GEOPHYSICAL SOCIETY HOUSTON

*The Epicenter of
Geophysical Excellence*

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On The Cover.

*9-Track tape library
facility in the 1980's.*

*Photo courtesy of
WesternGeco*

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A Word from the Board

By Chris Egger, Treasurer

2020, what can we say? The term "unprecedented" is cliché, and many of us readily invite in the New Year as if we can leave 2020 problems in the past. As we look back, at times, it seemed things could not get worse; then we were surprised all over again. To summarize this year would be dismal; memes sometimes represent the moment best or at least make you smile, which I am sure we could all use about now. Such as the meme where the famous infomercial artist Billy Mays, said: "2020 every second…BUT WAIT THERE'S MORE!". Or maybe a Zoom meme is appropriate, since we instantly became experts with this meeting format; a popular meme pictures the same person with and without their video on, which are shockingly different pictures. I hope you do not feel I am making light of any tragedy but providing humor and some hope that we endured. Yes, this year consisted of an impeachment trial of the President, murder-hornets, negative West Texas Intermediate prices, toilet paper shortages, riots, Greek alphabet named hurricanes, and COVID-19, which is far from the complete list. 2020 has challenged us; it devastated some with a loss but undoubtedly affected us all. This year will shape many years to come, but as we persevere, we should focus on what is important, concentrate on what lies ahead and be grateful for the moments remembered.

December is upon us, my role as GSH Treasurer is at a half-way point, and I look forward to a remarkable recovery in 2021. With current in-person restrictions, the GSH has been limited to virtual event formats, providing content and member benefits via the web. We can examine the current downside or financial impact of this change, such as reduced revenue as the Treasurer might. Although I would like to report, these restrictions have been a positive opportunity for the GSH to examine how your professional Society delivers our mission. Staying true to our stated mission grounds us and influences our reactions to current events with a longer-term outlook. Our mission's first sentence states: "The Geophysical Society of Houston was formed in 1947 to promote the science and profession of geophysics and to foster fellowship and cooperation among all persons interested in geophysics".

With the advent of COVID-19, some positive changes, and a modernization of the GSH are taking place. We are now Zoom capable. We are making some up-to-date changes and working out related issues in the new processes. Access to technical events, Special Interest Group talks, previously recorded technical meetings, Zoom Saloon, and other opportunities are now online. These developments are significant because online content delivery enables the GSH to continue promoting geophysics in the current environment and enables future options in a highly content competitive world. With our tools, volunteers, strong membership base and technical substance, we will continue to follow through, adapt, and strive to deliver on our mission, staying relevant to our professional community.

Other helpful news includes the announcement of GSH Membership Fee Waiver for Unemployed. This compassionate program addresses those affected by the recent turn of events. While this is a token offering during these challenging financial circumstances, the GSH felt driven to act where we could. I believe this action partly defines our Society's character, and this caring support in-part drives my motivation to participate. Ultimately, my hope is everyone with interest can partake and contribute to an effective Society.

Our New Year is almost here, the pages of that year are blank, so it is on us to write our new chapter. Our Geophysical Society of Houston offers great fellowship and opportunity to build valuable relationships with like-minded individuals. In 2020, the Society has adjusted to become more current, delivering on our mission in troubling times. Adversity has allowed the GSH to examine how we become a more efficient useful organization. While some event changes will return to normal, others might be permanently altered. Please reach out and become involved, take a risk, improve on your past, be successful, and march forward. Thank you to all the members of our Society for your continued support and contribution. □

From the Other Side

By Lee Lawyer

I spotted an item in SEG SmartBrief stating that South Sudan will offer 14 oil-exploration blocks. Chevron's work in Sudan is one of the most interesting projects I have been associated with, but I am 30 years out of date with Sudan. Chevron took a block about the size of Oklahoma. It was located between North and South Sudan. That line was imaginary but political. Very scary.

From 1820 to 1874 the entirety of Sudan was conquered by the Muhammad Ali dynasty. In 1881 and 1885, the harsh Egyptian reign was eventually met with a successful revolt led by the self-proclaimed Mahdi Muhammad Ahamad resulting in the establishment of the Caliphate of Omdurman. This state was eventually toppled in 1898 by the British, who would then govern Sudan together with Egypt. Remember General Gordon and his problems with the Mahdi. In 1953, Britain granted Sudan self-government. Independence was proclaimed on 1 January 1956.

When Sudan instituted Islamic law in 1983, it caused trouble between the Islamic north and the Christian south. I am not going into Sudan's and South Sudan's current or recent past. There is a lot of good stuff on Wikipedia, if you are interested. But it brings back memories for me. I was Chief Geophysicist of Chevron Overseas at the time. When visiting the field operation, a very large ostrich and her chick were between my quarters and the mess hall. Every time I tried to pass by, that giant bird stared right at me and fluffed her wings. Very scary. I took the long way around. I recall a group of native women that objected to my taking pictures of them by sounding a high-pitched trill. Another time, a large elephant charged toward us when our helicopter tried to set down too close to the herd. Then, there was the fire in the hotel we were staying at that required us to evacuate in the middle of the night. We were very near the building where General Gordon was killed by the Mahdi forces.

The operations located in Sudan required floating equipment. The base camp was a string of barges pulled from location to location, which was no small task. The answer to this problem was the Ty Tiger, which was a huge vehicle buoyed by gigantic wheels. Unfortunately, it had a heavy chain drive, which broke periodically. Finally, we had to abandon it on site. It has been occupied by local natives. Maybe it is a fishing resort. The canoe is in the picture for scale purposes.

