# Spring 2023 Newsletter

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Texas Consortium for Computational Seismology • The University of Texas at Austin

## Welcome to the 25th *TCCS Newsletter*!

The Texas Consortium for Computation Seismology (TCCS) is a joint initiative of the Bureau of Economic Geology (BEG) and the Oden Institute for Computational Engineering and Science at The University of Texas at Austin. Its mission is to address the most critical and challenging research problems in computational geophysics as experienced by the energy industry while educating the next generation of research geophysicists and computational scientists.

## Hope to see you in Houston

TCCS has submitted nine abstracts to the 2023 IMAGE Meeting in Houston. The submitted papers fall into six subject areas: Acquisition, Borehole, Full-Waveform Inversion, Machine Learning and Data Analysis, Seismic Processing, and Seismic Theory.

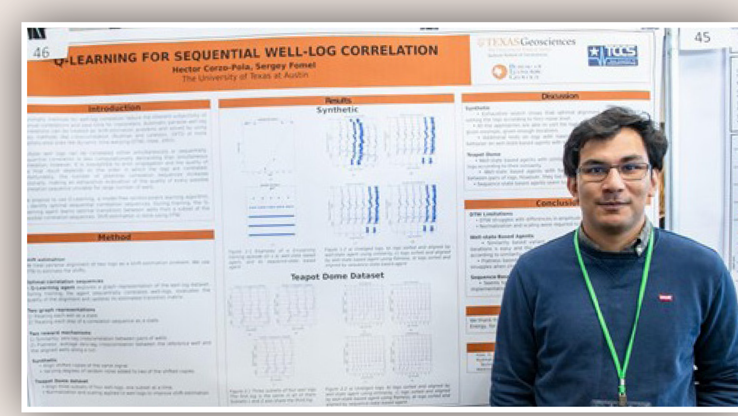

## Spring Meeting

The Spring 2023 Research Meeting of the Texas Consortium for Computational Seismology will occur in Houston on April 20–21, 2023. Hosted by the Bureau of Economic Geology, it will be held at the Bureau's Houston Research Center.

Participated company representatives are invited to register for the meeting by following the link at http://www.beg.utexas.edu/tccs/.


## Spring 2023 Jackson School Research Symposium

Each spring semester, students of the Jackson School of Geosciences (JSG) at UT Austin present their research in a day-long poster competition. Faculty, research scientists, and industry representatives evaluate the posters. The Research Symposium aims to provide cross-disciplinary collaboration among under-graduate students, graduate students, and faculty/research scientists at the Jackson School. The event is sponsored by ConocoPhillips.




Hector Corzo Pola standing next to his poster "Q-learning for sequential well-log correlation" at the JSG Symposium.

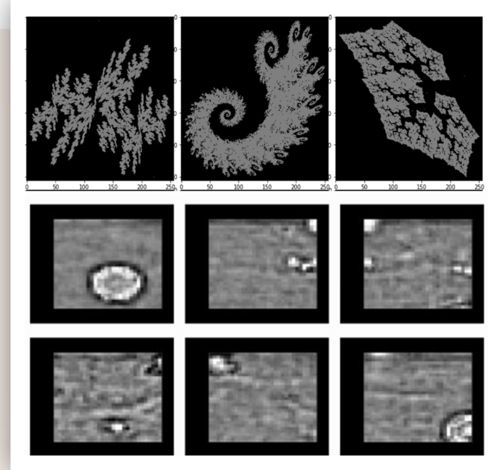
Ben Gremillion presenting "Elastic seismic imaging of a fracture with time-lapse DAS VSP" at the JSG Research Symposium.

## TCCS Sponsors

TCCS appreciates the support of its 2023 sponsors: Aramco, BP, Chevron, ConocoPhillips, ExxonMobil, Petrobras, PetroChina, Sinopec, and TGS.

## Research Highlights

**Rebecca Gao** has been working on utilizing fractal decomposition and deep learning to enhance geologic structure characterization from seismic images. The process comprises five steps: (1) Preprocessing seismic images to accentuate geologic structures; (2) Generating fractal images using Iterated Function Systems and labeling them using generating vectors; (3) Applying fractal decomposition with wavelet-based multi-scale analysis to extract patterns; (4) Developing a modified ResNet-based architecture to recognize geologic structures in decomposed images, training and validating on a labeled natural-image dataset; (5) Fine-tuning the model on labeled seismic datasets with delineated structures of interest. This approach capitalizes on the self-similar nature of fractals to capture complex patterns and improve geologic structure recognition accuracy and efficiency from seismic images, thereby enabling better generalization to unseen images.



