayesian battle** (no armistice was ever reached), that began two centuries earlier. A **1977 article** in *Scientific American* by Brad Efron and Carl Morris brought the **Stein Paradox** to the attention of the Great Untutored Public.

Until Charlie **Stein** came along, it was generally agreed among statisticians that the **prediction** of future occurrences was **best estimated** by **past performance**, specifically, that the **current average of event  $x = \bar{x}$** , is the best estimator of future values of  $\bar{x}$ . A good example of this is a standard calculation in baseball, the



Angry Frequentists

**Batting Average:  $BA = (\text{Number of Hits}) / (\text{Official At Bats}) = \text{Hits} / \text{OAB}$** . In 1970, the great **Roberto Clemente** had a  **$BA = Y = .400$** , after 45 OAB. The Frequentists would have us believe that at the end of the season, Clemente's average would also be **.400**, since that was the best estimator of future value. **Stein** knew better.



Roberto Clemente

Based on what he observed and knowledge of **Bayes**, Stein reasoned that a better estimator of the future averages had to be something that accounted for the wide spread of **BAs** at the beginning of the season – many of which were “**outliers**”, both hot and slumpy hitting streaks. He settled on the idea of “**shrinkage**”. In this case, **Charlie** decided to **shrink** all current averages toward the “Grand Average” of a group of players who all had about the same number of at bats. Among those were **18 MLB** players with a combined **BA of .265**. While 45 OABs is only about **10 to 12** games into a **162-game** season, Stein's predicted “ **$Z_i$** ”, the future batting average for a given player, “ **$i$** ”, more closely than the treasured current average, much to the dismay of the gang back at **Static U**. The war was on.

Shrinking Factor

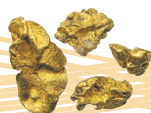
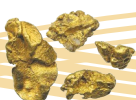
Current BA of player  $i$

$$\bullet \text{ Stein's Predictor: } Z_i = \bar{Y} + C[Y_i - \bar{Y}]$$

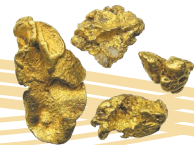
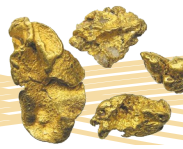
Predicted BA of Player  $i$

Current Grand Average of 18 players BA

The Frequentist's **Most Likely** (probable) predictor:  $Z_i = Y_i$ . Stein's predictor says a better predictor (even **More Likely** than their “**Most Likely**”) shrinks the **current average  $Y_i$**  toward the **Grand Average** of the **18** players being used (kind of the central limit theorem of batting averages). What really annoyed the elite statistical corps was that these players had virtual nothing to do with one another, some weren't even in the same League (American or National). Undaunted, what Stein did next, turned a paradox into a **Paradox**, and sent the elitist academics into spasms of annoyance which brought out cries for the **pitchforks** and cries **burning** of **Stein's** publications.



Tutorial Nuggets continued on page 21.



**Frequentists and camp followers annoyed**

Stein proposed using another interesting statistic along with the BA of 18 players, namely, the fraction of **foreign cars** passing an intersection in San Francisco.  $Y_{19} = \text{Foreign cars} / \text{Total cars} = 9/45 = .200$ . “What the hell does that have to do with baseball??!!” “Nothing,” responded Stein, “but nowhere in my theorem does it state any correspondence in the statistical averages is required.”

It was uncomfortably apparent, even to **frequentists**, that their **iron rule** on the **Most Likely Future**,  $Z_i = Y_i$  was in full **melt down**.

Stein expanded the theorem to state, in **baseball** terms, that using **3** or more player’s BA allows for the beneficial use of his theorem (which, by this time had another contributor and became named the **James – Stein Theorem**. Frequentists remained unconvinced and especially upset with Stein’s “**disconcerting indifference**” to **common sense**, using foreign cars and MLB batting averages together. And yet, the more averages he threw into the pot (with different means but similar variances, the better the estimates of the future individual averages (for each type of statistic, be they **cars**, **people**, or **ice cream preference**.

