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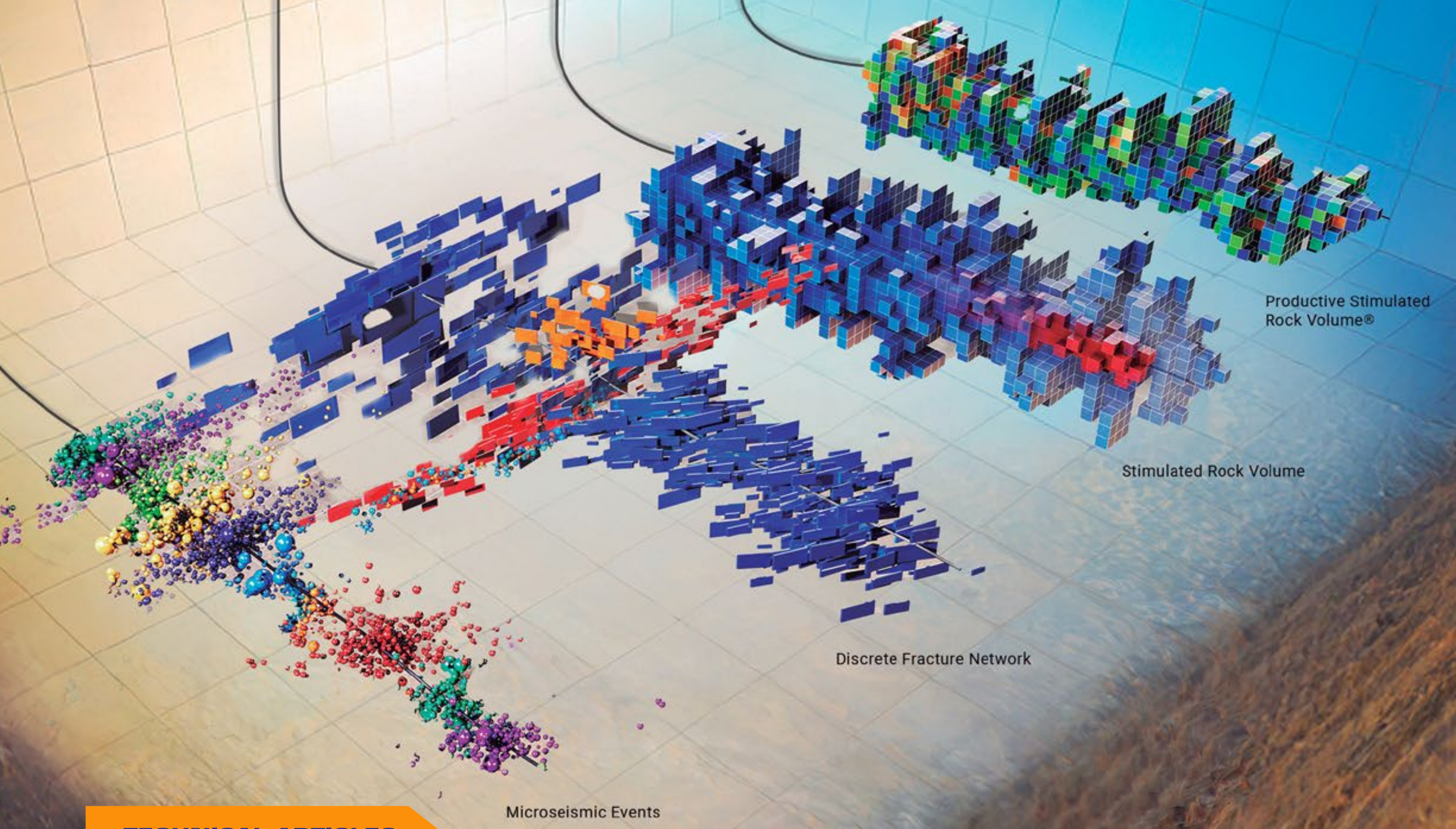

TECHNICAL ARTICLES

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TECHNICAL ARTICLES

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LOOK INSIDE

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On The Cover...

This visualization illustrates how advanced microseismic monitoring transforms hydraulic fracturing data into actionable insights. Beginning with the detection of tiny seismic events, engineers map the Discrete Fracture Network (DFN), quantify the Stimulated Rock Volume (SRV), and ultimately identify the Productive Stimulated Rock Volume (PSRV®) – the portion of rock that truly delivers hydrocarbons. By capturing and interpreting these subsurface dynamics in real time, MicroSeismic enables operators to make heroic decisions to maximize production, reduce risk, and optimize well performance.

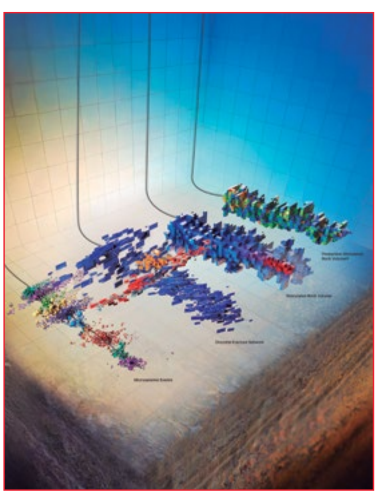

Image courtesy of **MicroSeismic, Inc.**

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Word from the Board

By: Rene Mott, President

Greetings to Houston and GSH members! I want to provide you with an update about the Geophysical Society of Houston. Last year, we finished strong thanks to the 2024-25 board and the many volunteers who helped make it happen.

This year, we're starting off with another terrific program! The Fall Forum, scheduled for October 16, 2025, is open for registration. This year's theme is *"From Waveforms To Insights: Latest Developments in Processing, Inversion, and Artificial Intelligence."* Please join us to explore dynamic developments in seismic data processing, inversion, and artificial intelligence.

On January 15, 2026, we will co-host a seminar with the Geological Society of Houston titled *"Lessons Learned from Missed Opportunities and Surprise Successes."* The premier Spring Symposium on "Innovations" will take place on April 22-23, 2026, in honor of Tom Smith, and should not be missed. The Academy of Geophysical Training follows, with industry experts offering their knowledge and experiences on over 12 subject matters. The Academy is a fantastic place to learn new skills or refresh the skills you already have. If you wish to join us in supporting the Houston Area Geophysicist, please contact the office at office@gshtx.org to learn about the various ways for making a contribution.

The GSH also offers a fantastic calendar of social events to help you network with other geophysicists in the Houston Metro area. These events provide an opportunity to catch up with familiar acquaintances, make new friends, and have a lot of fun along the way. Check our calendar for times and locations: Event calendar.

Our young professional group, Next Gen, is off to a strong start with three meetings and plans to grow. If you would like to join this network of early-career professionals, please contact office@gshtx.org to be linked and included to this growing list.

GSH's Outreach group is really significant. This team is about professionals giving back. Volunteers showcase the exciting possibilities and potential of geophysics in STEM programs for grades K-12, as well as on-site presentations for groups at the GSH Center. The Outreach team is enhancing their program to be relevant with today's science. If you appreciate teaching, meeting new people, young minds and aspiring scientists, please contact office@gshtx.org to be linked and included in the STEM Outreach group.

Rene Mott

The Bob Sheriff Library now has over 3000 titles for research; some materials have been used in patent lawsuits and international research. The Library also provides GSH members with free geophysical books. If you are not a member, joining is easy and cost is low. Follow this link to join: Join GSH.

The GSH is honored to have one of only three museums in the world dedicated only to geophysical material, with over 2500 items on rotating exhibits. Come visit us and join me for a cup of coffee every Thursday at 1790 W Sam Houston Beltway North Houston, Texas 77429.

We are looking forward to a great year starting now and including you!

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From the Other Side

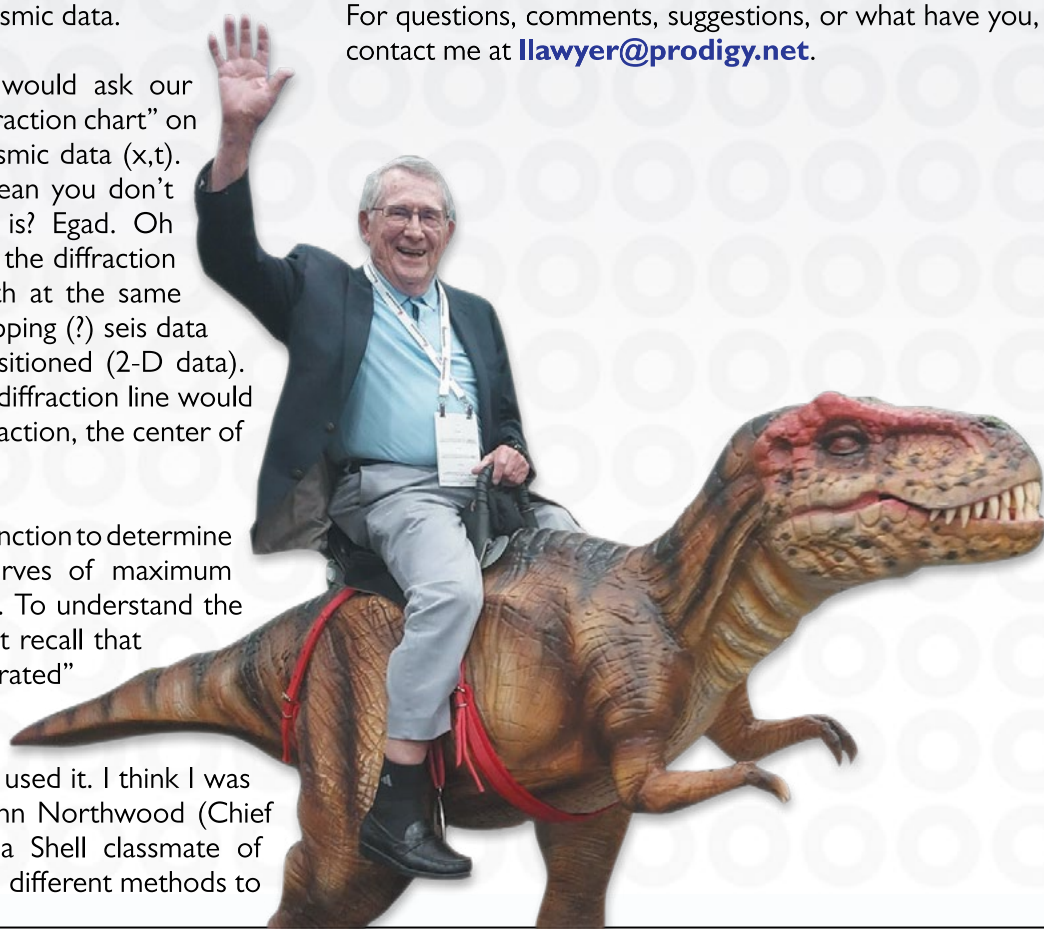
By: Lee Lawyer, 2025

FTOS revisited: Remembering the good old days, I really liked the jargon we used back then. Try this one on for size taken from FTOS in The Leading Edge, January 2014:

I believe it was in 1954 when a Dutchman named Hagedoorn published a paper called, "Curves of Maximum Convexity". What a strange title? But it was understandable to anyone who was working with "live data", i.e., Interpretation. I am not sure how many casual/ temporary/ neophyte/ etc. interpreters really understood or had ever heard of that subject. I used it extensively in interpreting 2D seismic data.

When going into a project, I would ask our computer people to make a "diffraction chart" on film at the same scale as my seismic data (x,t). What? I can't hear you! You mean you don't know what a diffraction chart is? Egad. Oh well, in any case, I could overlay the diffraction chart over my seismic line (both at the same scale) and determine how far dipping (?) seis data would move when properly positioned (2-D data). Any event that was parallel to a diffraction line would migrate to the origin of that diffraction, the center of the diffraction chart.

Of course we needed a velocity function to determine the diffractions, that is, the curves of maximum convexity! (back to Hagedoorn). To understand the impact of this method, you must recall that we were dealing with "unmigrated" 2-D time data. This was a simple (?) graphical method of migrating seismic data. Very few used it. I think I was singular in Chevron although John Northwood (Chief Geophysicist of SOTEX) was a Shell classmate of Hagedoorn). There were several different methods to migrate picked data. It was customary to do that on the crew using individual 24 trace records. I am talking about CDP seismic time sections rather than individual records. In his paper, Hagedoorn extended the graphical method to the migration of time maps. To do that, you would need a companion 'Wave Front Chart'.



For questions, comments, suggestions, or what have you, contact me at **llawyer@prodigy.net**.

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Letter to the Editor

From Dave Monk

First of all, congratulations on the new GSH Journal. In the past I used to read the journal from front to back, but never seemed to find the time to look at it online.

Of personal interest was Scott's Doodlebugger Diary article on Telseis in the March 2025 Journal. Early in my career, and as a last stint in West Africa, I ran a Telseis crew. I'm pretty sure that we had 96 units on the crew, but the number of radio frequencies available was limited to 60, so you could never record more than 60 channels at a time. Given that this was over 40 years ago I might have the numbers out by a little, but certainly limited to 2D!

The crew worked in a strong tidal area, so if you deployed the units at low tide the anchor was heavy enough to ensure that the float did not "float away" when lifted by the rising tide... but this means when the tide came in the anchor rope was shorter than the water depth, and the unit would be held underwater, often only visible as a short length of the aerial sticking out. The electrical connection to the cable and bottom deployed hydrophone was notorious for getting wet (this was of course an operation in water!), and the result was signal loss from a particular receiver. The observer could see this, since data was transmitted back real time to the doghouse. The observer would then send out a maintenance guy on a fast skiff to "squirt-squirt" the plug. WD40 to the rescue ..If you ever owned an original mini, you probably did this to the carburetor when it rained.