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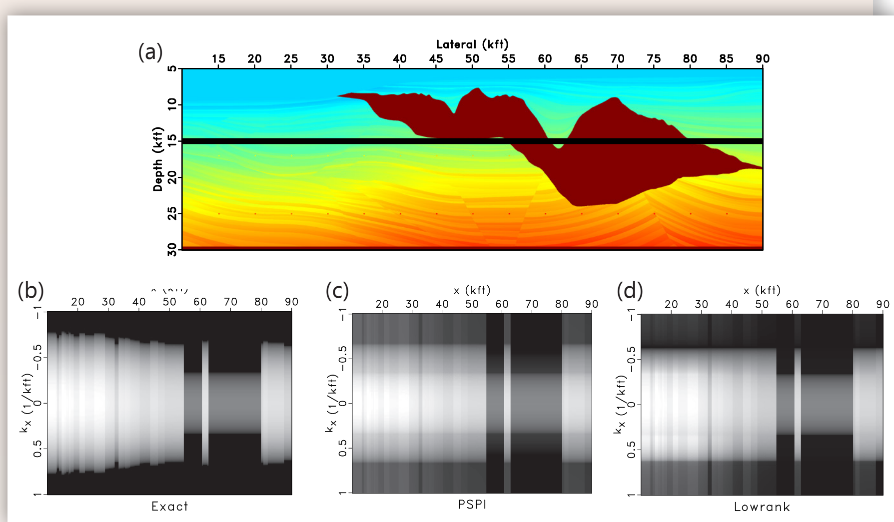
**Ben Gremillion** has been working on a low-rank approximation of the phase-shift operator used in one-way wave-equation migration. The low-rank decomposition approximates the full extrapolation matrix using a limited number of rows and columns, corresponding to a representative set of velocities and wavenumbers. The method can be interpreted as a form of migration by phase-shift plus interpolation (PSPI) with an optimal selection of velocities and weights for each depth step. The figure shows (a) the Sigsbee velocity model along with (b) the exact extrapolation matrix, (c) the PSPI approximation, and (d) the low-rank approximation at the highlighted depth and a single frequency. Both approximations use only two velocities.

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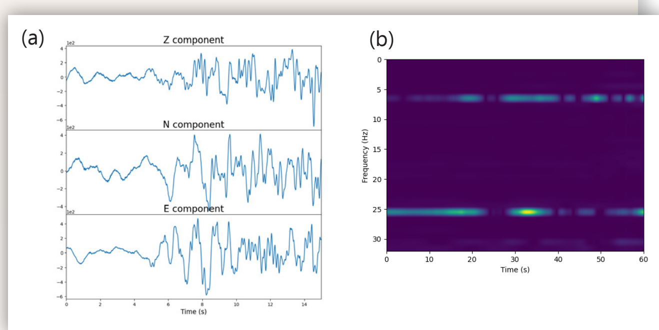
**Matan Lebovits'** research focuses on improving the use of machine learning to identify earthquakes. Traditionally, passive seismic recordings are processed as one-dimensional waveforms, limiting the data density available to the machine-learning model (Figure a). A time-frequency decomposition of the waveform provides a two-dimensional representation (Figure b), which significantly increases the resolution for detecting  earthquakes. The developed classification model is applicable as a real-time earthquake detector.

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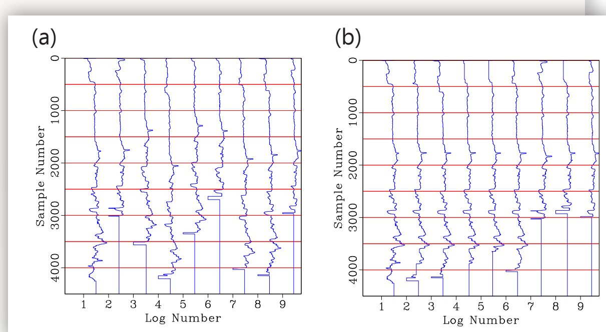
**Hector Corzo Pola** has been working on finding optimal well-log correlation sequences using reinforcement learning with Q-learning agents. The quality of the final alignment in sequential well-log correlation depends on the order of correlation. Unfortunately, the number of potential correlation sequences increases factorially, making an exhaustive evaluation of the quality of every possible correlation sequence computationally unfeasible for many wells. Q-learning agents learn optimal transitions among wells from a subset of the possible correlation sequences instead of evaluating all possible sequences. The agents sequentially correlate well logs, assess their alignment, and update the estimated transition matrix. The figure shows Teapot Dome's gamma-ray logs: a) before alignment and b) after sorting and alignment by a Q-learning agent.