As I write the column, the SEG is holding its 90th Anniversary Annual Meeting online, which was originally scheduled for Houston. The Keynote Speaker was Michael Oristaglio, who is a Senior Research Scientist at Yale. He started his talk by saying, "The Earth is heterogenous in all scales." He addressed five issues: SEAM, FWI, Mining, Near Surface, and the need for a new business model, which would be a Risk Management-multi-disciplinary governance. The talk was well presented. I am sorry you missed it. My next scheduled event is the traditional dinner of the SEG Past Presidents. This is also online. I guess we find out who is the oldest "living" President. I usually get that honor. □

GSH Technical Events

Rock Physics SIG
Modeling and Estimation of Kerogen Evolution in Source Rocks
Mita Sengupta, Aramco Services
Abstract and Bio
Online presentation
December 2, 2020 - 12:00pm-1:00pm CST

Register

Unconventional SIG
Addressing Land Seismic Data Quality Issues that Cannot Be Easily Fixed by Huge Fold
Christof Stork, Land Seismic Noise Specialists, Inc.
Abstract and Bio
Online presentation
December 3, 2020 - 12:00pm-1:00pm CST

Register

Technical Breakfast
Salt/Sediment Proximity to Delineate Salt Boundaries with P and PS Waves using Seismic While Drilling in the Gulf of Mexico
Bryce Jensen, Shell Exploration & Production Co
Abstract and Bio
Online presentation
December 9, 2020 - 7:00-8:00am CST

Register

Data Science and Machine Learning SIG
Unsupervised Machine Learning as a Tool to Address the Challenges of Multi-attribute Seismic Interpretation
Carrie Laudon, Geophysical Insights
Abstract and Bio
Online presentation
December 9, 2020 - 11:00am-12:00am CST

Register

NextGen Under a Different Rock
From Wiggles to Catalogs: Using Seismic and Infrasound Data to Detect and Locate Events
Dr. Stephen Arrowsmith, Huffington Dept of Earth Sciences, Southern Methodist University
Abstract and Bio
Online presentation
December 14, 2020 - 6:00-7:00pm CST

Register

GSH Gets Down to Business: a new business-oriented online series

The traditional technical marketing meeting, whether it is a proprietary client in-house event or a booth presentation at a convention, is another casualty of Covid-19. The GSH has now started a new online presentation series, where geophysical companies are able to deliver information on their latest products and services to GSH members and friends! Key features are:

    * A vendor offers their commercial presentation as an online event through GSH.
    * The event is announced, promoted and managed by GSH; attendance is free.
    * As in a booth presentation, both potential customers and competitors may be attending.
    * After the presentation, there will be an interactive Q&A session.
    * Attendees contact information will not be shared by GSH, however, vendor contact is available and attendees are free to share their contact information.

Interested vendors please contact the GSH at 281.741.1624 or office@gshtx.org

GSH Movie Time

Now Showing
How I became a Geophysicist*
Cecil H Green

Cecil Howard Green, KBE (August 6, 1900 – April 11, 2003) served as vice president (1941-1951), president (1951-1955) and chairman of GSI (1955-1959).

This movie is the first of two in which Cecil Green tells his story. He starts mentioning how he unconsciously decided to be a Geophysicist at age 5, when he was roughly awakened at 5:00 AM on April 18, 1906 during the Great San Francisco Earthquake.

He was restless in the search of his true vocation. After working for several non-geophysical companies, he joined, in 1930, Geophysical Services Incorporated (GSI), a newly created company dedicated, exclusively, to provide Geophysical services.
He started as an observer and suffered many of the hassles associated to today's Oil and Gas business, including being asked to "get off the payroll" because the West-Texas oilfield had blown in and driven oil price to 10 to 15 cents per barrel.

* GSI vintage videos courtesy of Schlumberger – WesternGeco

An Integrated Reservoir Characterization Study with Data Analytics in Búzios Field, Santos Basin, Offshore Brazil

Shihong Chi*, Zakir Hossain, Andrew Hartwig, ION Geophysical, Yijie Zhou, Noble Energy

Summary

The deep-water sub-salt carbonate reservoirs in Brazil are important plays that draw the attention of the E&P community. However, accurately characterizing the sub-salt reservoirs is still a challenging task due to the difficulties in the sub-salt imaging, velocity model building, and data quality and resolution. In this study, we explore a set of analytic predictive models to extend beyond the traditional reservoir characterization practice, which may be constrained by the data quality and the limitations of the 1D convolution model, thus allowing for an improved characterization of the ultra-deep sub-salt reservoirs, offshore Brazil. Our studied area is located in the Búzios field, Santos Basin, offshore Brazil. We start with the petrophysical analysis, followed by facies classification, and AVO inversion. Finally, we predict rock properties from the 3D seismic volume by applying an integrated interpretation procedure that utilizes data analytic techniques, which incorporate seismic inversion results, facies predictions, well logs and geological interpretation. The predicted 3D reservoir properties show a good match with well data.

Introduction

The ultra-deep-water sub-salt carbonate reservoirs are excellent exploration and production prospects, thus becoming the focus of Brazil's oil and gas exploration and production for decades. They will continue to be one of the most import oil plays in the future. Reservoir characterization studies can play an important role in exploration and production by understanding the reservoir properties from seismic data. However, the reservoir characterization study of sub-salt carbonate reservoirs faces several challenges (Johann et al., 2013; Huang et al., 2010): limited well log data and seismic coverage in the deep targets, complex 3-D seismic velocity, poor-quality subsurface imaging, low seismic resolution, acoustic/elastic inversion instability, and ambiguity in the rock physical relations between elastic measurement and rock properties, etc.

Figure 1: a) Map of the Búzios field, Santos basin (left) and the seismic RMS amplitude map with the existing well locations for the studied area (right). b) A seismic section along a random line crossing the eight wells from north to south, with the P-impedance log inserted at the well locations, the horizon of the base of salt is displayed in blue.

In our work, we utilize data analytics tools to improve the traditional reservoir characterization practice in the sub-salt reservoirs in Santos Basin, offshore Brazil. Objectives of the data analytics are: 1) to predict the shear logs whenever the well data does not contain shear measurements; 2) to verify the effectiveness of the analytic predictive models in the ultra-deep subsalt reservoirs when the traditional reservoir characterization practice suffers from the data quality, and the underlying limitations of the 1D convolution model; 3) to improve reservoir properties delineation from elastic attributes with the guidance of local geology. We select a small study area, in the Búzios field, Santos basin, covering 8 wells, among which 4 wells have the shear measurement to demonstrate our workflow. We demonstrate that with the data analytic tools, we can have an improved reservoir properties prediction, which matches with the known distribution at well locations. The data analytic algorithms still rely on the seismic inversion to provide inputs, thus it is not intended to replace seismic inversion, but serves as a supplement to improve the reservoir characterization under the unfavorable conditions for the sub-salt deep-water reservoirs in offshore Brazil.