Anyway, the article reminded me of just how far the technology has evolved. Today the industry is recording ocean bottom node data in the ten's of thousands of nodes for each shot, and that's if the nodes are stationary.

Other operations deploy nodes that fly through the water from one location to another, and in most cases a single hydrophone has been replaced with 2,4 or 7 measurements of the wavefield at each node. And if you are wondering what the last 3 are, then they are the rotational components of the wavefield.

Many thanks for reminding me of how it all started.

Regards
Dave Monk

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GSH Museum News

The Bob Sheriff Library

The GSH Museum collection started in 1960 has always included some vintage geophysical books, in addition to the inventory of geoscience related vintage instruments. In 2013 Dr. Bob Sheriff donated his personal library of books, papers, journals, and materials to the GSH. Glen Bear and his Boy Scout troop helped load and bring about 140 boxes of books, periodicals, and other materials to the Geoscience Center *(Figure 2)*.

This donation greatly expanded the range and extent of our collection of geoscience publications and includes many of the awards, publications, and items from Dr. Sheriff's global travels and outstanding career. A picture of the cabinet with some of his awards, and copies of many of the editions of his "Encyclopedic Dictionary of Exploration Geophysics" *(Figure 3)*.

Dr. Bob Sheriff

We continue to receive donations of books and other materials that are added to our library inventory; which now includes over 2300 books and over 600 training manuals of geoscience related topics. The manuals include publications from the SEG, AAPG, oil companies, and contractors. Many of the books in the library, especially some of the older ones, are out of print and not available online.

Figure 2

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Figure 3

The Library also includes the following periodicals: Geophysics, The Leading Edge, Interpretation, AAPG Bulletin, CSEG The Recorder, DGS The Record, EAGE First Break, EAGE Geophysical Prospecting, Environmental Geoscience, Exxon Profile, The Humble Way, Humble The Lamp, GeoExpro, Western Profile, Geophysical Directories, GSH Newsletters and Journals, HGS Bulletins, Southeastern Geophysical Society Newsletters, GCAGS Transactions, and various membership directories of geoscience organizations. Some of these collections do not include every year of publication.

The Sheriff library also includes papers and files from Enders Robinson, Tom Portwood, Carl Savit, Hugh Hardy, and others *(Figure 4)*. Last year, a graduate student from out of town spent 3 days reviewing Enders Robinson papers for his research, showing that our GSH Library can be an important resource for research on just about any geoscience subject. The library also includes a collection of exploration reports from the early days of the industry including torsion balance and seismic refraction, and reflection reports. A digital file of some of the publications in the library is being organized and includes CD's and older VHS tapes of various presentations of the SEG and AAPG.

Another collection of materials is included in the "P" Files, located in a 3 drawer tan file cabinet. These files include personal papers from various individuals, oil companies and contractor publications, historical marketing materials, and miscellaneous documents.

Many of these materials can be checked out by members or used for research when visiting the Library. Under the Outreach tab on the GSH web site, you can find more information about the Museum and Sheriff Library, including links to the Museum inventory and the Library inventory. Volunteers are always welcome and needed to help maintain and update these collections of books and other materials.

Bill Gafford
cypbill@gmail.com

Figure 4

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Enhancing Structural Interpretation with Deep Learning: A Case Study on CNN-Based Fault Detection in Southern Mexico

Daniel A. Pineda[1], Fabian Rada[2], and Jie Qi[2]

Abstract

Fault detection and characterization are essential for understanding subsurface structural complexity in hydrocarbon reservoirs. This study integrates conventional seismic attributes with advanced computational techniques, particularly Convolutional Neural Networks (CNNs) and Self-Organizing Maps (SOMs), to enhance fault interpretation. Traditional attribute-based methods, such as coherence and variance attributes, provided an initial framework for fault identification but faced limitations in areas with chaotic signals or high noise levels. The application of CNNs, trained on a synthetic dataset, enabled more accurate segmentation and classification of seismic patterns, improving the detection of conjugate faults and overlapping deformations. The analysis of Fault Dip Magnitude and Fault Dip Azimuth revealed dominant fault orientations between N60E and N90E, with prevailing vergence azimuths from 0° to -30° and 150° to 180°. Integrating traditional attributes, with CNN, image-processing and SOM, resulted in clearer and more detailed seismic volumes, offering a robust and scalable workflow for structurally complex settings.

Introduction

Commonly, the first step in seismic interpretation involves defining the structural framework based on fault positioning. Displacement along fault planes generates compartmentalization, with fault-bounded blocks frequently hosting hydrocarbon accumulations.

Traditional methodologies supporting three-dimensional seismic interpretation have primarily relied on structural seismic attributes that measure variations in Coherence and Semblance. These attributes help identify zones where amplitude discontinuities may indicate fault boundaries. However, there is no clear guideline on when to use Coherence versus Semblance or how their differences impact the results. Coherence is calculated by averaging trace-to-trace amplitudes over a window, followed by cross-correlation to identify zones with similar characteristics. This process generates a new "Dissimilarity" volume that represents the averaged response over the interval of interest (Bahorich and Farmer, 1995). In contrast, Variance measures differences relative to a mean value, providing more precise results through direct measurement without an intermediate step (Van Bemmel, 2000).

Among these structural attributes, Variance has traditionally been the primary tool for three-dimensional fault extraction from seismic data. It serves as the foundation for various workflows aimed at isolating seismic amplitude edges by considering both lateral and vertical variations. Notable examples include Ant Tracking (Pedersen et al., 2002) and Fault Likelihood (Hale, 2013). However, these methods often introduce anomalies due to the inclusion of random noise and processing artifacts, complicating interpretation in areas with chaotic amplitude responses.

Additionally, accurately inferring the strike and dip of fault surfaces using these traditional technologies remains a challenge. Tuning effects, wave interference, and closely spaced intersecting faults can introduce errors in fault orientation. As a result, significant expertise and calibration efforts are required to fine-tune the signal toward a specific objective—structural or stratigraphic—while applying filters that might otherwise obscure or blend responses from both domains.

Alternatively, the implementation of Convolutional Neural Networks (CNNs) for fault detection enables scalable and automated segmentation and classification of seismic patterns. This approach leverages a pre-trained model using synthetic seismic volumes to generate Fault Classification and Fault Probability volumes. These outputs integrate fault dip and fault dip azimuth (or

[1] PEMEX
[2] GEOPHYSICAL INSIGHTS

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vergence azimuth), enhancing fault prediction by filtering out zones with incoherent or unreliable responses. The CNN algorithm significantly improves the signal-to-noise ratio and enhances the spatial continuity of fault features, providing continuous estimates of fault dip angles and azimuths. These angles are computed as weighted averages based on the fault probability cube. Using the combined information from Fault Probability, Fault Dip, and Fault Dip Azimuth volumes, fault surfaces can be automatically extracted via a linked data structure. This represents a significant advancement in structural seismic interpretation (Qi et al., 2022).

Methodology

This document describes a methodology that enabled the generation of a reliable framework for targeting Cenozoic objectives in structurally complex areas. The structural complexity arises from compressional deformation events during the Miocene, followed by extensional events in the Pliocene-Pleistocene, compounded by the strong influence of salt tectonics and the presence of canopies. These conditions produce in a combination of reverse and normal faults, making the interpretation and tracking of discontinuities particularly challenging.

Fault detection was performed using a Convolutional Neural Network (CNN), a deep learning algorithm widely used in image analysis to identify visual patterns such as edges and textures. This algorithm has been adapted for geoscience applications to detect patterns associated with vertical and horizontal discontinuities in seismic images.

The CNN-based fault detection methodology automates the identification of geological faults in seismic volumes, eliminating the need for manual fault picking of training volumes and associated interpreter bias. By removing the uncertainty associated with manually selecting training lines, this approach ensures a more objective and reproducible workflow. The methodology rapidly generates consistent Fault Probability, Fault Dip Magnitude, and Fault Dip Azimuth volumes, improving structural interpretation accuracy. From an operational perspective, the workflow requires only five minutes to set up and produces high-quality results without the need for continuous human-computer interaction, significantly increasing efficiency in fault detection workflows.

Figure 1 illustrates the Fault Detection workflow: Step 1 is pre-conditioning of seismic data mostly using the Structure Oriented Filter (SOF3D) program. This integrates the edge-preserving workflows developed by Fehmers and Höecker (2003) and Luo et al. (2002), incorporating several key refinements by Marfurt (2006). In Step 2, CNN-based Fault Probability and Classification volumes are computed, then in Step 3, fault features in the CNN Fault Probability volume are enhanced by an image-processing-based method known as Fault Enhancement and Skeletonization, providing not only enhanced Fault Probability, but also Fault Dip and Fault Dip Azimuth volumes (Qi et al., 2019). In Step 4, we use Fault Dip Magnitude and Fault Dip Azimuth volumes as input to a Self-Organizing maps (SOM) neural network for fault classification (Laudon et al, 2021). Finally, in Step 5, we use the fault attributes as guides in manual structural interpretation.

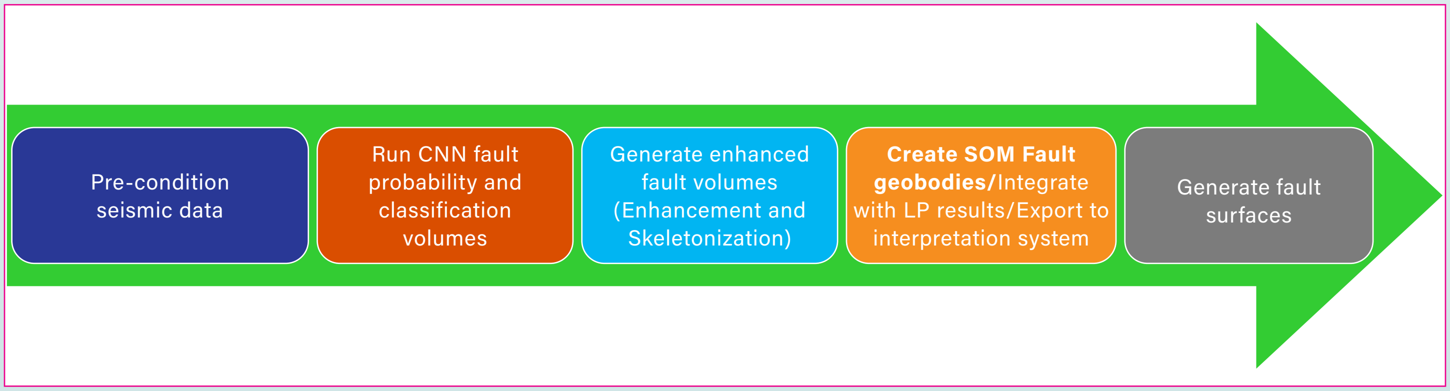

Figure 1. Simplified workflow for Fault Detection followed in this study.

Automatic Fault Detection Using Deep Learning

Convolutional Neural Networks (CNNs) are particularly effective in image processing and spatial data analysis. The Fault Detection process began by applying the Deep Learning Fault Detection algorithm to the in-house cleaned seismic amplitude volume. This algorithm

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utilizes a pre-trained database of approximately 4,000 synthetic volumes, generated by varying key reflectors and faults characteristics (e.g., density, noise, dip, azimuth, displacement, throw, among others).

Outputs included a Fault Probability volume (0 to 1) and a Fault Classification volume (binary: 0 for non-faults, 1 for faults), enhancing discontinuity identification and improving fault interpretation clarity.

Unlike conventional workflows, the CNN-based approach analyzes the Amplitude volume, eliminating the need to compute a Variance volume or specific filters. Figure 2 highlights this difference, showing CNN-based results (Figure 2-A) providing greater detail than the Variance attribute (Figure 2-B), advancing fault interpretation.

Fault Imaging Enhancement (Enhancement and Skeletonization)

Enhancement uses reflector dip behavior, incorporating attribute volumes like Dip Inline, Dip Crossline, and optional weights (e.g., Similarity Total Energy or Envelope). Structural dip attributes estimate seismic event tilt angles (apparent dip), ideally ranging from 0 to 90 degrees. In practice, to avoid false positives potentially associated with stratigraphic features, faults with dips below 10 degrees were discarded.

Analyzing dip behavior with Dip Magnitude and Dip Azimuth help distinguish fault orientation changes. Typically, near-vertical faults with Dip Magnitude between 80° and 90° are related to strike-slip regimes. Fracture zones show high dip magnitude angles, while normal and antithetic faults usually display dips between 50° and 70°. Reverse faults commonly have dip angles between 25° and 45° aiding fault type identification and structural understanding. Dip Magnitude is measured from the steepest angle of descent of a tilted bed or feature relative to a horizontal plane (Strike and dip, 2025).

A third cleaning process improved responses near anomalies using Directional Laplacian of Gaussian filters: one parallel to fault planes to elongate anomalies, and another perpendicular to them. These steps, "Fault Enhancement" and "Skeletonization," are detailed in Qi et al., (2019) and Palágyi (2024).

The method calculates Fault Dip Azimuth and Dip Magnitude only within fault response areas, ensuring consistent local orientation estimates.