## Papers Accepted and Published 2022–2023

### Accepted

Y. Chen, A. Savvaidis, Y. Chen, O. Saad, and S. Fomel, 2023, Enhancing earthquake detection from distributed acoustic sensing data by coherency measure and moving-rank-reduction filtering: Geophysics, accepted.

Y. Chen, A. Savvaidis, S. Fomel, Y. Chen, O. Saad, H. Wang, Y. Oboue, L. Yang, and W. Chen, 2023, Denoising of distributed acoustic sensing seismic data: Seismological Research Letters, accepted.

Y. Chen, A. Savvaidis, S. Fomel, Y. Chen, O. Saad, Y. Oboue, Q. Zhang, and W. Chen, 2023, Pyseistr: a python package for structural denoising and interpolation of multi-channel seismic data: Seismological Research Letters, accepted.

H. Kaur, J. Sun, M. Aharchaou, A. Baumstein, and S. Fomel, 2023, Deep learning framework for true amplitude imaging: Effect of conditioners and initial models: Geophysical Prospecting, accepted.

H. Kaur, Q. Zhang, P. Witte, L. Liang, L. Wu, S. Fomel, 2023, Deep learning based 3D fault detection for carbon capture and storage (CCS): Geophysics, accepted.

N. Pham and S. Fomel, 2023, Seismic data augmentation for automatic fault picking using deep learning: Geophysical Prospecting, accepted.

L. Yang, S. Wang, X. Chen, W. Chen, O. Saad, X. Zhou, N. Pham, Z. Geng, S. Fomel, and Y. Chen, 2023, High-fidelity permeability and porosity prediction using deep learning with the self-attention mechanism: IEEE Transactions on Neural Networks and Learning Systems, accepted.

### Published 2023

Y. Chen and S. Fomel, 2023, 3D true-amplitude elastic wave-vector decomposition in heterogeneous anisotropic media: Geophysics, v. 88, C79–C89.

Y. Chen, S. Fomel, and R. Abma, 2023, Joint deblending and source time inversion: Geophysics, Geophysics, v. 88, WA27–WA35.

Y. Chen, A. Savvaidis, S. Fomel, Y. Chen, O. Saad, H. Wang, Y. Oboue, L. Yang, W. Chen, 2023, Denoising of distributed acoustic sensing seismic data using an integrated framework: Seismological Research Letters, v. 94, 457–472.

Y. Chen, A. Savvaidis, S. Fomel, O. Saad, and Y. Chen, 2023, RFloc3D: a machine learning method for 3D real-time microseismic source location using P- and S-wave arrivals: IEEE Transactions on Geoscience and Remote Sensing, v. 61, 5901310.

H. Kaur, S. Fomel, and N. Pham, 2023, Automated hyperparameter optimization for simulating boundary conditions for acoustic and elastic wave propagation using deep learning: Geophysics, v. 88, WA309–WA318.

H. Kaur, N. Pham, S. Fomel, Z. Geng, L. Decker, B. Gremillion, M. Jervis, R. Abma, and S. Gao, 2023, A deep learning framework for seismic facies classification: Interpretation, v. 11, T107–T116.

O. Saad, S. Fomel, R. Abma, and Y. Chen, 2023, Unsupervised deep learning for 3D interpolation of highly incomplete data: Geophysics, v. 88, WA189–WA200.

L. Yang, S. Fomel, S. Wang, X. Chen, W. Chen, O. Saad, and Y. Chen, 2023, Denoising of distributed acoustic sensing data using supervised deep learning: Geophysics, v. 88, WA91–WA104.

L. Yang, S. Fomel, S. Wang, X. Chen, W. Chen, O. Saad, and Y. Chen, 2023, Porosity and permeability prediction using transformer and periodic long short term network: Geophysics, v. 88, WA293–WA308.

### Published 2022

Y. Chen, O. Saad, A. Savvaidis, Y. Chen, and S. Fomel, 2022, 3D microseismic monitoring using machine learning: Journal of Geophysical Research–Solid Earth, v. 127, e2021JB023842.

L. Decker and S. Fomel, 2022, A probabilistic approach to seismic diffraction imaging: Lithosphere, v. 2021, 6650633.

L. Decker and S. Fomel, 2022, A variational approach for picking optimal surfaces from semblance-like panels: Geophysics, v. 87, U93–U108.

B. Engquist and Y. Yang, 2022, Optimal transport based seismic inversion: Beyond cycle skipping: Communications on Pure and Applied Mathematics, v. 75, 2201–2244.