Seismic and Well Data

The Santo Basin began its tectonic generation during the breakup of the Gondwana supercontinent and the opening of the South Atlantic Ocean during the Late Jurassic/ Early Cretaceous. The area we selected is located in the Búzios oil field of the Santos Basin *(Figure 1a)*, with Inline range 51280-55040, and Xline range 59400-62800, approximately 2,000 km2 of 3D data. *Figure 1a* also shows the RMS amplitude of this area between the ranges starting at the base of salt, to 350ms deeper; a random line crossing the eight wells from north to south is also shown in this map. *Figure 1b* displays the vertical section of this random line, with the P-impedance log inserted at the well locations for the 8 wells.

The seismic data is stacked in 4 different angle ranges: 2° to 10°; 10° to 18°; 18° to 28°; and 28° to 34°, to increase the signal to noise ratio (SNR); it is acquired with 4 ms sample rate, with a total 6000 ms trace length. Our inversion window starts from 50 ms above the base of salt to 350 ms below the base of salt, with a total 400 ms

Figure 2: a) Well log analysis for 3-BRSA-944A-RJS, from left to right; it displays Gamma, Neutron-Density, Sonic, Shear, P-Impedance, VpVs ratio, deep resistivity, along with interpreted lithology, porosity, fluid saturation, and facies. b) Multi-well crossplot of AI vs. VpVs, color-coded by facies (left), and the classification results for well 3-BRSA-944A-RJS (right).

time window. The wells inside this area all have the quad-combo well log data set, including sonic, density, etc. Electrical measurements are available for most of the wells, except the 9-BUZ-7-RJS, thus no petrophysical analysis is done for this well, but it is still included in the inversion and interpretation study. Meanwhile, only four wells in the middle have shear measurements, the shear logs need to be predicted when the measurements are not available.

Petrophysical Analysis and Facies Classification

The traditional well log analysis is done for the wells within the survey, with the guidance of the corresponding mud log report. *Figure 2a* shows the Gamma, Neutron-Density, Sonic, Shear,

P-Impedance, VpVs ratio, deep resistivity, along with interpreted lithology, porosity, fluid saturation, and facies, from left to right track, for the well 3-BRSA-944A-RJS. The reservoir rocks are mainly carbonate, with a thin overlaying anhydrite layer; the oil-water contact (OWC) is around 5780 m, and the porosity is around 10-20% for reservoir rocks, with oil saturation approximately 75-85% above OWC. The facies are defined from the interpreted lithology and fluid, including: wet carbonate (Sw>70%), oil-saturated carbonate (So>70%), shale (shale volume >60%), and anhydrite (anhydrite >60%).

As discussed, the shear logs are predicted when the measurements are not available. To predict the shear logs, we use a simple machine learning model by taking the sonic, gamma ray, density, and water saturation as the input. The model is trained with the wells which have the shear measurements. The predictions are then carried out on all the wells. The prediction is displayed as the blue curves in *Figure 2a*. As a comparison, we also run the empirical Greenberg-Castagna prediction (Greenberg and Castagna, 1992) to predict shear, shown as the green curve. The comparison in *Figure 2a* shows machine learning has a more accurate prediction than the Greenberg-Castagna model, which only works in brine-saturated rocks. Compared to the measurement data in *Figure 2a*, the Greenberg-Castagna model predicts lower shear velocity which generates a higher VpVs ratio for the carbonate rocks.

All well data in the sub-salt interval are plotted in the AI vs. VpVs crossplot to analyze the elastic response of each litho-facies defined above *(Figure 2b)*. Overall, shale shows a higher VpVs value (>1.85). Oil-saturated rock mostly occurs in the porous carbonates, with an elastic signature of low P-impedance and low VpVs ratio. In contrast, water-saturated rock mostly occurs in the tight carbonates, with an elastic signature of high P-impedance but the VpVs ratio is lower than 1.9. Oil and water-

Figure 3: Inversion results on the cross well random line, P-impedance on the top, VpVs ratio on the bottom. The corresponding well log measurements are overlain on the top of this vertical section.

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saturated rocks seem to have a large overlap in this crossplot, thus the fluid response is not quite sensitive in the AI~VpVs domain.

To further test the sensitivity of each facies in their elastic response, the statistical rock physics (SRP) classification (Zhou et al., 2013) is employed to estimate the facies, for the eight wells we have studied. SRP workflow utilizes the naive Bayesian classification scheme, to estimate the probabilities of each facies, given the cluster distribution in the selected elastic domain. The predicted facies are assigned with the maximum probability. *Figure 2b* shows the classification results for well 3-BRSA-944A-RJS, from left to right track, it displays the facies, predicted facies, and the probabilities to each faices. Even though the oil and wet carbonate show a large overlap in the crossplot, most of them still could be identified from the detailed classification workflow.

AVO Inversion

After the wavelet estimation and well to seismic tie for each well, the AVO inversion is performed with a simultaneous pre-stack seismic inversion algorithm (Hampson et al., 2005), a pre-whitening factor of 5% is selected to stabilize the inversion process.

Figure 3 shows the inversion results, P-impedance on top, VpVs ratio at the bottom, on the same cross-well random line in *Figure 1b*. The corresponding well log measurements are overlaid on the top of this vertical section. From the VpVs ratio profile, the bottom shale could be identified clearly with a relatively high VpVs ratio (purple area), the overlying carbonate shows a relatively homogeneous VpVs ratio, varying in the range of 1.70 ~1.75. In contrast, among the carbonate layers, the P-impedance shows a relatively large variation, with porous carbonate showing relatively low impedance values. Based on the analysis of well data *(Figure 2)*, most of the oil bearing carbonates have relatively high porosity and low impedance. Overall, this study shows the VpVs ratio which may serve as a lithology indicator seems helpful to discriminate the carbonate rocks from shales, while P-impedance which may serve as a porosity/fluid indicator may be able to tell the quality of the reservoir rocks in the carbonate.

Reservoir Properties Prediction with Data Analytics

The complex rock physics relations between reservoir properties and elastic attributes are not clear for the carbonate rocks in the ultra-deep water environment. Thus, using the rock physics relations for accurate reservoir properties predictions is not achievable for this study. However, data analytics, including various multivariate regression and neural network predictions, seems to provide a better solution under such unfavorable conditions. The advantage of such techniques is that such algorithms can incorporate many related data/measurements, not only inversion products, but also the seismic attributes, into the training input dataset. Through the training of the data analytic model, the model parameters have been optimized to predict the target reservoir properties, such as porosity, water saturation, etc.