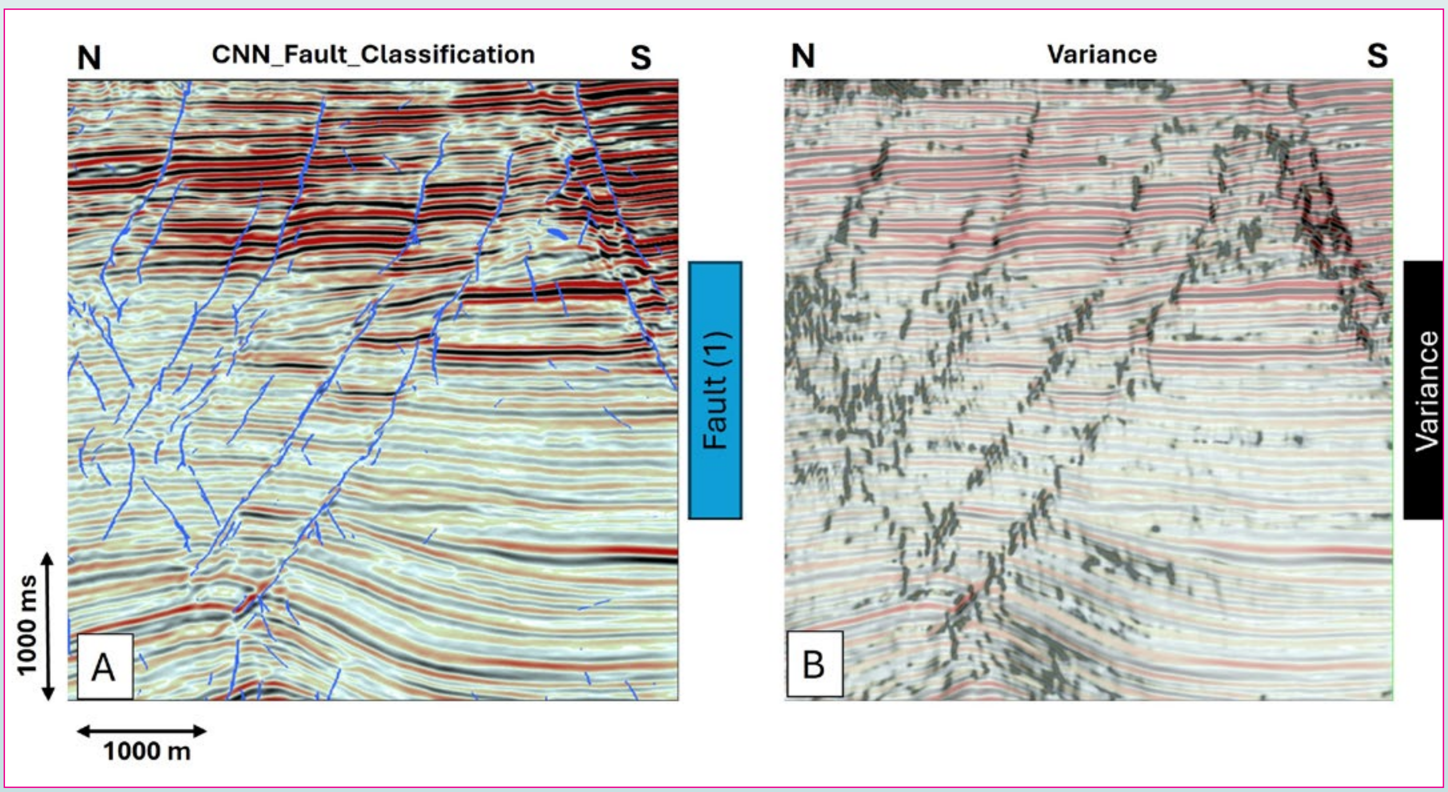

Figure 2. Comparison between the CNN result (left) and the geometric Variance attribute (right).

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In Figure 3, the Fault Dip Azimuth represents the direction of the normal vector to the fault plane, with values ranging from -180° to +180°. A value of 0° corresponds to north (blue arrow pointing north), with positive values increasing clockwise up to 180°. Conversely, when measured counterclockwise from the north, values are negative, reaching a minimum of -180° (yellow arrow pointing south).

This technology reduced attribute run times, calibration efforts, and the need for alternate workflows, streamlining seismic discontinuity analysis.

Application

The study area features reservoirs in a southern horst and a northern graben influenced by a listric fault and secondary faults. Results showed high-quality responses in fault-related areas, enabling manual updates to the structural interpretation. This simplified analysis in complex zones, such as fault crossings, junctions, and terminations.

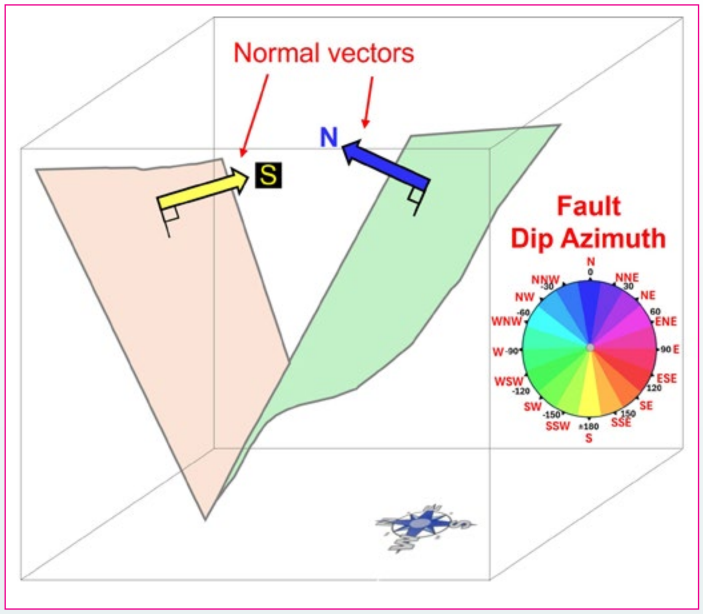

Figure 3. Schematic illustration depicting two fault planes with their respective normal vectors oriented towards the North (blue arrow) and South (yellow arrow).

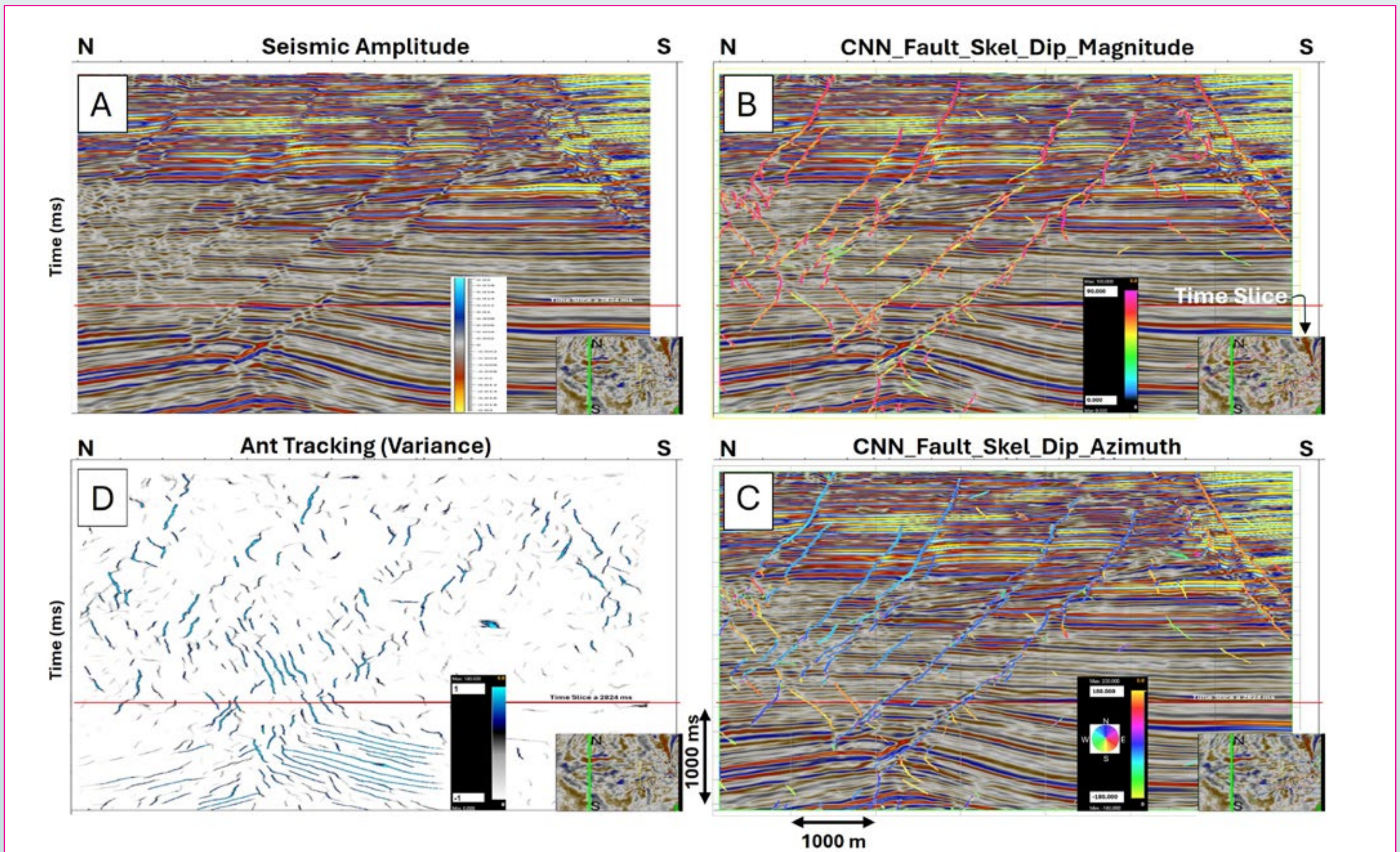

Figure 4. Section oriented N-S located to the west, showing the comparison of CNN Faults vs. traditional fault attributes.

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Case Study: CNN vs. Traditional Methods

Figure 4 compares results along a North-South section located in the western part of the area. Figure 4-A shows the amplitude attribute, while Figure 4-B illustrates the CNN derived Fault Dip Magnitude (skeletonized). Figure 4-C represents the CNN derived Fault Dip Azimuth (skeletonized), and Figure 4-D shows the variance attribute processed with the "ant-tracking" algorithm.

As seen in Figure 4, CNN-derived fault attributes provide greater continuity, significantly reducing "step-like" noise artifacts and are less sensitive to reflector dip, even at greater depths.

Advanced Structural Analysis with CNN-Derived Fault Attributes

Analysis of Fault Dip Magnitude (Figure 5-A) reveals 93% of faults have steep dips (50°–90°), indicating a highly structured, near-vertical fault setting. The Fault Dip Azimuth rose diagram (Figure 5-B) indicates two main vergence orientations: between 0° and -30° (28%) and between 150° and 180° (21%), representing reciprocal angles.

When considering fault strike directions, rather than dip azimuths, the main structural trend aligns between N60E and N90E, representing 49% of the total. The time slices in both figures further show the spatial distribution of these attributes, confirming a dense network of faults with well-defined orientations. The combination of Fault Dip Magnitude and Fault Dip Azimuth data provides critical insights into the structural framework, aiding in fault interpretation and geological modeling.

Subsequently, the simultaneous classification of these attributes using a Self-Organizing Maps (SOM) neural network on a seismic sample scale with 12 classes isolated fault families and reduced the time of interpretation (Figure 6-A).

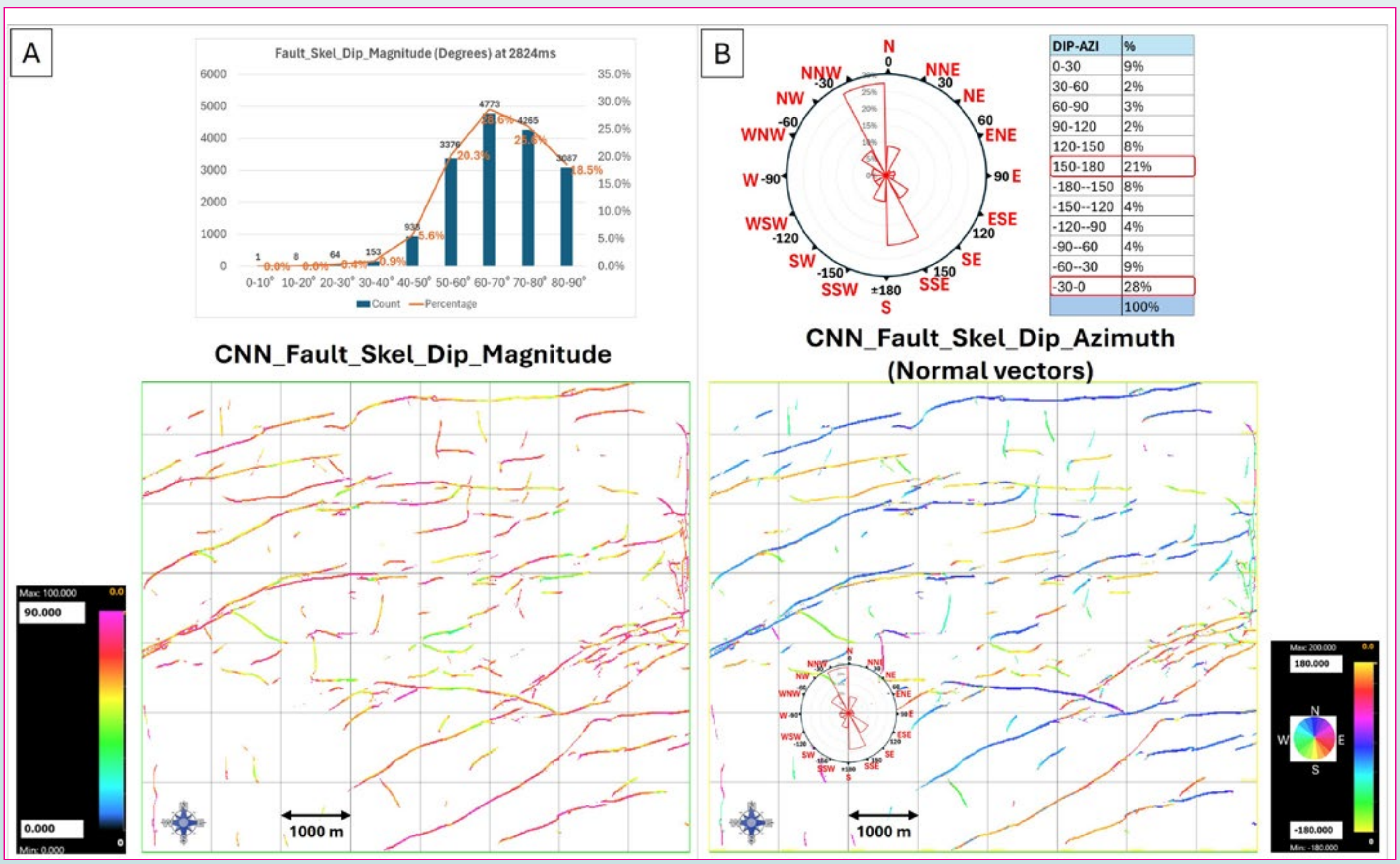

*Figure 5. **A)** Histogram and time slice at 2824 ms from Fault Dip Magnitude. **B)** Rose diagram and time slice at 2824 ms from Fault Dip Azimuth.*