## Shrinking Factor **C**

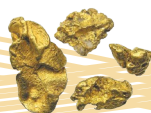
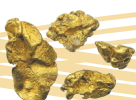
$$C = 1 - \frac{(K - 3)\sigma^2}{\sum_i (Y_i - \bar{Y})^2}$$

The idea behind the “C” is to bring the individual BA ( $Y_i$ ) closer to their true batting ability (average), call it  $\theta$ . This, unfortunately, is an unknowable quantity, at least before the season is over when we can equate it to the final BA. Lacking that number after only 45 at bats, Stein calculates a  $Z_i \approx \theta_i$ , for each player,  $i$ , by compressing the wide range of  $Y_i$  toward the Grand Average of Averages BA,  $\bar{Y}$ .

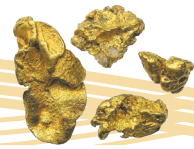
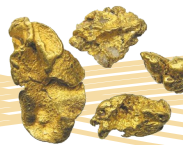


**A** few other notes and assumptions: in this definition of **C**, the  $\sigma^2$  represents the squared standard deviation for the individual BA, here considered to be the same for all means,  $Y_i$ . **K** is the number of players and their **individual BA** being considered. Note that if **K = 3**, **C = 0**, and the prediction of  $Z_i = \bar{Y}$ . As **K** increases the Stein estimator gets better. It has been demonstrated that in the baseball example, the Stein **estimator** is superior to the simplistic current BA,  $Z_i = Y_i$ , so treasured by **Elites** for **16 out of the 18** studied.

In our next get together, we will discuss the **Risk Reducing capabilities** of using the **Stein predictor** in **Exploration Applications**, the relationship between **Bayes and Stein** (they are essentially **twins**), and how **you can apply** this discovery to your **geophysical applications**.







## The Final Solution: R.I.P. Monty Hall and Thomas Bayes

**The Problem.** The one remaining **Bayesian issue** is that of the *Monty Hall problem* - the one which got **Marilyn Vos Savant** in such trouble with overzealous and uninformed **Frequentists** in the ranks of academia. Recall the essence of the problem is to **select a door** behind which is a valuable **car** - **\$500K Roll Royce Phantom**. There are **3 doors** (behind **2** are **goats**). The probability that the car is behind any one is simply **1/3**. You choose **door A**. Monty then shows you behind **door B is a Goat**.

This is game changing information to assist you answering the next question: would you like to **switch** your first choice from **door A to door C** (given you now know it's **not** behind **door B**). At first glance it seems as if there is equal probability for **A and C**:  $P(\text{Car}@A) = P(\text{Car}@C) = 1/2$ . **But is it?** We have **new information** since your pick of **A**. Let's pose the problem as **Bayesian**.

Here we calculate the probability the **car** is behind **C** given that Monty shows us that of the behind

$$P(\text{car}@C|\text{openB}) = \frac{PP(\text{openB}|\text{car}@C)(\text{car}@C)}{P(\text{openB})}$$

**door B is a Goat..** What you need, to fill in the blanks correctly, is to **consider why** he chose **door B** knowing both what you selected and the actual location of the **treasured Phantom..**

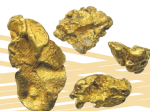
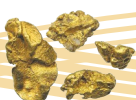
**The Answer:** The denominator of the right-hand term is **critical**. You must account for the situations in which **door B** would be chosen to **open** AND the probability that it would or **wouldn't** be. These are governed by Monty's ethics and game principles: **(1) Never show the door with the car** (here, **A or C**); and **(2) Never show** behind the **initial selection (A)**. Thus -

$$P(\text{car}@C|\text{openB}) = \frac{P(\text{openB}|\text{car}@C)(\text{car}@C) \text{ (1) (1/3)}}{P(\text{openB}|\text{car}@A) + P(\text{openB}|\text{car}@B) + P(\text{openB}|\text{car}@C)} = (2/3)$$