A set of analytic predictive models have been tested, including multivariate regression, multi-layer feedforward neural network, generalized regression neural network (GRNN), and radial basis function neural network. They all produce similar results, but GRNN typically produces a slightly more accurate prediction than the other models. *Figure 4* shows the predicted effective porosity (top), and the water saturation (bottom), on the same cross well random line. The corresponding well log interpreted results are overlaid on the top of this vertical section. The predicted results are consistent with the inversion results and oil-saturated rocks are mostly concentrated in the areas.

Conclusions

An integrated reservoir characterization study of the Búzios field, Santos Basin, Offshore Brazil is conducted. Through our analysis with the well log data and seismic inverted elastic attributes, we find that for this area, the VpVs ratio is a good attribute to discriminate the carbonate rocks from shales, which may serve as a lithology indicator. P-impedance can be used to infer the quality of the reservoir rocks in the carbonate, which may serve as a porosity indicator. The data analytic technique we utilized here, can effectively convert such qualitative understandings into the quantitative interpretation, which may provide a good alternative interpretation tool for improved reservoir characterization.

We successfully incorporate the data analytics into the reservoir characterization practice, for the Búzios field in Santos Basin, offshore Brazil, but data analytics may not be a universal solution for all reservoir characterization studies. Training of the analytical models should be guided by the local rock physics and geology, and its effectiveness should be verified on a case-by-case basis. ☐

Figure 4: The predicted effective porosity (top) and the water saturation (bottom) on the same cross well random line. The corresponding well log interpreted results are overlain on the top of this vertical section.

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Mystery Item

This is a geophysical item...

Do you know what it is?

This month's answer on page 22.

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

Fall has been uneventful for the GSH Outreach volunteers due to COVID-19 but some organizations have gone virtual. The Houston Geological Society offered their members and guests a virtual program to celebrate Earth Science Week, Oct. 11-17 with different videos and web links every day. The Women's Energy Network conducted their Young Women Energized free virtual S.T.E.M. Event for high school students on November 7.

2021 Science Engineering Fair of Houston will be held virtually and has been expanded
this year to include 6th grade, so it will be open to grades 6 through 12.
GSH volunteers will be needed to serve on the GSH Special Awards Judging Team and as Place Awards Judges. Watch the SEFH 2020 Showcase Video at https://sefhouston.org/ to see what
it is like to attend the in-person event. Some of these students have really amazing projects.

Project finalization and submission deadline is January 29, 2021
and judging will be conducted in February.

Judging for Place Awards will be done in three rounds (on three Saturdays).

- Round One
  (project viewing) – Notebook as PDF

- Round Two
  (interactive audio-video)

- Round Three Judging of Grand Award Candidates
  (interactive audio-video) – Video and PowerPoint

Special Awards Judging procedures will include selection of Summer Intern Awardees. The summer interns are high school students who are granted a paid internship at the Houston Museum of Natural Science. They are selected by representatives from several local professional societies. The diverse group of 15 2020 interns from 13 different schools worked in the Astronomy department developing and giving presentations to the public, preparing Mars videos for the Planetarium, Martian Farming exhibit with video, Solar Energy and solar cooking video, programming Mars and Fisheye Simulations, Night Sky Zoom programs, Summer Solstice Event (live and Zoom) and the Perseverance Lift Off event. Interns created Mars simulations for the Mars exhibit and for the Expedition Center.

GSH Outreach needs volunteers to create some new presentations for classrooms and our booth.
We would like to present current and future geophysical career opportunities outside of
traditional oil and gas exploration. There are a wide variety of options including

GPR,
Multi-Beam Sonar,
EM,
carbon sequestration,
offshore engineering geophysics for wind turbines and tidal power,
DAS passive seismic surveillance for earthquake and landslide monitoring,
the search for potable water and
the ever popular use of drones.

If you are interested in volunteering to help us create new materials and/or participate in any post-pandemic outreach events, please contact Lisa Buckner at outreach@gshtx.org. □

Enlightened Decisions Using Probability

In November's learned discussion, the Guru noted that the Probability Distribution Function (PDF) of the sums of such random events as dice faces, approaches a bell-shaped (Gaussian) curve as we increase the number of dice being summed. He further taught us that the mechanics of producing the bell-shaped PDFs is done by convolving together their individual PDFs.

Grown geophysicists have been known to faint when first exposed to this profound **Great Truth**. This is the *Central Limit Theorem* of convolution now applied to the generation of **PDFs**.

Stunned reaction

The Guru is slowly but surely building a ***Unified Theory of Everything.*** Stay tuned for many more epiphanic insights coming up in the next few months(!).

The number output points **x**, along with their starting and terminal values (x_{MIN}, x_{MAX}) and probability values, **Psum(x),** depends on such factors as how many PDFs are being convolved, their individual lengths, and shapes. NB: in general, the individual **PDFs do not have to be the same.** In the example, above, they are the same, but that is an unnecessary restriction. When the first 2 PDFs are convolved, **P(x)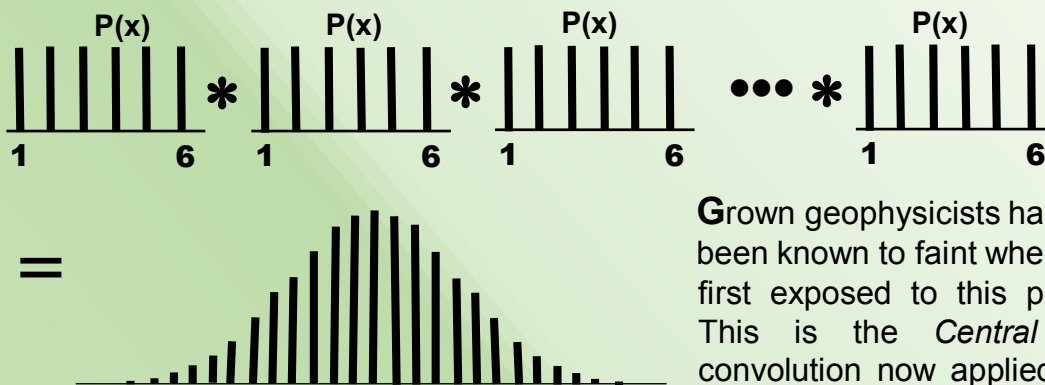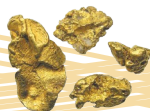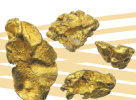 * P(x),** the result is a **triangular PDF**, (see last month's Nugget for details). To get the **sum of 3 components** we convolve this **triangular** shape with another **uniform** (flat) PDF which produces **a trapezoidal shape**. This process continues until the final PDF will assume a **bell-shape** close enough to a **true Gaussian** normal distribution to qualify for both industrial and governmental purposes with **tax benefits** for the former.