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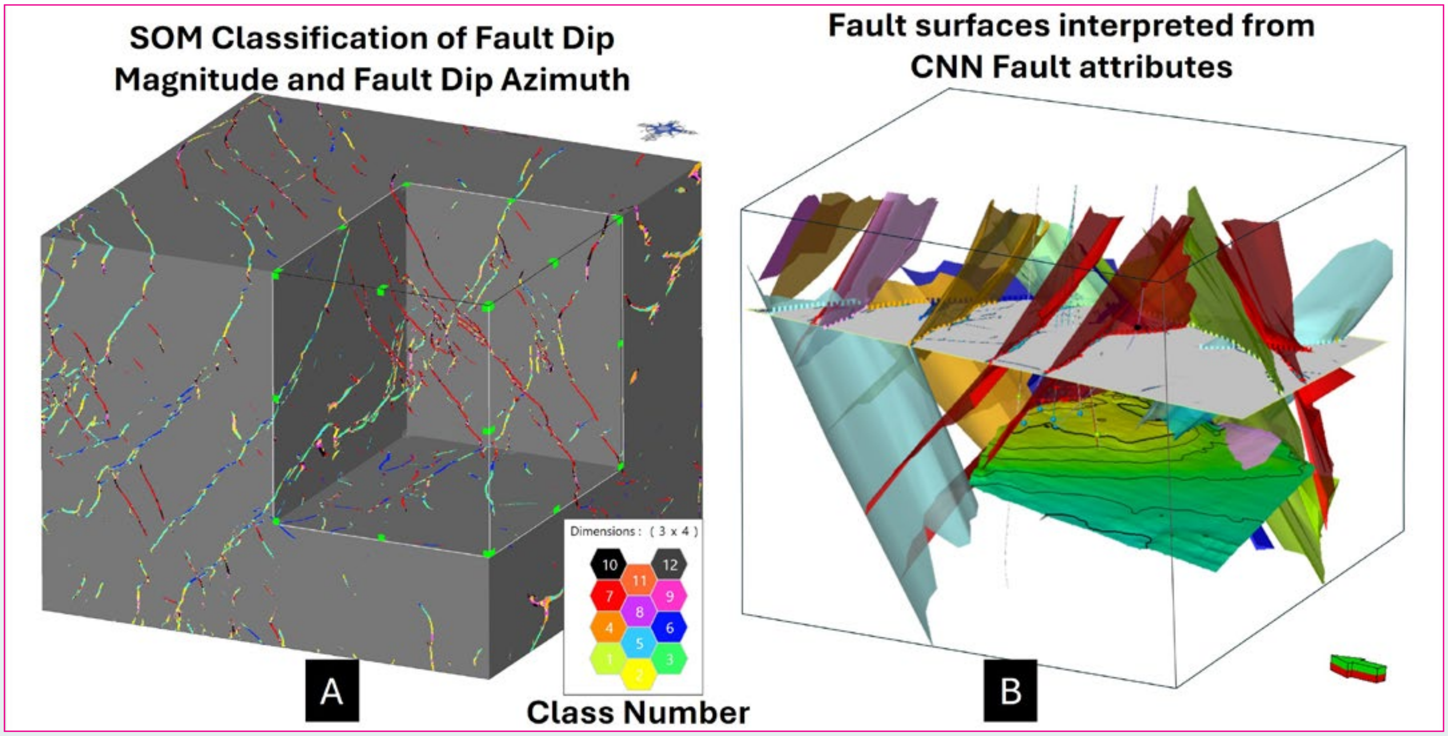

Figure 6. ***A)*** *Fault SOM classification volume.* ***B)*** *3D Fault Interpretation planes using the CNN Fault attributes as a guide.*

Two structural styles were identified: compressional reverse faults from salt canopy stresses and extensional normal faults. Previously, their coexistence complicated interpretation, but CNN-assisted analysis differentiated faulting regimes in the northern graben (Figure 6).

Conclusion

The structural analysis presented in this paper integrated conventional methods with modern computational techniques, significantly improving fault identification and seismic interpretation efficiency, ensuring greater certainty for drilling location visualization.

Traditional methods like coherence and variance attributes effectively identify discontinuities but struggled in noisy or chaotic regions, requiring extensive filtering and calibration.

Convolutional Neural Networks (CNNs) trained on synthetic data advanced fault detection, have enabled better segmentation and classification of seismic patterns. The resulting volumes (Fault Probability, Dip Azimuth, Dip Magnitude, and Fault Classification) provided exceptional clarity, surpassing geometric attributes.

Combining advanced computational tools with traditional workflows effectively addressed complex tectonic challenges, such as conjugate faults and overlapping deformations. This approach enhanced accuracy and offers a scalable solution for future studies in geologically complex regions.

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High-frequency visco-elastic MP-FWI for direct AVA-consistent property estimation

Fabio Mancini, James McLeman, Jennifer Badry and Tom Rayment, DUG Technology

Summary

Elastic multi-parameter full-waveform inversion (MP-FWI) offers a powerful alternative to conventional imaging by directly deriving AVA-consistent elastic parameters from minimally processed seismic data. This paper presents a detailed case study from the Australian North-West Shelf, acquired in 2006 with a dual-source towed-streamer configuration. Results demonstrate that high-frequency visco-elastic MP-FWI not only improves structural and stratigraphic resolution but also yields quantitatively robust rock property volumes aligned with well-log control.

Introduction

Increasing geological complexity in hydrocarbon exploration has driven the demand for advanced imaging techniques capable of delivering high-resolution amplitude-versus-angle (AVA) attributes. Traditional imaging workflows, such as reverse-time migration (RTM) and Kirchhoff depth migration (KDM), rely on the Born approximation and require extensive pre-processing to remove wavefield components that violate this assumption. Although least-squares extensions (Nemeth et al., 1999; Guitton, 2017) enhance amplitude fidelity, they remain limited to utilising primary reflections only.

Full-waveform inversion (FWI) (Tarantola, 1984), traditionally applied to diving waves for Vp estimation, has evolved into a multi-parameter methodology that incorporates reflected energy and allows for the simultaneous estimation of many subsurface parameters,

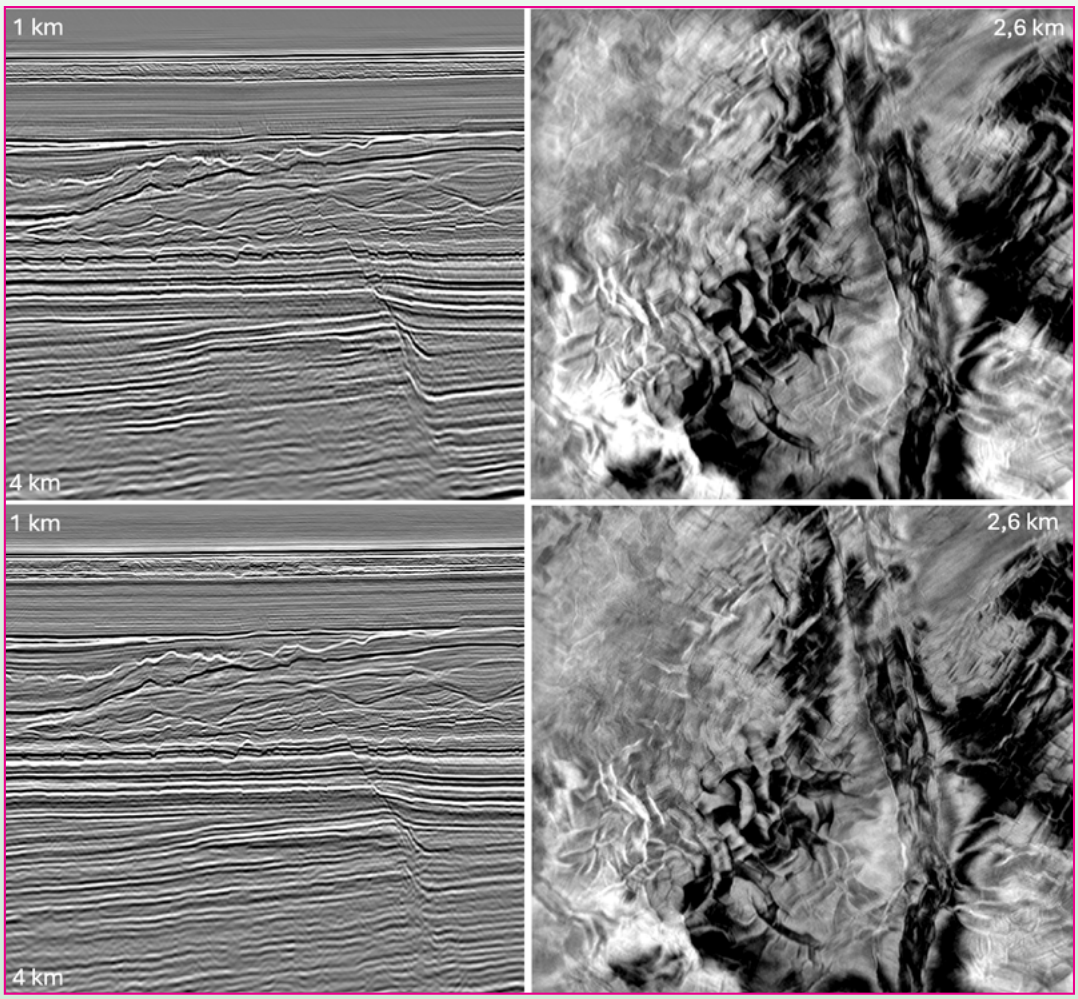

Figure 1. Imaging results at 60 Hz for LS-RTM (top row) and elastic MP-FWI (bottom row). Inline on the left and depth slice at 2600 m on the right.

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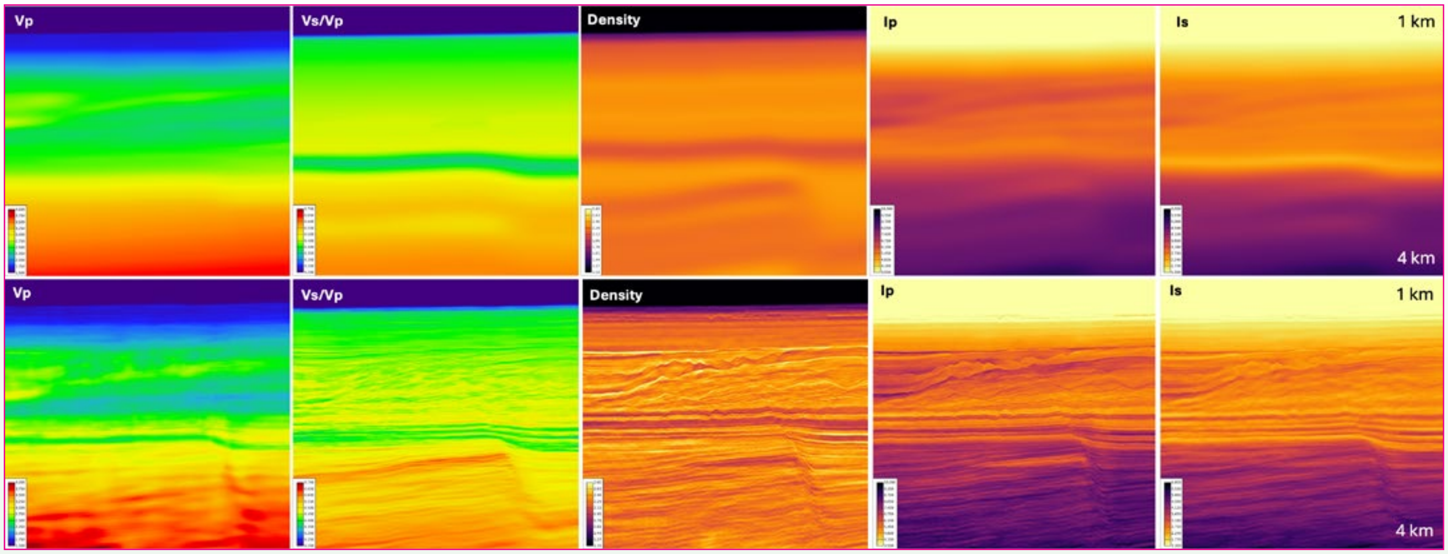

Figure 2. ***Top row:*** *starting models of Vp, Vs/Vp, density, P-impedance and S-impedance.* ***Bottom row:*** *final models of Vp, Vs/Vp, density, P-impedance and S-impedance.*

such as Vp, density and reflectivity (McLeman et al., 2023). MP-FWI leverages multiples as useful signal, enhancing data utilisation and resolution. Although early implementations often used acoustic assumptions, recent advances in high-performance computing have made 3D elastic MP-FWI (Gomes et al., 2024) feasible. This enables direct retrieval of additional elastic properties such as S-impedance and Vs/Vp ratio from raw seismic data without relying on angle stacks or conventional AVA inversions.