$\frac{(1/2)(1/3)}{(0) (1/3)} \quad (1) (1/3)$

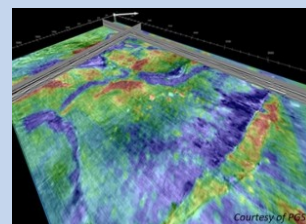
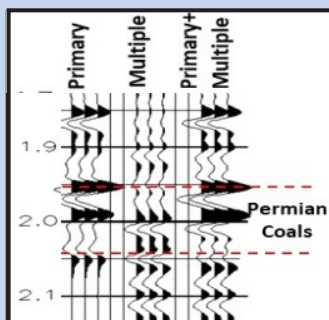
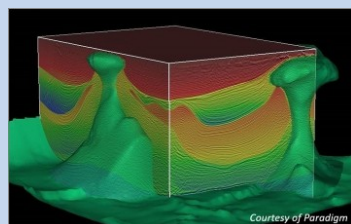
Since the **total probability = 1**, the  $P(\text{car}@A | \text{open B}) = (1/3)$ . Go ahead and compute it. Thus, you will win **twice** as often by **switching your choice**.

**Puzzles for May:** **(A)** Paul left home running for awhile, turned left and ran the same distance, turned left again, ran same distance, and repeated the left turn to return home where he was greeted by **2 masked men**, Who were they? **(B) Lee Lawyer** wrote in his **FTOS** column in **April**, that back in the **40's and 50's**, when all seismic **interpretation was done on paper records**, the standard acquisition technique was done "**split spread**" (source in between middle channels (traces), **12 and 13 of 24** recorded channels spaced at **110 ft.**.. The next shot would be placed at the position just 55 ft past where **trace 1** was and what had been channels **12-1** would become **24-13** of the **new recording**, with what had been **24-13** (the "back cable") would be moved forward to become the new traces, **12-1**. [Sketch it out]. **Why did they do it this way?** So compelling that even **marine recording** was done the same way. **How?**



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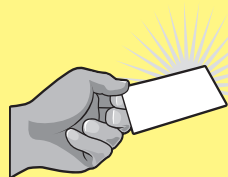
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# 35<sup>th</sup> Annual GSH Sporting Clays



Many thanks to everyone who made it out to the 35<sup>th</sup> annual GSH Clay Shoot! The weather could not have been nicer and although attendance was lighter than in previous years, thanks to everyone who participated, we were able to raise over \$3000 for the GSH! Thanks to all the sponsors who donated during these tough times, without your generosity, events like this would not be possible. The sponsors this year were Fairfield Geotechnologies, CGG, NodalSeismic, SEG, Z-Terra and American Shooting Centers.

In addition to amazing weather Brisket Houston treated everyone to a great breakfast and some fantastic BBQ for lunch. Thanks to Kyle and Mike for whipping up some excellent BBQ on short notice. The BBQ was washed down with a keg of Love Street which was generously donated by CGG.

Overall winners on the day were Greg Nasser with a 78, and Courtney Noppe with a 64. Thanks again to everyone who attended, we appreciate your participation and look forward to seeing everyone again in August.