Now for another profundity. Suppose the values we are summing are drawn from a **population** of **real numbers** (**16.7345017 …**) as opposed to **integers**, e.g., dice face values, **{3, 7, 22},** or discrete values at a uniform interval e.g., **sampled data** at 0.5 ms (**… 9.5, 10.0, 10.5, …**). While the latter two examples have only discrete possibilities, they may have an infinity of possibilities, theoretically, but in our realistic world this would not be practical nor necessary (who wants to record an infinite number of samples on each trace?). This leads to some **mathematical compromises**, but nothing serious or mis-leading. Let's look at some examples to clarify the murky picture. For this noble pursuit we call on our old friend, the **Boxcar** function as an example of a **real number** (**continuous function**) population of values to be summed.

Old Friend

$\frac{1}{T}$

$\frac{-T}{2}$ 0 $\frac{T}{2}$

The **Boxcar** (left) may be structured to represent a **PDF** of a reasonably common type, namely selecting a number from a population of real **x** numbers ranging continuously from **–T/2 to T/2**, where **T** is a value representing the real data extent. This Boxcar happens to be symmetric, but that's not a necessary condition. We'll deal with that when we discuss the "Standard" Normal PDF.

You may wonder about the scale label (**1/T**) for the probability of the uniform distribution. The question arises philosophically because if there really an infinity of r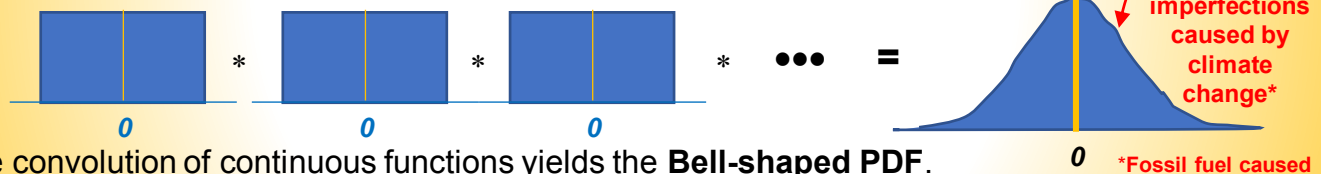andomly selectable values between –T/2 and T/2, then the actual probability in the sense we used it when selecting blindly from a finite set is 1/N, where N is the total number of possibilities. Since the continuous case has N = ∞ , we are dismayed to find the probability of any given real number selection is 0. Instead we talk about probability **density** over a **finite interval**, say, $\Delta x = (0.1 \bullet T)$ on the x axis. The **1/T** amplitude is a factor which shows (A) the **relative probability** for different x values between **–T/2 and T/2** (here the same – "uniform"); (B) that if you summed up the values from -∞ to ∞, the value would be 1 (much like area under the Boxcar: T• (1/T) = 1. This simply means the **sum of all probabilities is 1**, just as it is in the discrete case. For discrete intervals of x, = Δx, the product is **(1/T)(Δx) = (1/T)(0.1T) = .1**. The sum of 10 such intervals = **1.0**, just as before. In this regard we treat the (1/T) as a **density** of probabilities and the sum over the interval as a "weight". If the densities vary, as they generally would, their variation is captured in the **P(x)**, which is now a Probability **Density** Function or **PDF**, as before.

Lumps and imperfections caused by climate change*

0   *Fossil fuel caused

The convolution of continuous functions yields the **Bell-shaped PDF**. When standardized, by appropriate parameter transforms and normalization, the mean of this PDF is **μ = 0** and the variance is given by **σ² = 1**, with the standard deviation, sd = σ = 1. The shape of the PDF is specified by two parameters, **μ** and **σ²**, the **mean** and **variance**.

PDF Normal

$$P(z) := \left(\frac{1}{\sqrt{2\pi \cdot \sigma^2}} \right) \cdot e^{\left[\frac{-(z-\mu)^2}{2 \cdot \sigma^2} \right]}$$

The random variable **z** replaces the usual **x** to indicate we are dealing with standardized PDF. It is common to LSE fit this curve to discrete data, especially if the data are drawn from a population affected by many factors.

Decisions We'll restrict today's discussion **expectancy** in simple games with dice or coins. Later we can see how to apply to more complex geophysical decisions and estimates.

Some definitions. **E**xpected value of **x** is **E(x)**:

$$E(x) = \sum_{x=min}^{Xmax} P(x)\,x = \mu, the\ mean\ of\ x$$

Note that this definition is a weighted average of **x**.

In a **fair game** the amount of the **bet** should equal the **expected winnings, E(x)**. This would be fair to both the House and the bettor. **E (Win) = 0**. Test: Would you take the bet **either way?**

Back to Index

The November Puzzle & One for Christmas

The Puzzle	**You** are in a completely **dark room**. I dump a bag of **1017 Othello chips** on the floor. These chips are **black on one side and white on the other**. You can feel around for the chips, but you **cannot see which side** is up because it is dark. I tell you that exactly **23 have the black side** up. I ask you to divide the **chips into two piles** (every chip must be in one [and only one] of the piles) such that the two piles have the **same number** of chips with the **black side up** (they may have different numbers of chips with the white side up). **How do you do it?**
The Answer	Separate the chips into **two piles**, one with **23**, and the other with **994**. **Turn over all chips** in the pile with **23 chips**. Now both piles have the same number of black chips. Simple, eh?

A New Puzzle

The St Petersburg Paradox

The Guru taught us, on preceding pages, that to be Good Citizens one should only make bets that are **fair to all participants** in the wagers. Here is an interesting example for you to consider just how much Good Citizenship could cost you.