Methodology and results

The dataset was acquired in 2006 using a dual-source towed-streamer array northwest of Barrow Island. The towed-streamer vessel consisted of eight streamers with 6 km maximum offsets. The geology in the survey area is characterised by shallow carbonate heterogeneities and complex channel features.

Legacy Vp models were initially refined using diving-wave FWI up to 19 Hz. Initial low-frequency models for Vs/Vp and density were built using well logs and regional geology. These inputs were used in a multi-stage visco-elastic MP-FWI workflow: Vp and P-impedance were first updated at 11 Hz, 14 Hz, and 19 Hz; anisotropy was refined at 19 Hz; and a targeted single-parameter inversion further improved P-impedance using near-angle reflections. The inversion for Vp, Vs/Vp, and P-impedance followed at 19 Hz, 25 Hz, 35 Hz and 60 Hz. Parameter crosstalk was minimised through data partitioning and an L-BFGS optimizer with adaptive gradient preconditioning.

The inversion used raw hydrophone field recordings, with wavelets modelled and iteratively updated during inversion. No near-field hydrophone data were available. Pre-processing was deliberately minimal to preserve the full recorded wavefield; no deghosting, demultiple, or bandwidth shaping was performed.

Figure 1 compares the imaging results from least-squares RTM (LS-RTM) and visco-elastic MP-FWI at 60 Hz. Although LS-RTM used the velocity model derived from MP-FWI, its input data had undergone a full sequence of pre-migration processing. In contrast, visco-elastic MP-FWI operated directly on raw shot records. Even so, the MP-FWI reflectivity volume exhibits sharper channel definition, more coherent deep reflectors, and improved fault continuity. Fault shadows present in LS-RTM are resolved in MP-FWI, and deeper events display greater continuity.

The full value of visco-elastic MP-FWI is further illustrated in Figure 2, where inlines of the starting and final models for Vp, Vs/Vp ratio, density, P-impedance, and S-impedance show substantial resolution gains across all parameters. Fine-scale stratigraphic features, sharp fault boundaries, and subtle lithological variations, absent in the starting models, become clearly visible in the final models. Gas bodies and their associated flat spots are well defined in the updated Vp and P-impedance volumes, while, as expected, the gas-related anomaly is weak in the inverted S-impedance, confirming the fluid sensitivity of these parameters. These improvements are entirely seismic-driven as no well information was provided to

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the inversion itself. Wells were used only to construct the initial low-frequency background models, meaning all higher-frequency detail, stratigraphic clarity, and parameter contrasts in the final results are products of the recorded seismic wavefield. This demonstrates the method's ability to extract geologically meaningful, AVA-consistent rock property volumes directly from field data without explicit well control.

The available wells were used to QC the results, as shown in Figure 3. Here, well information (grey), initial models (red), and final visco-elastic MP-FWI results (blue) are compared at the well location. The agreement between the inverted parameters and the measured well logs is strong across all properties, with MP-FWI accurately capturing the P-impedance drop and associated reductions in Vp and density, alongside an increase in Vs/Vp in the gas-bearing interval marked by the orange arrow. This close match provides independent validation of the inversion, confirming that the seismic-driven updates are geologically realistic and that parameter crosstalk has been effectively mitigated.

The lithological discrimination benefits are evident in Figure 4, where crossplots of P-impedance versus Vp/Vs ratio reveal noticeably tighter clustering and clearer separation between lithologies compared to those derived from conventional LS-RTM followed by AVA inversion. The improved clustering enhances confidence in lithology classification and fluid prediction. This tighter distribution also reduces interpretational ambiguity, providing a more robust basis for quantitative reservoir characterisation.

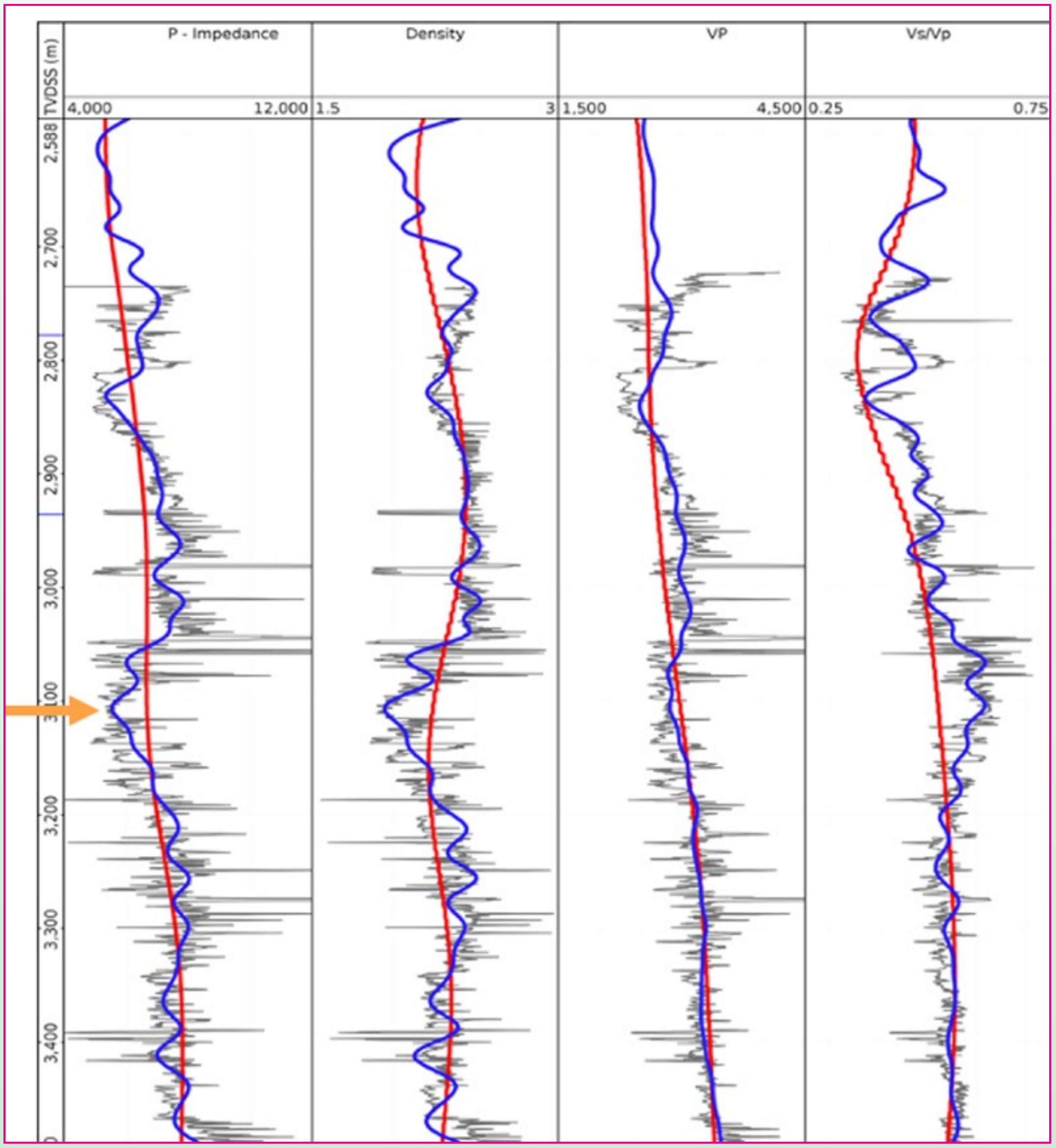

Figure 3. Results of P-impedance, density, Vp and Vs/Vp at the well. Well information is in grey, the initial models are in red and the Elastic MP-FWI imaging models are in blue.

Discussion

This case study highlights several operational and interpretational advantages of visco-elastic MP-FWI. By inverting directly for elastic parameters, the method removes the need for pre-processing, pre-stack migration, angle-stack generation, and subsequent AVA inversion, streamlining the entire workflow. It makes full use of all recorded seismic events, including multiples, treating them as valuable signal to enhance resolution and illumination. The minimal pre-processing required reduces the number of subjective parameter choices that can affect conventional workflows. MP-FWI ensures robust parameter recovery by suppressing crosstalk between Vp, Vs, and density, enabling reliable quantitative rock property estimation.

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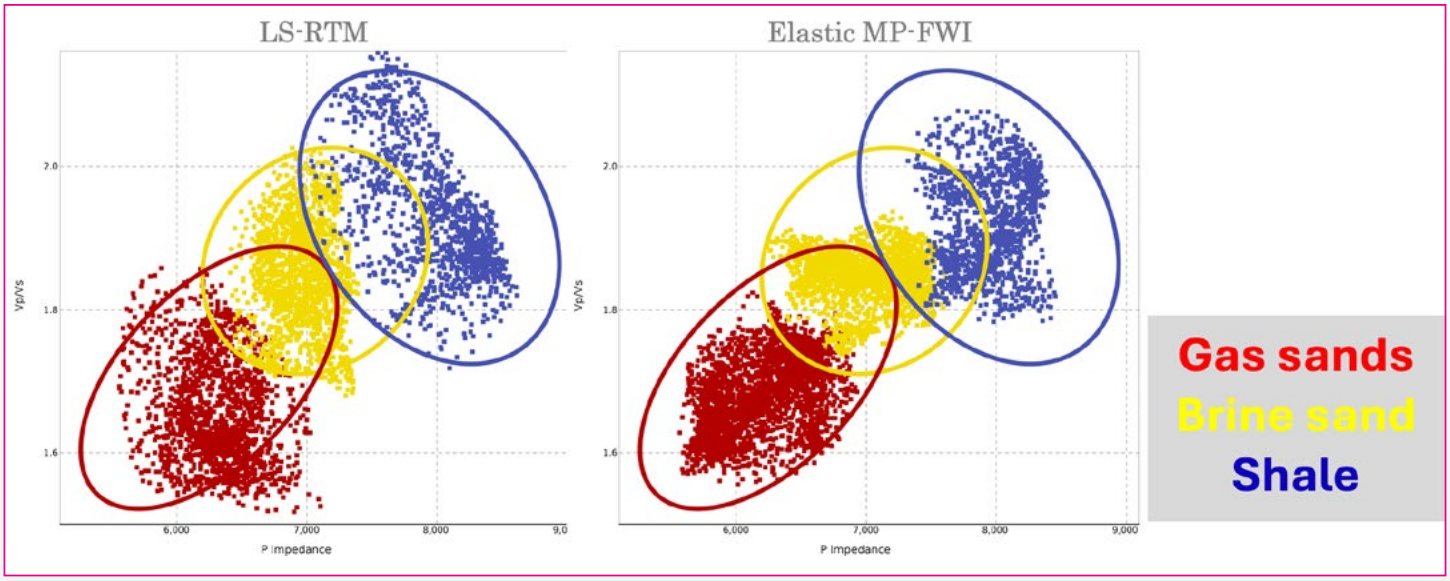

Figure 4. Crossplots of Vp/Vs and P-impedance were performed to define the most likely lithology, left using LS-RTM sub-stacks and, right, using the results of the elastic MP-FWI.

Conclusions

The presented case study shows the efficacy of visco-elastic MP-FWI in directly estimating AVA-consistent elastic properties from minimally processed seismic data. The method provides high-resolution, geologically realistic models that align with well-log data. Elastic MP-FWI simplifies AVA attribute extraction by removing dependence on pre-stack angle gathers and angle stacks, offering a robust and efficient alternative for modern seismic imaging in complex environments.

Acknowledgments

The authors thank DUG Technology for permission to publish these results and DUG Multi-Client for access to the BEX MC3D dataset.

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The Architecture of CO_2 Storage: Stratigraphic Continuity and Migration Pathways at Sleipner

Robert Van Eykenhof[1], Basil Onyekayahweh Nwafor[2], John Castagna[2], Marianne Rauch[1]

Introduction

The Sleipner project, located offshore Norway in the North Sea, represents the first industrial-scale carbon capture and storage (CCS) operation worldwide. Since 1996, more than 20 million tonnes of CO_2 have been injected into the Utsira Formation. The public availability of both baseline and time-lapse seismic datasets makes Sleipner an essential natural analogue for studying subsurface CO_2 migration. While repeated monitoring surveys have imaged the CO_2 plume, the 1994 pre-injection baseline lacked sufficient resolution to delineate the reservoir's stratigraphy. As a result, early interpretations assumed plume migration was mainly structurally driven. Subsequent monitor surveys revealed segmented and asymmetric accumulations inconsistent with this assumption. To address these uncertainties, we carried out Sparse Layer Spectral Inversion (SLI) with spectral reshaping to the 1994 dataset. This approach enabled improved thin-bed imaging and the derivation of new seismic attributes, including the Stratigraphic Continuity Attribute (SCA) and Apparent Time Thickness (ATT), which provide insight into the stratigraphic controls on CO_2 migration pathways at Sleipner.

Geological Setting

The Utsira Formation is a medial to distal submarine fan complex extending approximately 400 km north–south and 50–100 km east–west, with an areal extent of ~26,000 km². It is composed of unconsolidated fine- to medium-grained sandstones, with porosity values of 27–42% and permeability ranging from 1 to 8 Darcy. The unit lies between 700 and 1000 m subsea, sealed by a thick succession of mudstones and shales that provide effective regional containment. Thus, plume migration is governed primarily by internal stratigraphy rather than seal integrity. Incised channel systems and overbank deposits are prominent features within the Utsira. Channel fairways act as high-permeability conduits, whereas finer-grained or disturbed intervals behave as lateral baffles. Recognition of this internal architecture is critical to understanding plume evolution at Sleipner.