- Scott Sutherland, Chair









The Mystery Item  
on page 16  
is a

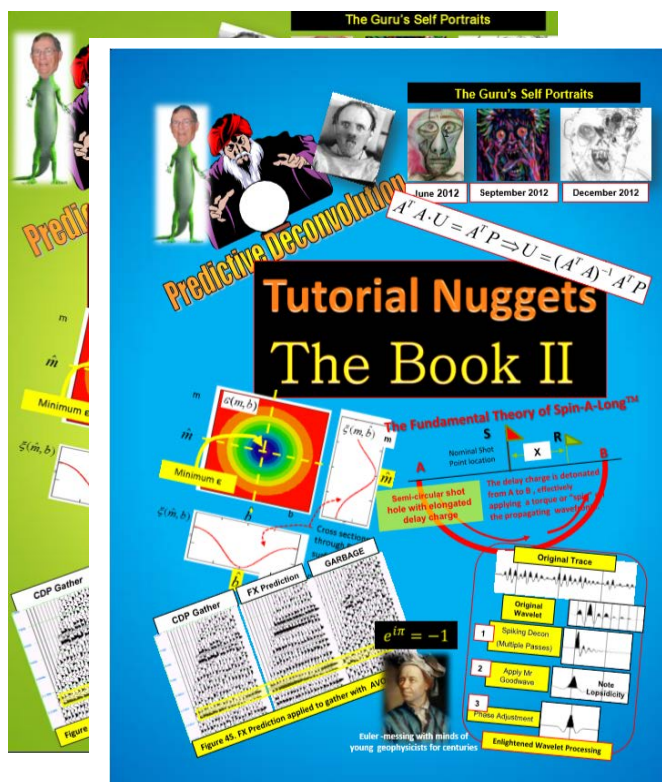
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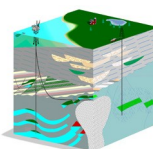
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# Doodlebugger Diary

## *Black Magic in Geophysical Prospecting, Part 2*

By L. W. Blau, Geophysics Department, Humble Oil & Refining Company

*The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. This month I am continuing to build on our January Doodlebugger Diary by Dan Plazak that discussed the early history of the term 'doodle-bugs', which was followed in March by Gene Sparkman's recounting of his early experiences with doodle-bugs. Last month I started a 3-part series that reprints the very first article published in Geophysics in 1936. This month I submit part 2 for your amusement.*

*If you have any similar stories you would like to share, please send them my way. I'll be happy to print them.*

**Reprinted from** Blau, L.W, 1936, *Black magic in geophysical prospecting: Geophysics*, 1, 1-8, doi: [10.1190/1.1437076](https://doi.org/10.1190/1.1437076)

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Principle #1: oil, gas, sulphur, even lime and granite, emit corpuscular radiations which can be observed by means of instruments at the surface of the earth.

One of the processes based upon corpuscular radiations comprised a specially sensitized photographic plate contained in a plate holder which was impervious to the radiations from the oil or gas. When one considers that the plate was alleged to be sensitive to radiations from deposits at a depth of 10,000 feet, it becomes evident that the plate holder must have been made of formidable stuff if it prevented exposure from shallow deposits. To find oil, it was necessary to take the plate from the holder, to face north, to turn the plate from an upright to a horizontal position and back to the upright, to reinsert it in the plate holder, between 12:00 and 2:00 in the daytime, and in the "light" of the moon. Four plates were furnished for a trial; these were to be exposed as directed and returned to the inventor for development and analysis. Although he had one chance in sixteen of guessing all four plates correctly, he made a poor showing.

Another instrument which worked on the same principle consisted of a small box which had a dial and pointer on the front side and several buttons on the back. To take a reading, it was necessary to push one of the buttons; this rotated the pointer into a vertical position. If radiations from oil reached the instrument, the pointer remained in the vertical position or dropped only slightly due to the upward force of the radiations, but when no oil was present the pointer dropped to the horizontal without further ado. Only the inventor could operate the device. The most attractive feature of the instrument from a prospective operator's viewpoint was that it could be operated only from 11:00 in the morning until 2:00 in the afternoon in the vicinity of Houston.



*Figure 1: A farmer in Devon, England, holds a hazel twig to find water on the land around his farm, circa 1942. From Agriculture in Britain – Life on George Casely's farm, Devon, England, 1942.*  
<https://en.wikipedia.org/wiki/Dowsing>.

*Doodlebugger continued on page 33.*

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



An ordinary electroscope fitted with a specially designed indicator of the rate of discharge has been found to be sensitive to corpuscular radiations from oil; such an instrument could also be employed, so it is claimed, in medical diagnosis and was exceptionally useful in the determination of pregnancy. This device operated during all daylight hours but could not be used at night; it was not quite as reliable on cloudy, rainy days as we learned after we had had it demonstrated in rainy weather.