The GSH Emergency Game Plan for Generating Enough Revenue to Keep The Elders Supplied in Medicinal Cabernet Sauvignon (**GSHEGPGERKTESMCS**, for short) includes a Geophysical Institute for Advanced Statistical Studies (**GIASS**) which uses a casino room strictly for educational and monetary pursuits. The Room, as it is called, features **a special game** which attracted the attention of descendants of the famous science family, Bernoulli (without whom, the GSH 16-passenger jet, *a Koster Bi-Wing,* would not fly, and the **"Law of Averages"** would be repealed). *Merry Christmas!*

The Game: Using a **fair coin [P(Heads) = P(Tails) = 1/2)],** you, the bettor, flip the coin until you get a **Heads**. In other words, **you flip until you win**. You will be paid 2^K, where **K** is the number of flips it take to get a heads. The least you can win is $2 if you're unlucky enough to get a **Heads** on the **1st flip**. A **fair price** to play this game for both **you** and the **GSH**, is set by your expected winnings, **E[W] = ?** Make this calculation and decide if you're willing to pay it.

If not, consider setting a limit to the winnings of something realistic like, say, **$1,048,576.** If you're agreeable, the **E(W) = ?** Assume you will still have to flip until Heads shows up, but your winnings after **20 flips** is limited to the **$Million** plus change stated above.

Are you now willing to play? We're talking a **Million dollars** here, you, Holiday Hustler! What would you be willing to pay? Careful, the **GSH** reserves the right to **reverse the roles!!**

U of H Wavelets

By Faith Walton and Michael Martinez

As the lockdown continues, so do the Wavelets' events. The Wavelets continued hosting the College of Natural Sciences and Mathematics (NSM) and the Earth and Atmospheric Sciences (EAS) Structure and Tectonics Seminar throughout the month of October, and attendance has been strong despite being everyone socially distanced at home. The NSM EAS Structure and Tectonics Seminar featured ten graduate students in October, including two visiting graduate students from The China University of Petroleum, Dr. Yin Liu and Gang Li. EAS's Makayla Jacobs, advised by Dr. Julia Wellner, gave an impressive presentation over her research work on the Cenomanian–Turonian Frontier Formation in the greater Green River Basin, Wyoming. SEG Wavelets Vice President Michael Martinez, advised by Dr. Paul Mann, presented his work on giant oil and gas fields of South America, Africa, and the Gulf of Mexico, and SEG Wavelets President Benjamin Miller (advised by Dr. Mann) shared his thesis work on the Lesser Antilles forearc provinces. Nahid Hasan (advised by Dr. Mann) shared his research on the Campeche Salt Province and Kamil Qureshi (advised by Dr. Shuhab Khan) presented his work on the active tectonics of the frontal Himalayas. Our upcoming seminar speakers include Hualing Zhang, Yin Liu, Michael Daniel, Gang Li, Mei Liu, and Thomas Casteel.

The Wavelets continue to maintain their relationships with academia and industry. We hosted Brian Casey of the Texas Bureau of Geology, who presented his basin model research for the Midland and Delaware Basins and shared a lot of insights with students looking to do further researcher in the Permian Basin.

Keep up with the Wavelets by following us on our LinkedIn and Facebook accounts – search "SEG Wavelets". Track our events by adding our Google calendar to yours (segwavelets@gmail.com), and join SEG at the local level with the UH Wavelets through GetInvolved via AccessUH and at the national level following our site's instructions – search "UH SEG Wavelets" □.

Item Of Interest

Shadow Zone

In the early 1940s, the U.S. Navy was experiencing difficulties with its sonar equipment. The Navy asked Maurice Ewing and J. Lamar Worzel to investigate. They discovered that temperature effects were bending the sound waves in such a way as to create a "shadow zone" – a region in which sonar transmissions went undetected. This discovery had enormous implications for submarine warfare in that a submarine could "hide" beneath it.

Moreover, Ewing and Worzel discovered that sound waves could be focused into a narrow region in which they traveled for great distances. They called this phenomenon sound channeling, and it became the basis for SOFAR (Sound Fixing and Ranging), which the Navy used to locate downed airmen and SOSUS (Sound Surveillance System), the navy's Cold War Underwater acoustic array established to detect Soviet submarines. □

from Plate Tectonics, An insider's History, Naomi Oreskes, Editor.

Under a Different Rock
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October 20 — Matthew Hughes, "New Marine Geophysical Techniques for Analyzing Shallow Substrates"

November 16 — Dr. Richard Esposito, "The Emerging Nexus Between the Electrical Power Industry and Geological Pore Space"

December 14 — Dr. Stephen Arrowsmith, "Revisiting how we use seismic data to detect explosions"

January 19 — Dr. Daniel Bigman, "Applications of Ground-Penetrating Radar (GPR)"

February 18 — Dr. Mel Best, "Geophysical Applications in Mineral Resources"

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- Henry Ford

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The Mystery Item on page 15 is a
Small hydrophone used with a floating cable from 1950.

Donated by
Gulf Research and Development

NextGen-NeoGeos Trivia Night

October 8, 2020 *By Michael Martinez and Peter Lanzarone*

GSH's NextGen committee is creatively adapting to hosting virtual events and held their second trivia night on October 8, 2020, this time as a co-host with the Houston Geological Society's NeoGeos, an equivalent group for students and early career geoscientists.

The trivia event was held in conjunction with the Houston AAPG Student Expo and consisted of multiple themed sections featuring questions related to geology, geophysics, and employer-specific questions to help students prepare for their interview opportunities.

The hosts and approximately 60 participants connected with each other through Zoom and answered trivia questions using Kahoot! software. Although everyone had fun, the winners of the trivia event earned an extra look from recruiters and companies, including offers to review resumes and discuss opportunities in the oil and gas industry. □

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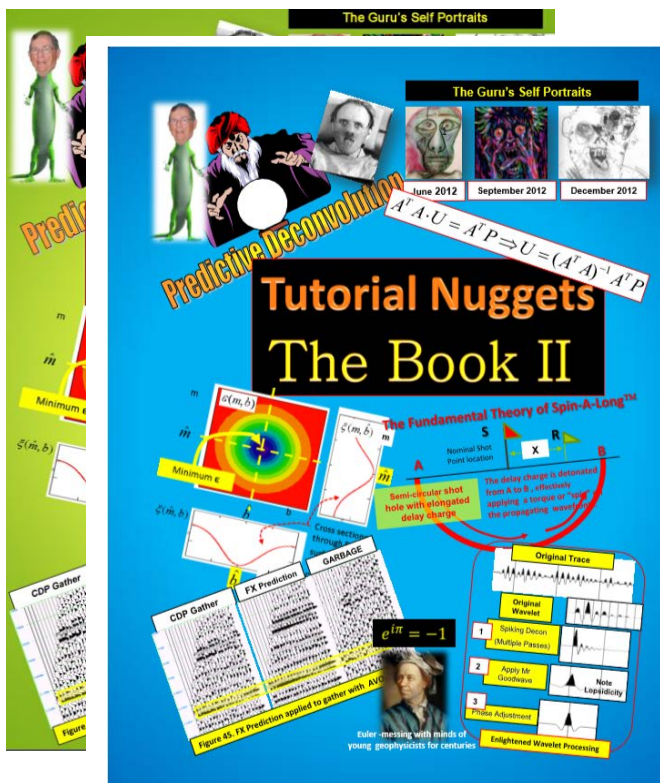|	
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WHY SHOULD YOU ATTEND?