Z. Geng, Y. Chen, S. Fomel, and L. Liang, 2022, LOUD: Local orthogonalization constrained unsupervised deep learning denoiser: IEEE Transactions on Geoscience and Remote Sensing, v. 60, 5924912.

Z. Geng, Z. Hu, X. Wu, and S. Fomel, 2022, Semi-supervised salt segmentation using mean teacher: Interpretation, v. 10, SE21–SE29.

Z. Geng, Z. Zhao, Y. Shi, X. Wu, S. Fomel, and M. Sen, 2022, Deep learning for velocity model building with common-image gathers: Geophysical Journal International, v. 228, 1054–1070.

G. Huang, X. Chen, O. Saad, Y. Chen, S. Fomel, A. Savvaidis, Y. Chen, 2022, High-resolution and robust microseismic grouped imaging and grouping strategy analysis: Geophysical Prospecting, v. 70, 980–1002.

H. Kaur, A. Sun, Z. Zhong, and S. Fomel, 2022, Time-lapse seismic data inversion for estimating reservoir parameters using deep learning: Interpretation, v. 10, T167–T179.

O. Saad, Y. Chen, A. Savvaidis, S. Fomel, and Y. Chen, 2022, Real-time earthquake detection and magnitude estimation using vision transformer: Journal of Geophysical Research-Solid Earth, v. 127, e2021JB023657.

O. Saad, Y. Chen, D. Trugman, M. S. Soliman, L. Samy, A. Savvaidis, M. A. Khamis, A. G. Hafez, S. Fomel, and Y. Chen, 2022, Machine learning for the fast and reliable source-location prediction in earthquake early warning: IEEE Geoscience and Remote Sensing Letters, v. 19, 8025705.

H. Wang, Y. Chen, O. Saad, W. Chen, Y. Oboue, L. Yang, S. Fomel, and Y. Chen, 2022, A Matlab code package for 2D/3D local slope estimation and structural filtering: Geophysics, v. 87, F1–F14.

H. Wang, Y. Yunfeng, Y. Oboue, R. Abma, Z. Geng, S. Fomel, and Y. Chen, 2022, Simultaneous reconstruction and denoising of extremely sparse 5D seismic data by a simple and effective method: IEEE Transactions on Geoscience and Remote Sensing, v. 60, 5909212.

S. Zu, H. Cao, S. Fomel, and Y. Chen, 2022, Robust local slope estimation by deep learning: Geophysical Prospecting, v. 70, 847–864.

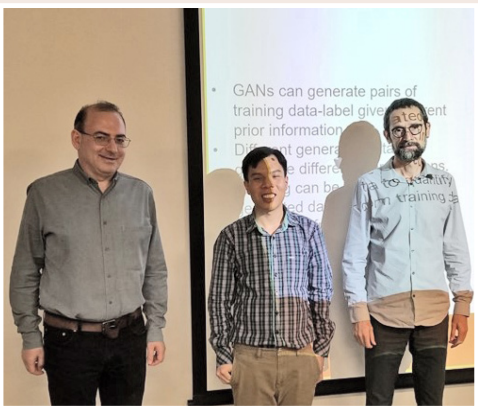
## TCCS Staff

The TCCS group consists of people from five countries. Our research staff includes two principal investigators, research scientists, and students.

Raymond Abma (Visiting Scientist)
Yangkang Chen (Research Scientist)
Héctor Corzo Pola (M.S. 3rd year)
Björn Engquist (PI)
Sergey Fomel (PI)
Rebecca Gao (Ph.D. 3rd year)
Ben Gremillion (Ph.D. 4th year)
Matan Lebovits (B.S. 3rd year)
Tyler Masthay (Ph.D. 6th year)
Yiran Shen (Ph.D., 6th year)

For more information, see http://www.beg.utexas.edu/tccs/staff.

## Testimonial




**Nam Pham:** *I feel very fortunate to join TCCS and be under the guidance of Dr. Fomel during my M.S. and Ph.D. years. Dr. Fomel always encouraged me to work on challenging geoscience problems and learn from the experts. The multidisciplinary nature of TCCS allowed me to collaborate with other excellent researchers in computational geophysics, geology, seismology, mathematics, and computer science. I gained valuable experience, insights, and feedback on my research projects. Within TCCS, my colleagues were talented, creative, productive, and friendly. We spent time together not only in the office but also outside. Dr. Fomel also guided me to write research papers and present at many conferences, where I found my current full-time job. Joining TCCS was one of the best decisions in my life. The experiences I had during my time there will remain with me throughout my career.*