Principle #2: *the minerals which it is desired to find radiate vibrations which react upon the observer and enable him to locate them.*

The most versatile radiation sensitive device consisted of a black rubber rod about six inches long on which was mounted a ball bearing; a brass rod carrying an adjustable weight on one end and a removable capsule about 2 inches long and one-fourth inch in diameter at the other end was fastened to the ball bearing and at right angles to the rubber handle. When the handle was held in a vertical position the brass rod could rotate in a horizontal plane. The radiations from the oil were said to issue from the ground in helical paths thus causing the rotation of the movable system. The speed of rotation was indicative of the gravity of the oil and also, in some rather involved manner, of the depth. When looking for other minerals, it was necessary to remove the oil capsule and substitute for it one which would respond to the particular mineral. For really accurate work, there were additional oil capsules which could be used to determine fine differences in the gravity of oil. It was exceedingly interesting and gratifying to see the device start rotating on approaching a producing well. Needless to say, only the inventor could hold it, and it was necessary for him to be in motion to receive an indication, either walking or riding in an automobile. A few times, when we "chanced" rather suddenly upon a producer hidden in the timber, we observed violent rotations while a salt water capsule was being used, but who can say that there was no salt water below the oil? In every instance the device indicated oil after an oil capsule was inserted. The device was further demonstrated on an oil tank farm. It gave a rapid rotation on a tank containing 50 feet of East Texas oil and the same speed of rotation on a tank containing 10 feet of Conroe crude which had originally been supposed to be full. The explanation was that the gravity of the oil was responsible. In order to test this explanation further the inventor was asked to try a tank of Sugarland oil; he did not know that the tank was empty at the time. The device rotated faster than ever, supposedly due to the gravity of the Sugarland oil which should have been in the tank.

One of the most interesting inventors of an alleged radiation sensitive device appeared on the scene very recently. He claimed that he could find salt or oil, that he had "shot" 187 locations, and that in each case he had been right. When questioned about the radiations, which he claimed were sent out by salt, he quoted physicists from three great American universities to the effect that "salt is more radioactive than radium itself." The wavelength of the vibrations emanating from salt was alleged to be 0.00005 cm, and he had a book to prove this point. He had found that a lead shield absorbed the radiations and nothing else did. His device enabled him to tune to the vibrations and was the result of ten years' continuous research.

The case is one of the best demonstrations of the truth of the statement, "a little knowledge is a dangerous thing." The inventor had read of artificial radioactivity, discovered by M. and Mme. Joliet; they discovered that sodium can be made radioactive by bombarding it with high speed electrons. The book gave the wavelengths of the sodium lines in the spectrum as 0.00005770 and 0.00005791 cm., respectively. Cosmic ray investigators use lead shields. The only difference, in the eyes of this inventor, between sodium and salt is a little chlorine; hence salt, sodium chloride, sends out radiations of the same wavelengths as sodium and all he needed was a device for tuning to them.

The most prominent example of an instrument which permits vibrations from buried substances to react upon an observer is the divining rod. Since books have been written upon the subject, it will suffice to mention here that divining rods have indicated oil near an abandoned hole which was drilled into salt water on the north edge of the Conroe field and a salt dome between two producers on the field.

Along the same line, it has been found possible to do geophysical prospecting from maps on which the north direction is indicated, without going on the ground. It is not even necessary for the person so beautifully endowed to be in the same country. Thus one can do prospecting in China without leaving his office in Houston, if only a map of the area in question can be procured. The mechanism of the process is not well understood. To one lacking imagination the description sounds fantastic, but we have the inventor's word of honor that the method works, and that he has been able to locate every known oil field of which he ever had a map.

**Next Month: Black Magic in Geophysical Prospecting, Part 3** □