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!

These just published, limited printing proof copy of the new industry standard for seismic theory (and other stuff) will surely be a valuable tool as well as a keepsake for your technical library!

$75

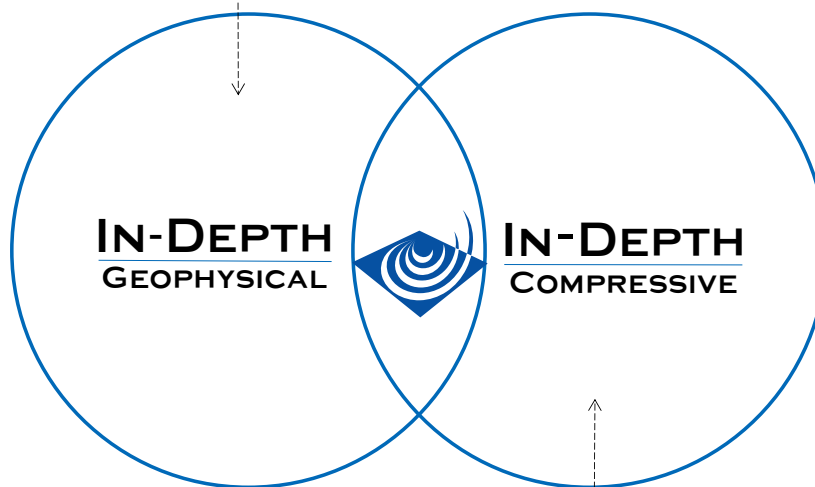**Member Price**

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Permian Coals

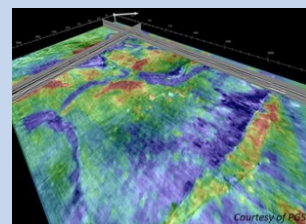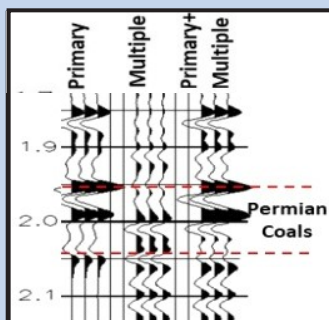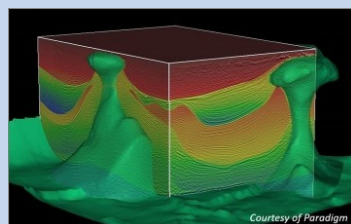Courtesy of PGS

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

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Doodlebugger Diary

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

Part 4: A Slight Mishap

By Scott Singleton

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. Since early 2018 I've 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 early doodlebugging experiences with Western Geophysical's Party 76.

As I recounted in Part 1 of this series, I had started working on the Western Gulf in May of 1979. In November of that year, we were docked in Freeport during our 6 days off. I had chosen to stay on the vessel along with one of the other seismic guys. The captain and his engineer were also onboard, as was standard protocol. It being November, a 'blue norther' had just blown through, dropping the temperature dramatically. Back in those days (before climate change had really taken hold) a blue norther was something to take seriously, especially if your job had you working offshore. In fact, in the near future, I'll have another segment describing what happens if one of these things blows through when we were doing seismic operations. I can assure you; it was not much fun.

So, with the passage of the norther in the early morning hours, temperatures dropped probably around 30 degrees (a standard drop from a blue norther). After daylight, the thermostats on board kicked in and realized that the interior of the boat was a tad chilly. So, being dutifully programmed, these thermostats turned on the heating units to blow some warm air through the boat. Well,

Figure 1: Burned charts on the chart table just aft of the main bridge. The person partially visible is Captain Jerry, hailing from Santa Barbara, CA, who was busy sweeping up the mess.

unfortunately for the rest of us, during the long summer months a significant amount of lint had collected in the ducts and on the heating coils, which had not been used for a very long time. So, as the heating coils quickly ramped up the temperature of the air that was being forced through the ducts, some of it burned off, likely on the coils first. Those sparks were then pumped through the ductwork, igniting other lint accumulations. Pretty soon all the ducts in the upper floor of the boat, housing the bridge, the nav room and the galley, were belching thick smoke. A disaster was rapidly unfolding.

Those of us onboard smelled the smoke immediately and stopped whatever we were doing to run outside. Simultaneously, the smoke detectors onboard also knew something was amiss and went off in full alarm mode. In that moment, the entire Freeport dock area knew there was a fire somewhere and everyone was running out of their boats to see where it was. Among the seafaring, fire is a serious matter not to be trifled with.