## Ph.D. Dissertations

| Name | Year | Title | Current Employer |
|---|---|---|---|
| Nam Pham | 2022 | Deep Learning for Automatic Geophysical Interpretation with Uncertainty | SLB |
| Zhicheng Geng | 2022 | Deep Learning For Pattern Recognition In Seismic Reflection Data | Amazon |
| Harpreet Kaur | 2022 | Improving Accuracy and Efficiency of Seismic Data Analysis Using Deep Learning | Amazon |
| Luke Decker | 2021 | Parameter Selection in Seismic Processing Problems | Chevron |
| Yunzhi Shi | 2020 | Deep Learning Empowers the Next Generation of Seismic Interpretation | Amazon |
| Yunan Yang | 2018 | Optimal Transport for Seismic Inverse Problems | Cornell University |
| Dmitrii Merzlikin | 2018 | Diffraction Imaging by Path- Summation Migration | SLB |
| Yanadet Sripanich | 2017 | Seismic Anisotropy Analysis Using Muir-Dellinger Parameters | PTTEP |
| Zhiguang Xue | 2017 | Regularization Strategies for Increasing Efficiency and Robustness of Least-Squares RTM and FWI | Meta |
| Junzhe Sun | 2016 | Seismic Modeling and Imaging in Complex Media Using Low-Rank Approximation | Meta |
| Yangkang Chen | 2015 | Noise Attenuation in Seismic Data from the Simultaneous-Source Acquisition | The University of Texas at Austin |
| Parvaneh Karimi | 2015 | Seismic Interpretation Using Predictive Painting | Oxy |
| Vladimir Bashkardin | 2014 | Phase-Space Imaging of Reflection Seismic Data | BP |
| Christina Frederick | 2014 | Numerical Methods for Multiscale Inverse Problems | New Jersey Institute of Technology |
| Siwei Li | 2014 | Imaging and Velocity Model Building with Linearized Eikonal Equation and Upwind Finite-Differences | SensorEra |
| Jack Poulson | 2012 | Fast Parallel Solution of Heterogeneous 3D Time-Harmonic Wave Equations | Hodge Star Scientific Computing |
| Xiaolei Song | 2012 | Application of Fourier Finite Differences and Low-Rank Approximation Method for Seismic Modeling and Subsalt Imaging | BP |
| Paul Tsuji | 2012 | Fast Algorithms for Frequency-Domain Wave Propagation | Lawrence Livermore National Laboratory |
| William Burnett | 2011 | Multiazimuth Velocity Analysis Using Velocity-Independent Seismic Imaging | ExxonMobil |

## M.S. Theses

| | | | |
|---|---|---|---|
| Ben Gremillion | 2019 | Seismic Data Interpolation with Shaping Inversion to Zero Offset and Least-Squares Flattening | The University of Texas at Austin |
| Nam Pham | 2019 | Automatic Channel Detection Using Deep Learning | SLB |
| Sean Bader | 2018 | Seismic and Well Log Data Integration Using Data-Matching Techniques | EOG |
| Mason Phillips | 2017 | Geophysical Data Registration Using Modified Plane-Wave Destruction Filters | DownUnder Geosolutions |
| Kelly Regimbal | 2016 | Improving Resolution of NMO Stack Using Shaping Regularization | Improbable |
| Ryan Swindeman | 2015 | Iterative Seismic Data Interpolation Using Plane-Wave Shaping | Noonlight |
| Luke Decker | 2014 | Seismic Diffraction Imaging Methods and Applications | Chevron |
| Shaunak Ghosh | 2013 | Multiple Suppression in the t-x-p Domain | CGG |
| Salah Alhadab | 2012 | Diffraction Imaging of Sediment Drifts in Canterbury Basin | Aramco |
| Yihua Cai | 2012 | Spectral Recomposition and Multicomponent Seismic Image Registration | Shell |

## B.S. Honors Theses

| | | | |
|---|---|---|---|
| Reem Alomar | 2022 | Seismic Data Analysis by Least-Squares Non-Stationary Triangle Smoothing | Aramco |
| Tharit Tangki-jwanichakul | 2021 | Chain of Operators for Inverse Hessian Estimation in Least-Squares Migration | PTTEP |
| Sarah Greer | 2018 | A Data Matching Algorithm and Its Applications in Seismic Data Analysis | MIT |
| Lubna Barghouty | 2013 | Surface-Related Multiple Elimination and Velocity-Independent Imaging of a 2D Seismic Line from the Viking Graben Dataset | MIT |
| Yanadet Sripanich | 2013 | An Efficient Algorithm for Two-Point Seismic Ray Tracing | PTTEP |



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