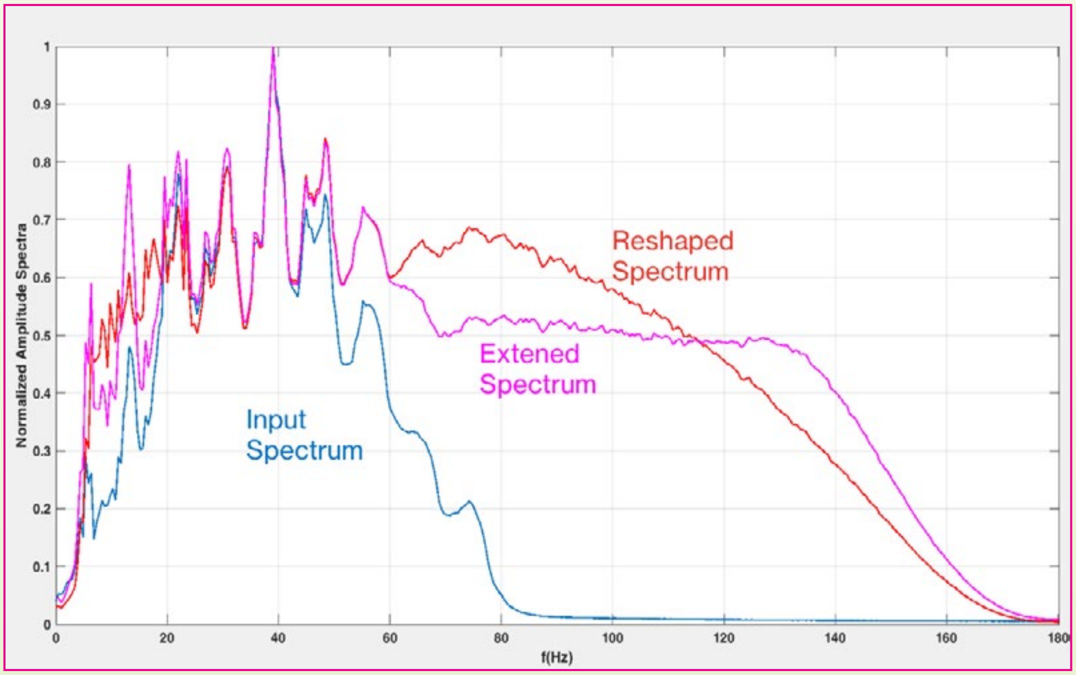

Figure 1. Frequency spectra comparing input (blue), extended (pink), and reshaped (orange) bands used in Sparse Layer Inversion. Spectral reshaping minimises ringing while preserving useful bandwidth for thin-bed imaging.

[1] Lumina Geophysical LLC
[2] University of Houston

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Methodology

Sparse Layer Spectral Inversion (SLI) was employed to enhance the 1994 baseline survey. This deterministic method resolves reflectivity from thin layers below tuning thickness by modelling reflections as pairs of coefficients rather than isolated spikes. High-resolution spectral decomposition was applied to extend the data bandwidth. To prevent the introduction of artifacts, the extended spectrum was reshaped, balancing around 70 Hz while tapering the slope above 135 Hz. This minimised Gibbs ringing while preserving additional high-frequency content, as illustrated in Figure 1. From the bandwidth-extended dataset, we derived two attributes. The Stratigraphic Continuity Attribute (SCA) quantifies lateral persistence of reflectors, highlighting areas of high continuity (connected channel sands) and discontinuity (potential barriers). The Apparent Time Thickness (ATT) attribute provides a frequency-derived estimate of layer thickness variations across the interval. Together, these products reveal channels and barriers that were unresolved in the original baseline.

Results

Sparse Layer Inversion reflectivity calculated from the 1994 baseline reveals stratigraphic detail not previously observable. Incised channel bases, formerly misinterpreted as mud diapirs, are clearly resolved. The derived Stratigraphic Continuity Attribute highlights three north–south channel fairways and a NE–SW discontinuity that acted as a lateral barrier, as shown in Figure 2. Comparison with the 2010 monitor survey demonstrates close alignment between plume migration and areas of high continuity. Where continuity is high, the plume migrated efficiently along channel fairways. Where continuity decreases, plume progression slowed or was diverted, as evidenced in Figure 3. These results confirm that internal stratigraphy exerts primary control on plume distribution at Sleipner.

Discussion

The plume's asymmetry and segmentation are best explained by stratigraphic architecture rather than structural dip or seal failure. Continuous channel sands formed preferential pathways, whereas low-continuity zones impeded or redirected migration. This interpretation is consistent with the geometry observed in the monitor surveys. The Sleipner case demonstrates that Sparse Layer Inversion applied to legacy baselines combined with derived Stratigraphic Continuity Attributes can

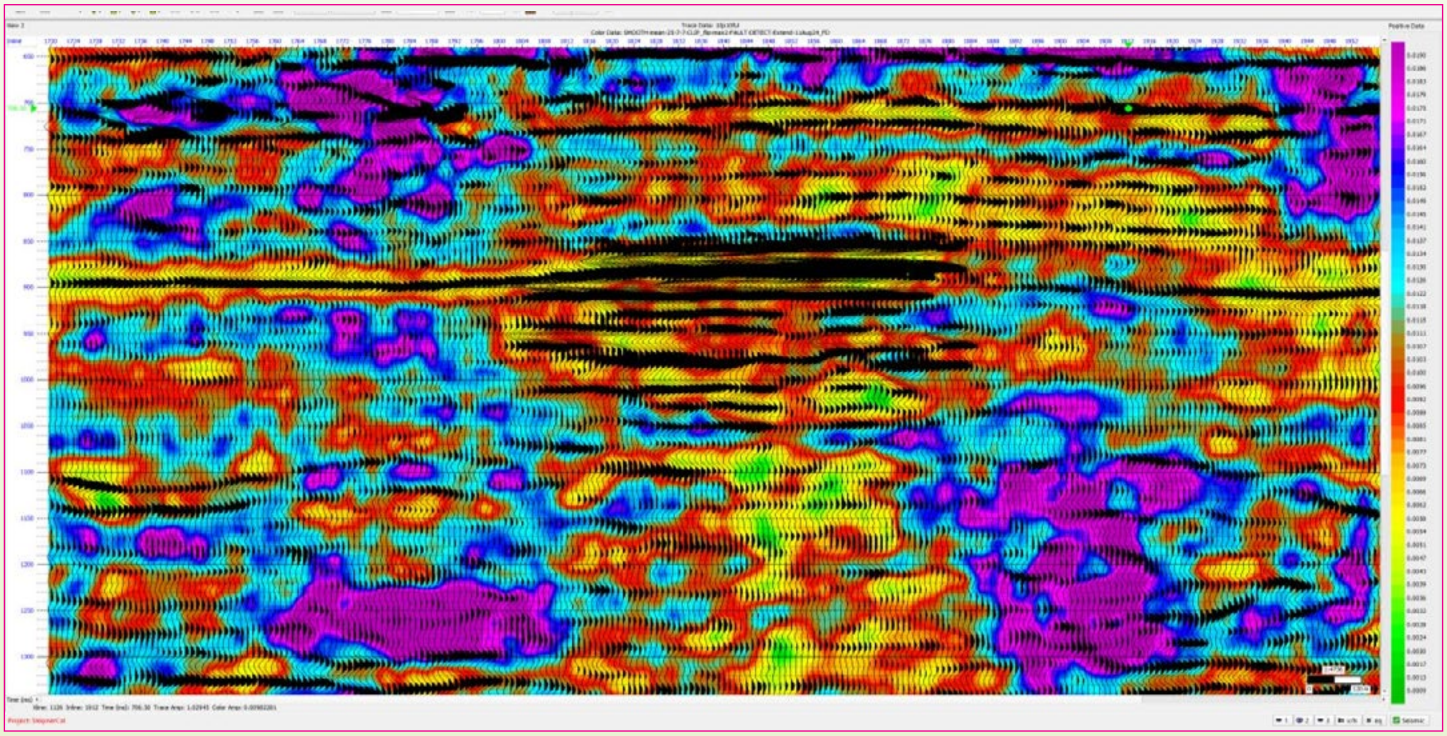

Figure 2. Stratigraphic Continuity Attribute (SCA) derived from the 1994 bandwidth-extended baseline with 2010 monitor overlay. High continuity (warm colours) delineates channel fairways that guided plume migration, while discontinuities coincide with plume segmentation.

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serve as predictive tools for plume behaviour. Workflows combining bandwidth extension, spectral reshaping, and continuity analysis are therefore highly relevant to CCS projects targeting channelised siliciclastic reservoirs.

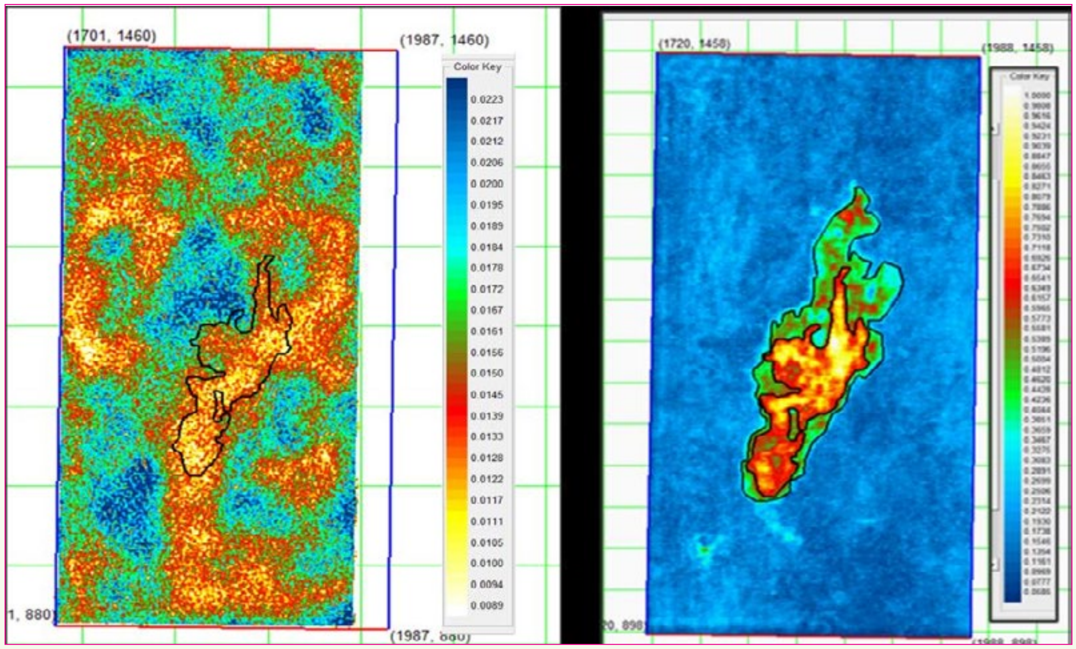

Figure 3. *RMS comparison between the 1994 SCA baseline (left) and the 2010 monitor survey (right). The plume migration pathway follows the channel fairway predicted by baseline continuity analysis.*

Conclusions

Application of Sparse Layer Spectral Inversion and derived attributes to the Sleipner baseline demonstrates enhancement of seismic resolution beyond tuning limits, improved imaging of incised channels and discontinuities, and strong correspondence between stratigraphic continuity fairways and subsequent plume migration. This confirms that plume migration at Sleipner is governed primarily by stratigraphic architecture. Reevaluating legacy datasets in this manner provides an effective predictive tool for appraisal and monitoring of future CCS projects.

Acknowledgments

We acknowledge Equinor and the Sleipner consortium for making the dataset publicly available, as well as SEG Evolve for fostering collaboration. We also thank colleagues and prior researchers whose work on sparse-layer inversion and spectral bandwidth extension underpins this study.

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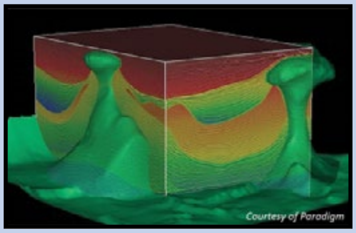

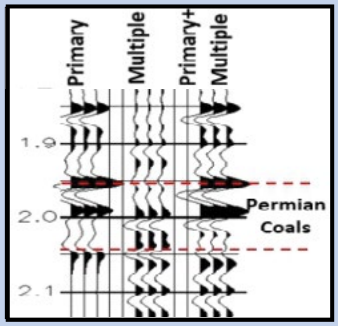

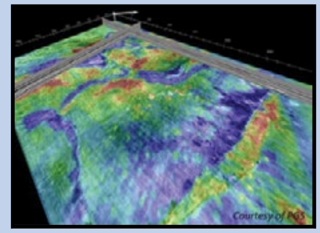

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Doodlebugger Diary

Silver Anniversary Celebrated by Western of Canada, Ltd.

Story by Western of Canada VP W.A. (Al) Knox and Western technical writer Pamela Carlin • Photos from Western Profile archives • Originally published in the 1977 Winter Western Profile • Recounted by Scott Singleton

The Doodlebugger Diary recounts the experiences of geophysicists during their working lives. I've published extensively on my own experiences and encourage those of you with experiences of your own to also contribute. Your fellow industry professionals would love to hear your stories.

Previously I reprinted a series of early 1980's articles from the GSI Shotpoints and GSI Grapevine that can be found at http://gsinet.us/. However, in the past few years I have been reprinting various interesting and engaging Western Geophysical Profile articles from the 1970's, which is interesting to me because this is when I first became a doodlebugger and Western Geo is the company that first hired me to work offshore. The full set of scanned Profile issues can be found at https://library.seg.org/page/western-profile.