I, being a greenhorn college grad, could only stand on the dock watching as smoke belched out of the upper portions of the boat. However, the other seismic guy, whose name was 'Red' (you can guess the color of his hair) and who hailed from Hattiesburg, Mississippi, instantly decided he was not going to let the boat burn down. I guess that country upbringing prepares one for the hazards of life much more than my suburban life did. He quickly took stock of the situation and decided on a course of action. He ran to the lower deck that housed the instrument room, grabbed one of the fire extinguishers that were liberally placed throughout the boat, and ran up the short flight of stairs into the galley spraying the contents of the fire extinguisher everywhere. Keep in mind that it was not like he could see anything – the galley was choked with smoke. He apparently knew he would only have one breath to work with.
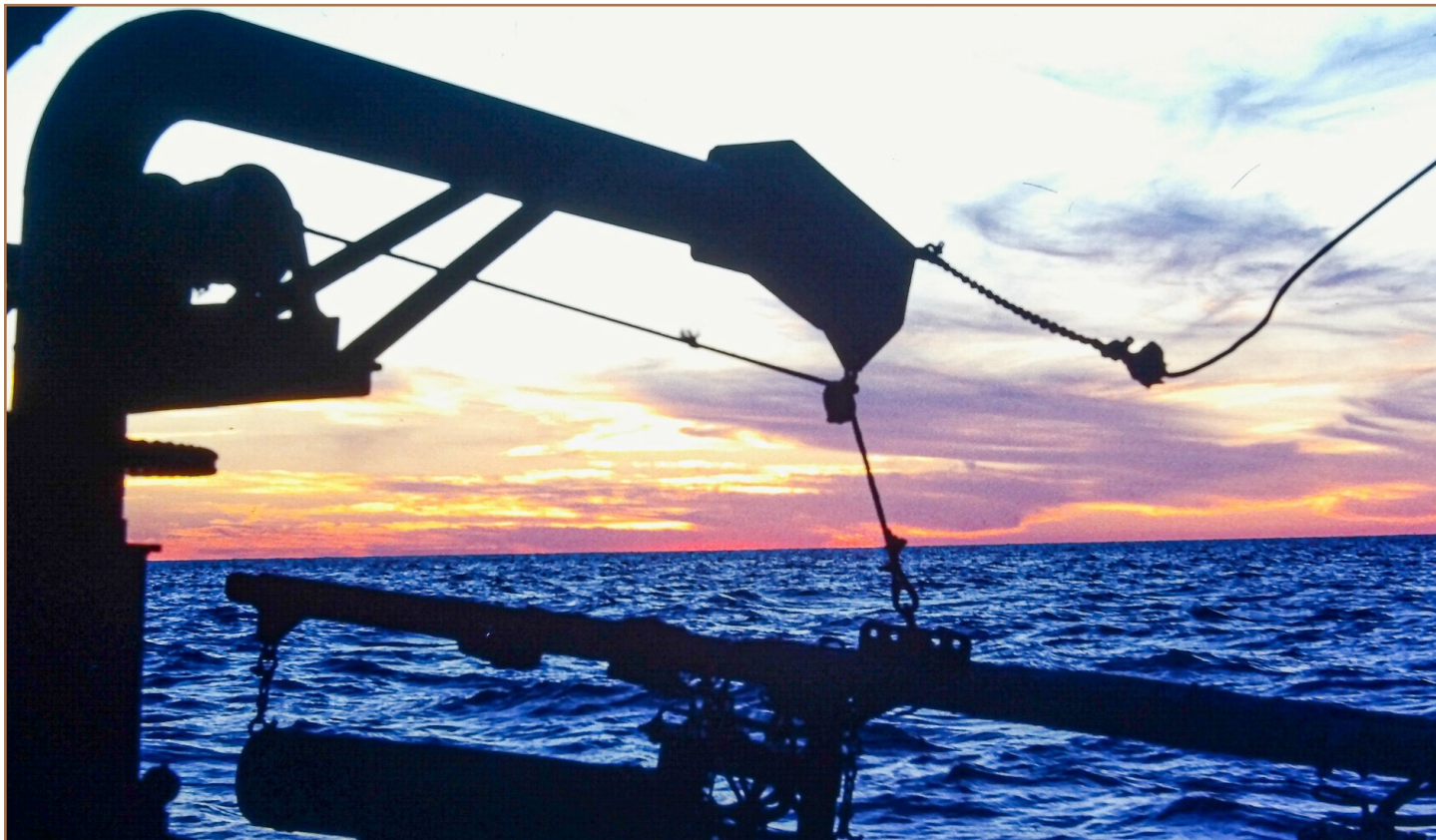
In what seemed like forever, we stood on the dock listening to the fire extinguisher being sprayed around. Gathering with us were crewmen from boats near us. We were all slowly realizing that if we stopped hearing Red's fire extinguisher being sprayed, some of us would need to rush into the galley to retrieve him. We started to make plans to do just that. We started tying facemasks of t-shirts around our heads as we steeled ourselves for a rescue

operation. Miraculously the spraying continued, and continued, and continued…

Eventually, Red emerged from one of the hatchways in the bridge section of the upper deck. He was gasping for breath but otherwise seemed to be very alive and conscious. Several of us approached him to make sure he was OK. He confirmed that he was fine. He said he sprayed the entire container at the vents because they were belching smoke and flame, and only came out of the boat when his extinguisher ran out. We were all looking at him incredulously. How could he stay in there for that long? He waved us all off, saying that he knew what he had to do to save the boat. And sure enough, as we led him away

Figure 2: Looking into the nav room which was just opposite of the chart table from Figure 1. As you can see, it was a total loss due to the heat and smoke. The worst damage was along the ceiling which was where flames were spewing out of the air vents.

Figure 3: Silhouette of a gun string and the deployment arm against a splash of colors.

onto the dock, the amount of smoke belching from the boat seemed to decrease and eventually tapered off significantly.

After a while, the fire department arrived and went on the boat in full firefighting gear. When they all came back out and started packing up, they said the fire had already been extinguished. They said it came from a vent, and that it had burned up the chart table *(Figure 1)* and the nav room *(Figure 2)*. They asked who had gone onboard a burning boat to extinguish the flames. We all pointed to Red. The captain thanked him for his bravery and said he could have easily lost his life doing that. Red was nonplussed. He said that was what he had to do. The captain just nodded at him and shook his hand before walking off. The rest of us were incredulous.

I became good friends with Red. He was a typical country kid, and of course they all thought I was a typical college dork. We were total opposites. But we both respected what the other brought to the table. He ended up inviting me to Hattiesburg, where I saw a world that I had never seen previously. I also spent a lot of time in Biloxi with another seismic guy from our boat and even lived there for a while. These were times that I'll never forget because they represented a different world, but one filled with fun-loving, friendly people.

And this is a lesson I want to leave you with. In the current atmosphere of polarization and hatred, we all are being indoctrinated with the philosophy that anyone who does not think like us is an enemy to be demeaned and defeated. This could not be farther from the truth. We all have something to contribute, even if we all do not think alike about every issue under the sun. But that does not mean your fellow man (or woman) is an enemy and deserves to be denigrated as not worthy. Quite the opposite – those with different views are what makes us strong. Embrace diversity. Practice inclusion, not hatred.

Sunset picture of the month – *Figure 3* was taken in October or November of 1979, about the same time as the events in this story. Enjoy! □