WESTERN GEOPHYSICAL Company of Canada, Ltd., celebrated its silver anniversary on November 1, 1977, commemorating 25 years of growth and exciting changes. Over these years Western of Canada has burgeoned to become the most important geophysical contractor in western Canada.

Here is how it all started.

Figure 1: *It is summertime in Canada, which means that vehicles with wheels cannot be used in the bush country.*

Eons ago, a placid, shallow inland sea stretched southeast from what is now northeastern British Columbia, through Alberta, southern Saskatchewan, and southwestern Manitoba into the Williston Basin of North Dakota. Basking under a warm sun in a benign climate, hundreds of reefs, atolls, and lagoons sprinkled the sea. As the ages passed, sediments filled the ancient Devonian sea, sealing many of the reefs with green shale. The organic matter contained within the sealed reefs was converted to oil that filled the voids in the reef structure.

In the late 1930's and early 1940's the Imperial Oil Company conducted extensive seismograph surveys in central and southern Alberta. Among a number of promising structures was one lying in the farming community of Leduc, a few miles southwest of Edmonton. Imperial began an exploratory drilling program over the structure, and after 114 dry holes (according to Ken E. Liddell in This Is Alberta), a prolific discovery was made at Leduc in February 1947. Folk legends have it that the discovery was an accident. One version alleges that a discouraged management decided to drill "just one more hole" before abandoning the prospect. Another version would have us believe that an enterprising on-site geologist decided to drill a bit deeper than scheduled, just to see what was there, and so tapped the Leduc D-2 pool. Whatever the circumstances, the Leduc discovery triggered an oil stampede that effected profound changes in Alberta's economy and in Western's future.

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Figure 2: *Tracked vehicles are always pressed into service whenever the Canadian bush country becomes almost impassable.*

Following the Leduc discovery, Western of America Vice President V. E. Prestine (now retired) visited Alberta in the fall of 1947. The following spring, 1948, he sent Parties 39 and 50 on temporary assignment to central Alberta. After the spring thaw in 1949 Party F-10 moved to Stettler on permanent assignment, followed in rapid succession by Parties F-11 and F-53. Soon thereafter Parties 34 and 52 moved somewhat farther north into the Athabaska-Peace River areas.

For the next two or three years Western's field operations were administered partly from the Los Angeles headquarters and partly from a local headquarters located in various temporary offices in Calgary and Edmonton. Headed by Lyall Campbell (now retired), Western's local

Figure 3: *The snow is falling as this bulldozer blazes a trail for wheeled vehicles in Canada's inaccessible bush country.*

Figure 4: *Since winter has come and the muskeg is as firm as solid ground, Western has wheeled vehicles operating in Canada's bush country.*

headquarters finally moved into a permanent building in Calgary in 1951.

By this time Western had become firmly established as a major geophysical contractor in Calgary, and autonomous local control of operations became essential. Accordingly, 25 years ago, in I 952, Western Geophysical Company of Canada was incorporated under the leadership of the late Harris Cox as vice president. A year later W. A. (Al) Knox was appointed vice president to assist Harris. In 1954 Harris resigned and was succeeded by Jack M. Desmond as vice president and operations manager. When Jack returned to the United States in 1963, Don Frisbee was made executive vice president, in which

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Figure 6: *Equipment such as this shot-hole drill mounted on a heavy duty tracked unit is practical in Canada's bush country.*

position he served Western of Canada until his transfer to Houston in late 1969. Jack's duties as vice president and operations manager were assigned to J W (Warner) Loven, who has held this post ever since. Warner grew up with Western of Canada, having started as a computer in his native province in 1951 and later becoming a party chief and supervisor before taking up his present duties.

Figure 7: *Early tracked vehicles tended to throw their tracks at awkward moments.*

In the early years of Western of Canada's operation, the bulk of the seismic surveys was confined to the gently rolling prairies of central Alberta and the Grande Prairie, Peace River, and Hay River regions of that province, to southern Saskatchewan, and later to western Manitoba. Except during the spring thaws, year-round operations were possible on the prairies.

Crews were housed in small towns. At times the presence of the crew personnel and their families swelled a town's population by 10 or 15%. Often remaining in the same town for two or three years, the crew members became responsible, concerned community citizens. Largely agrarian, the communities reaped substantial economic benefits from the hard-cash monthly party paychecks.

As exploration activities expanded, it became necessary for the field parties to push into the rugged, mountainous

Figure 5: *This primitive, half-track recording truck is the type first used in Canada. Portable instruments are mounted in the small cab.*

bush country that extends for hundreds of miles north of the flat lands. The bush country is characterized by scrub forests and muskeg swamps that are impassable by wheeled vehicles except in the dead of winter when the ground is frozen.

During the first years of bush operations it was customary for the truck-equipped field parties to move temporarily into the bush country after freeze-up. Except for a break around Christmas, the field parties would work continuously from late November until the spring thaw in late March or early April. If the weather brought the usual hard freeze with no intervening thaws, wheeled vehicles could work efficiently along bulldozed trails. At the end of the winter season the crews migrated back south.

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As spring approached, moving out of the bush country, while a welcome prospect to the members of the crews, became a serious operational problem demanding exact timing and extensive planning (Figures 1, 2). Almost overnight the frozen muskeg could become a spongy bog, making the bush trail impassable. While geophysical operations had to continue as long as possible in order to make every minute of the season productive, crews had to be ready to move out on short notice. If these preparations were not made in time, some of the equipment might have to be abandoned. One year a bulldozer, leaving the bush country too late and trapped on the thawing muskeg, sank in 20 feet of bog despite desperate attempts to save it.

Figure 8: *When Canadian vibrator crews work in the bush country they use equipment such as these dual track-mounted units.*

Western of Canada was quick to recognize the need for year-round bush operations and in turn, to realize the necessity for designing special equipment to negotiate the muskeg swamps (Figures 3, 4). Some aerial operations were attempted, as were a few surveys conducted from river boats. In the end, however, Western of Canada turned its attention to the use of tracked vehicles having a very low ground-loading pressure per unit of track area.

The first primitive track units were obtained from an eastern Canadian manufacturer of snowmobiles (Figure 5). These units were lightweight, half-track vehicles employing either wheels or skis in front for steering (Figure 6). Capable of carrying only a few hundred pounds, these vehicles habitually threw their tracks into awkward situations and were unable to survive in heavy-duty service (Figure 7). Their prime functions were scouting and transporting personnel and supplies.

In co-operation with clients and manufacturers, Western of Canada took an active part in developing heavy-duty tracked vehicles. These units are capable of carrying up to 10 tons, yet the ground-loading pressure per unit of track area is comparable to that of a man on snow shoes. With the engine and cab mounted 4 to 6 feet above the ground, 6-foot-deep water is no obstacle to their passage (Figure 8).

Figure 9: *The first Westerners going into the bush in the winter lived in primitive tent camps such as this one.*

Figure 10: *The first primitive tent camps set up in the Canadian bush had an undeniably backwoods feel to them. This airy "washroom" provides an example of the "roughing it" atmosphere in the early camps.*

In remote bush prospects the field crew was housed in a base camp. At first, insulated tents with crude kerosene stoves were tried experimentally (Figure 9). Sanitary facilities were primitive, food was cooked on a wood-burning stove, and seating was supplied by a fallen tree

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Figure 11: *Tent camps eventually turned into more modern camps with skid-mounted shacks. The camp shop (at right) is prefabricated from plywood panels.*

trunk (Figure 10). These rough quarters were quickly replaced by skid-mounted shacks sleeping four to six men each, plus a cook-shack and diner. Since these skid-mounted shacks were difficult to move from place to place, the party manager tended to leave his base camp in a single, central location if at all possible (Figure 11). As the survey progressed farther away from the base camp, the crew members were obliged to drive longer distances to and from the operational site.

To achieve greater operational flexibility, Western of Canada took the lead in designing self-propelled, folding, track-mounted camper units (Figure 12). The units were designed so that they could be dismantled and folded up after breakfast when the field crew went to work, moved to a new location, and reassembled in time for supper when the crew returned at night. Modern camper units

Figure 12: *One of today's modern, self-propelled Western base camps that is fully set up and ready for immediate operation is shown in a large clearing in the Canadian bush.*

provide a shirt-sleeve environment, even on the coldest days, for wash up, dining, and recreation at the end of a day's work.

Communication between crews operating in the isolated bush country and the outside world was

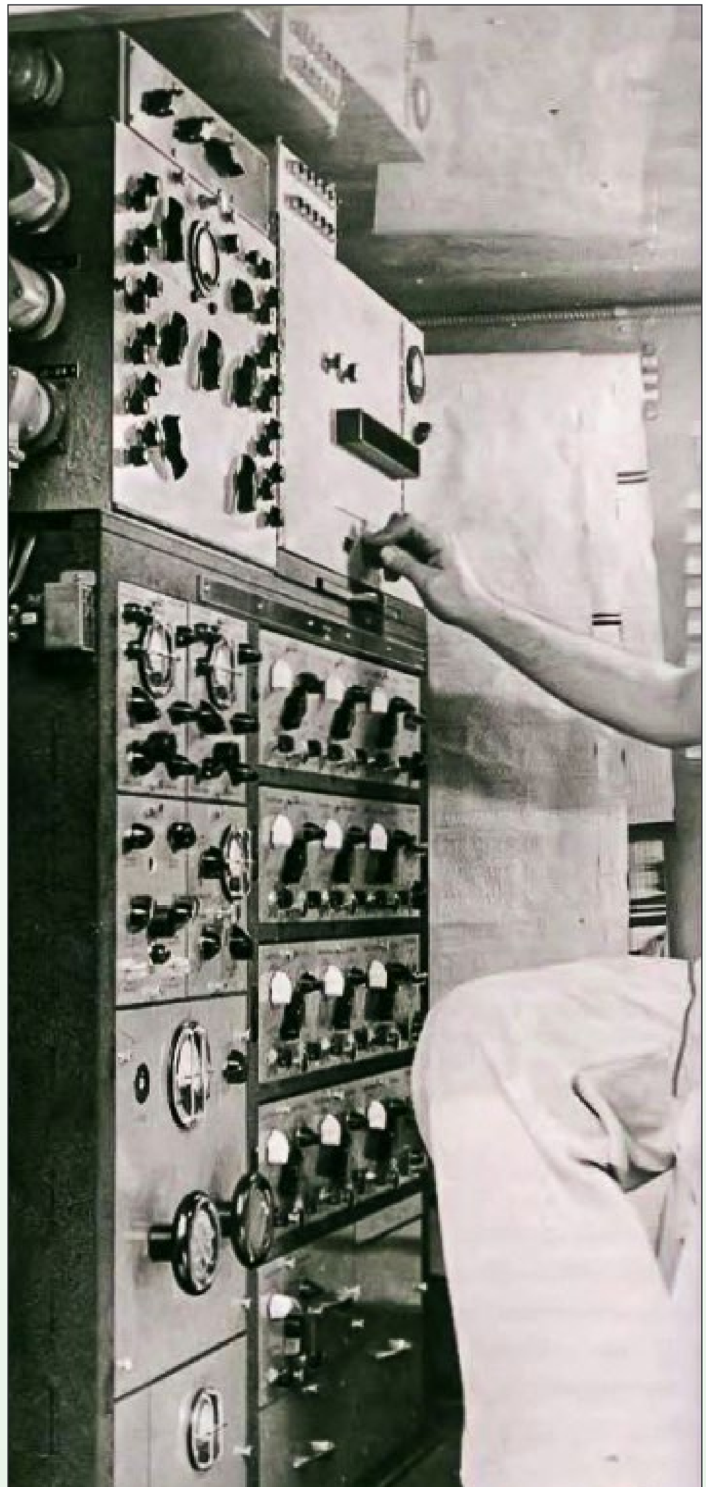

Figure 13: *The first Western crews working in Canada used early-day 24-trace FA-32 analog amplifiers and camera that looked like this.*

maintained by single-sideband radio, which provided a vital link in obtaining supplies and fuel. Today CB radios and walkie-talkies are used extensively for local crew communication.

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Western's first crews entered Canada with 24-trace FA-32 analog amplifiers (Figure 13). Alberta's peculiar geology prompted Western of Canada's research personnel to recommend an improved AGC, as well as means for conducting high-resolution profiling in selected areas. In the mid-1950's analog magnetic tape recording was introduced. To service the tape-recorded work product of the field crews, Western of Canada set up the first contractor-operated playback office in Calgary in 1957. With the advent of the "digital revolution" 10 years later, Western of Canada was, of course, among the first to switch from analog to modem digital recorders. Presently most of Western of Canada's crews are equipped with the ultramodern COBA® I-II systems (Figure 14). Present-day data reduction of both explosives and "Vibroseis"® data is done in the PRE/SEIS® processing system.

From the relatively small quarters of the original central office, Western of Canada moved to it new modem facility in southeast Calgary off McLeod Trail in 1970. Administrative and interpretive offices occupy a total of 10,000 square feet. The payroll includes more than 300 persons who staff seven to nine field crews during peak seasons.

Figure 14: *Today many of Western of Canada's crews use equipment such as this 96-trace COBA I system installed in one of our recording cabs. Observe the simplicity of the central panel as it compares to the forest of knobs and switches on the 24-trace FA-32 system.*

A fleet of more than 200 specialized seismic vehicles is serviced, as needed, in a 6,000-square-foot shop facility. The fleet includes 80 2-to-10-ton muskeg tractors, 50 mobile camp units, 28 track-mounted shot-hole drills, plus a number of wheel-mounted auger drills. Vibrator units include one mounted on an articulated buggy, a truck-mounted unit, and two dual track-mounted vibrators currently on loan to Alaska. Responsibilities of the shop area include not only vehicle maintenance but also original vehicle manufacture as required by client demand (Figure 15).

Figure 15: *The Calgary shop has facilities for the manufacture and the maintenance of Western of Canada's fleet of vehicles, both tracked and wheeled.*

Although incorporated in Canada, Western of Canada's scope of activities is transnational. In addition to conducting seismic surveys in the four western provinces, the Yukon, the Northwest Territories and Quebec, Western of Canada seismic crews have operated in Washington, Michigan, Illinois, California, North Dakota, Utah, Colorado, and Wyoming. In addition, Western of Canada was selected by the Canadian International Development Agency to train a group of Pakistani from the Pakistan Oil and Gas Development Corporation, the Pakistan government's national oil company. The eight-month training program was a multi-million-dollar enterprise sponsored and funded by the Canadian International Development Agency.

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MUSEUM

The Geoscience Center and Museum, formed in 1960, includes artifacts and materials from the 1920's forward and accepts donations of materials, instruments and documents related to the history of geophysical and geological exploration as well as periodicals from various companies and organizations. Our Museum has six satellite exhibits in Austin and Houston that showcase preserved artifacts of the past.

SHERIFF LIBRARY

The geoscience Center Sheriff library has a collection of over 2000+ technical books and manuals, and a variety of periodicals. The oldest library book dates back to 1900. Items are available for check out or use at the Library. The Sheriff library works with other non-profits to share extra books around the world to supply libraries in developing countries. In the year 2022, an estimate of over 1,200 books were donated.

OUTREACH

The Outreach Committee mission is to educate K-12 students, parents, educators, and the general public by demonstrating geophysical concepts and scientific methods.

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Cougar Tracks

Dignity in depth: Using geophysics to search for unmarked burials in historic Houston cemeteries

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Department of Earth and Atmospheric Sciences
University of Houston, USA
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Overview

Benjamin Franklin famously noted "Show me your cemeteries and I will tell you what kind of people you have" as he used burial grounds as a concise social indicator. We are thus admonished, Mr. Franklin! The Texas Historical Commission estimates that there are actually some 14,000 cemeteries in Texas with perhaps 2/3 of these abandoned or becoming so. A number of these are historic African-American cemeteries in the Houston area - some of which have fallen into disrepair with unmarked graves and deteriorating headstones. Restoring these cemeteries is profoundly important on social, historical, urban, and spiritual grounds to preserve the legacy and dignity of these sacred places. The "Dignity in Depth" project, supported by the Society of Exploration Geophysicists Foundation via the Geoscientists without Borders (GWB) program, is helping to restore these cemeteries and enhance their social as well as aesthetic value. The project involves the use of geophysical methods to locate unmarked burials, ascertain areas that show no evidence of interments, and provide educational opportunities for students and the community. This Dignity in Depth initiative, led by the University of Houston (UH), involves collaboration with numerous community groups and organizations and currently focuses on four cemeteries in the Houston area (Figure 1): the Conroe Community Cemetery, Evergreen Negro Cemetery, Olivewood Cemetery, and College Memorial Park Cemetery – the latter three sites are the three oldest African-American cemeteries in Houston.

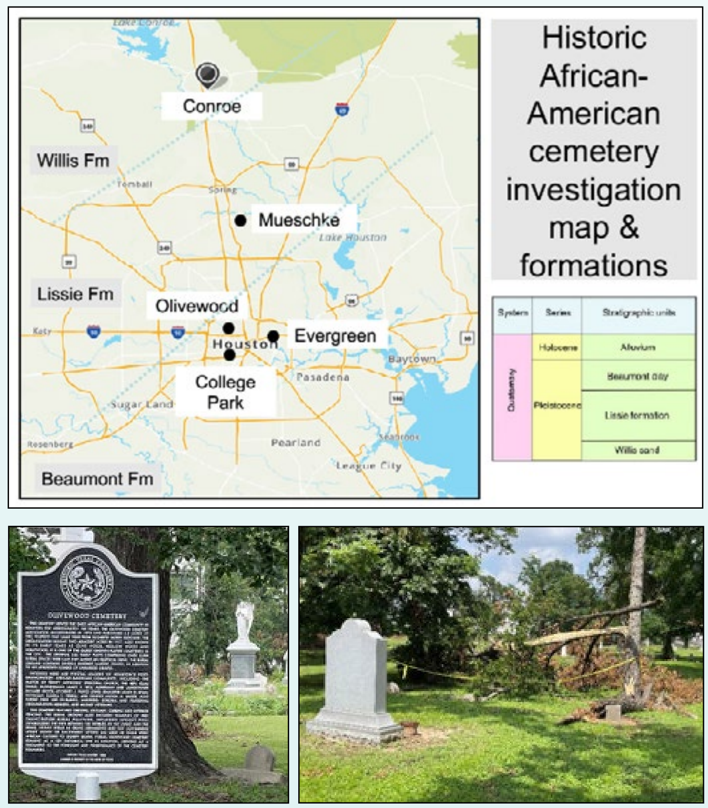

Figure 1. Overview map of Dignity in Depth surveying sites. Photos from the Olivewood Cemetery, Houston show that even well-tended cemeteries suffer from weather events which can damage and degrade the sites.

The project is employing various techniques including drone surveys (seeking topographic changes, thermal and vegetation burial signatures), soil changes, ground-penetrating radar (GPR), metal detection, magnetics, seismic, cultural indicators (shells, domestic goods, non-indigenous plants), and even cadaver dogs to identify burial sites and assist in refurbishment. The work has been

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highlighted in Houston TV news, the Houston Chronicle, and various UH communications. We have been integrating our GWB cemetery work with geophysics courses and other Departments at UH to provide research and educational opportunities and contributions in addition to building multiple relationships amongst the community, City, students, and faculty.

With a team of students and staff, we have undertaken a number of surveys at the four cemeteries, scanned headstones, held training programs, given talks, and convened field trips (Figure 2). In addition, we have been building a digital repository for scans of headstones to allow for on-line storage and access (Figure 3).

Figure 2. Field trip to College Memorial Park Cemetery, Houston with a local historian guiding us through the cemetery and discussing the headstones in the foreground which commemorate two soldiers buried in the Cemetery from the Houston Riot of 1917.

Much of our work has been dedicated to the Evergreen Negro Cemetery (Figure 4) where we have been working with the Cemetery's Project RESPECT group, Sheffield Foundation, and City of Houston to enhance the Cemetery. Our recent efforts at Evergreen are to investigate a possible site for a columbarium (above-ground structure to house funeral urns).

We have usually been using the Sensors & Software NOGGIN 250 MHz system for our GPR work with orthogonal grids and line spacings of 25 cm (Figure 5). We are able to acquire excellent and highly diagnostic data at Conroe with its lower clay-content soil. Houston has a conductive Beaumont clay close to the surface (about 1 m depth) which makes radar penetration and imaging difficult. Nonetheless, we use close line spacing and high-fold recording, plus detailed noise reduction to enhance images as best as possible.

Figure 3. 3D scanning of headstones in the cemeteries using Polycam software followed by uploading images to a digital repository for broad access.

Figure 4. Map of the Evergreen Negro Cemetery in Houston with one survey area highlighted which is the location of a proposed columbarium along with a drone photo of the Cemetery. UH students undertaking an experimental magnetics survey in the Evergreen Negro Cemetery, March, 2025.

We continue to conduct GPR and other surveys at the cemeteries including research into developing more advanced or enhanced diagnostic techniques (Figure 6). While this project is devoted to investigating and restoring cemeteries, there is a host of related urban and other infrastructure challenges that near-surface geophysics can address.

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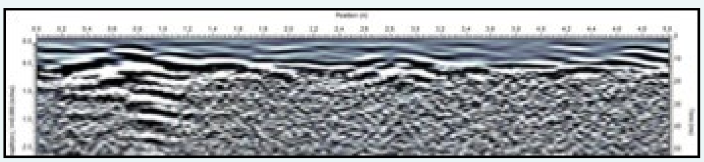

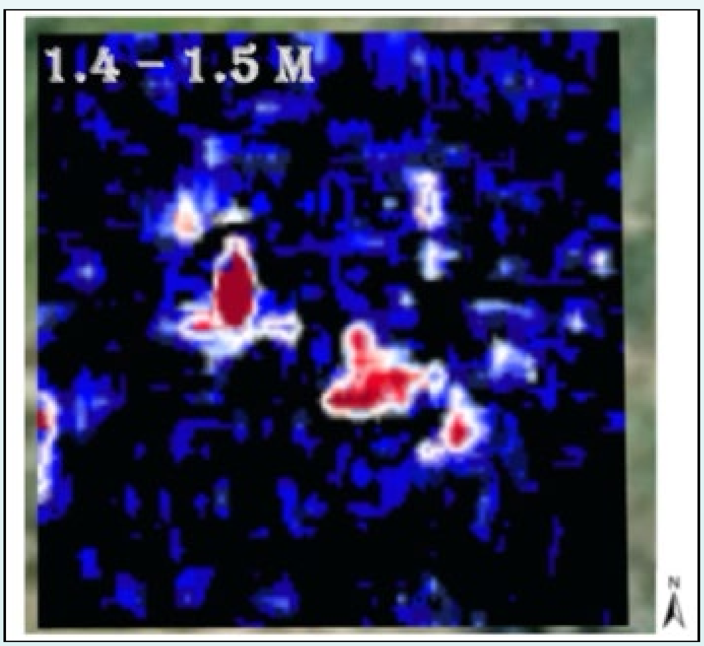

Figure 5. Above - Photo of a 3D grid laid out in the center part of the western section of the Evergreen Cemetery; Middle – a representative line of raw GPR data; Bottom - In another area, there are distinct anomalies at about 1.45 m depth - suggestive of burials.

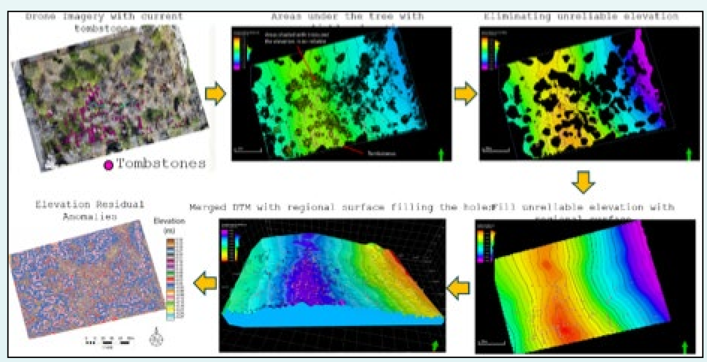

Figure 5. Using drone elevation images to scan for topographic anomalies at the Conroe Community Cemetery.

Summary

The "Dignity in Depth" project, led by University of Houston personnel, is actively using near-surface geophysical methods to search for unmarked burials in historic African-American cemeteries. The project is fostering collaboration among community groups, institutions, and geoscientists, who are contributing to the preservation and restoration of these cemeteries. The project's findings have been presented, published, and communicated via various media, raising awareness about the importance of preserving historic cemeteries. We are continuing to refine the geophysical methods for burial and other broadly applicable near-surface challenges while involving student and community education.

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GSH 40th Annual Sporting Clays Event
Orbs, wet feet and lucky weather

By: John Asma

As I was getting out of my truck at 7:45 am on Fri Aug 22, 2025, with rain clouds all around us, one of Team Orb's members asked, 'Hey John, think I should wear my rubber boots?' Considering we were about to walk the Sporting Clays course at American Shooting Club, in the George Busch Reservoir, that sounded like a really good idea. Better than the running shoes I was wearing (which are never used for running). There were some wet feet out there for those of us that forgot our boots, but the weather cooperated and the day was very nice, especially for late August in Houston, Texas.

We had good attendance this year, relatively speaking, with 70 Shooters, plus 5 for BBQ Lunch. Very fun lunch with Hickory Hollow BBQ and plenty of Yuengling beer on hand. (We promise to have more Amber Lager next year.) It was good networking and fun to get caught up with old friends and new. Of course, lunch is after shooting and guns are put away. Next year please join us for lunch if you don't shoot. They have a very nice Pavilion at ASC. Plenty of shade. Good networking opportunity.

Participation has been trending steadily upward from a low of 45 Shooters just a few years ago, to 60 last year, now up to 70 this past August. We are getting more women shooters as well. Thanks ladies, for coming out and participating in the GSH Sporting Clays Event. It really is an event, more so than a competition. Unless you are an "A" level Shooter and just can't help but be competitive (you know who you are), the rest of us are pretty average shooters. The main thing is practicing safety

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and shooting a shotgun (ASC has plenty of rental shotguns), walking around the course or riding a golf cart, and having a good time. Great warm up for Dove Season.

I would like to thank our Sponsors, 16 this year! At the top of the list is Tri Star, followed closely by Silverthorne as a Platinum Sponsor! Gold Sponsors were Dawson, Oxy, DUG, SAE Exploration, TGS and Sequitur. Silver sponsors were GPI who seem to be there for us every year, and Z-Terra. Three other sponsors who could not make it but chipped in anyway were PSI, Vanguard, and Skyway Field Services. In kind Sponsors were American Shooting Centers and Yuengling Flight.

Special thanks to all those who put Teams together. Especially Tri Star with three Teams and Z-Terra with two Teams. Without Shooters we don't get Sponsors. Of course, this event does not happen without Kathy Sanvido with GSH, Kenneth Mohn with Z-Terra, John Fortier with Silverthorne, Paul Vincent with Chevron and Madam WPresident, Rene Mott.

Thanks to everybody for participating and having a safe and fun time. Hope to see you all next year. Plan to bring a friend, or have them join us for lunch. We will have plenty of Hickory Hollow BBQ, beer, soft drinks and comradery.

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