Juniper Bay Software

Product Description

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Juniper Bay is a one-man software company that develops professionally crafted plug-ins for the SeisSpace ProMAX seismic processing system. I work out of the office of Absolute Imaging, a land seismic processing shop with centers in Calgary and Noida, India, and with clients from around the world. I have developed land seismic processing software for four decades, bringing an extensive research record, and sound mathematical, software engineering, and communication skills. My resume is at the end of this document.

Juniper Bay has developed numerous SeisSpace modules that are currently in daily use by Absolute Imaging, including (but not limited to):

- First-break shaping, noise removal, and improved picking.
- 5D interpolation based on rank reduction.
- Powerline noise removal.
- Surface-consistent scaling.
- High-resolution Radon-transform base multiple removal.
- Deblending (currently in testing stage).

Descriptions of these modules are included in the pages following. Projects were driven by the requests of Absolute Imaging processors who use ProMAX daily but felt that the system did not have all of the capabilities they needed, or that some modules did not deliver the results that they desired or were slow or cumbersome to use.

First-Break Shaping, Noise Removal, and Picking

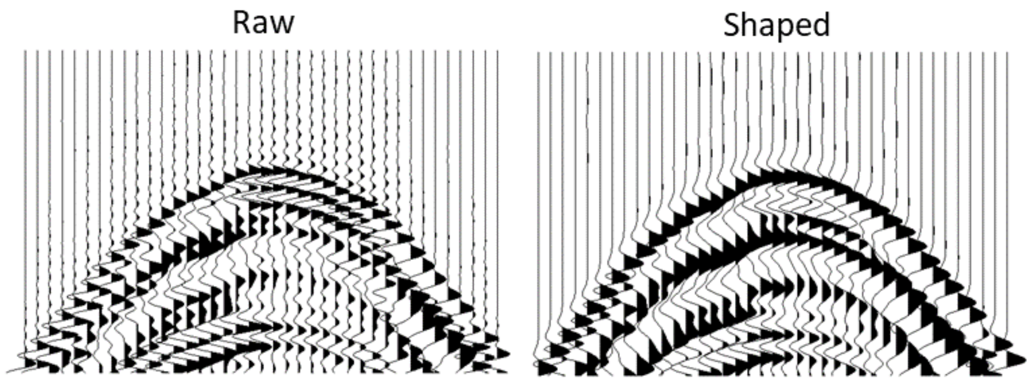
First-break picking is not the trendiest of research topics, but can be one of the most expensive, time-consuming, and frustrating steps for land processors. And the situation may be getting worse. Many seismic surveys now use simultaneous shooting with single small Vibrators as their source, producing noisier first breaks than before. For this reason, I have dedicated considerable development time to the issue of first-break picking.

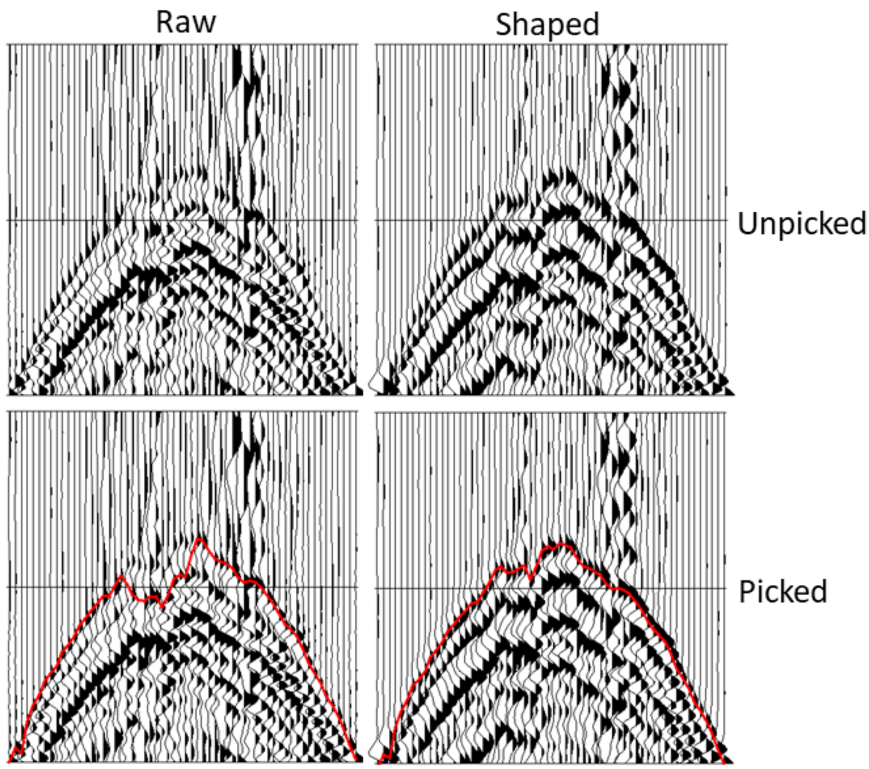
I have focused on three areas:

- Wavelet shaping to improve picking of Vibroseis data.
- Removing noise from first breaks.
- Spatially continuous first-break picking.

The result of these three technologies is more accurate picks generated quicker and at less cost. The next three pages describes these products.

First-Break Wavelet Shaping



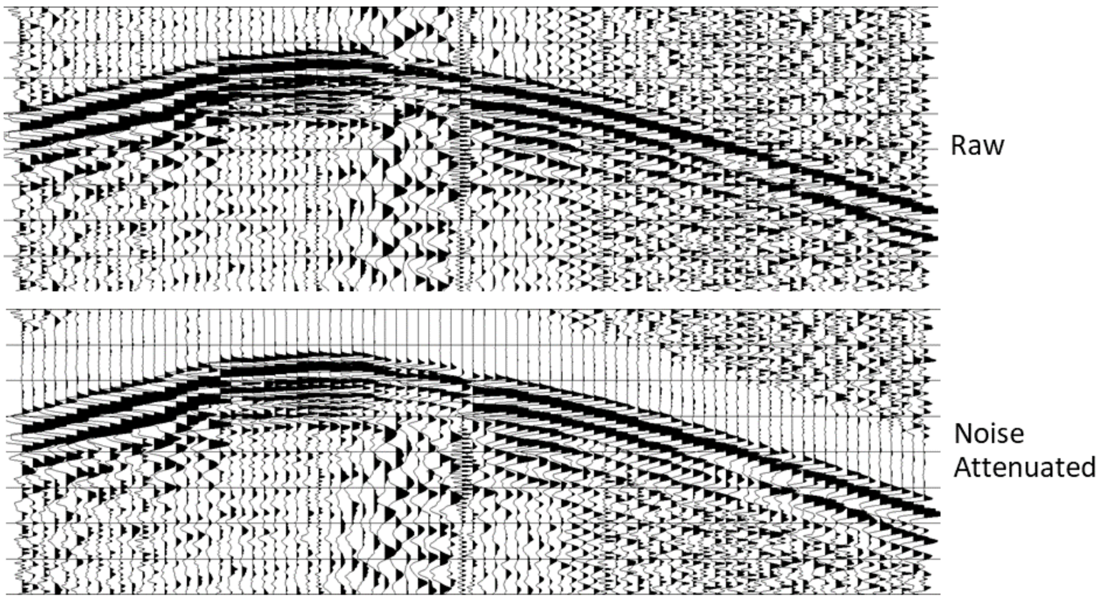


This novel wavelet-shaping filter significantly improve the results of picking Vibroseis data by:

- Removing ringyness, reducing the chances of cycle skipping.
- Focusing the first-break energy, reducing the chance of first breaks being overwhelmed by noise.
- Locating the initial peak of the first break at the true theoretical first-break time.

I have published a recent paper (Trickett, 2022 in the references below) on this topic.

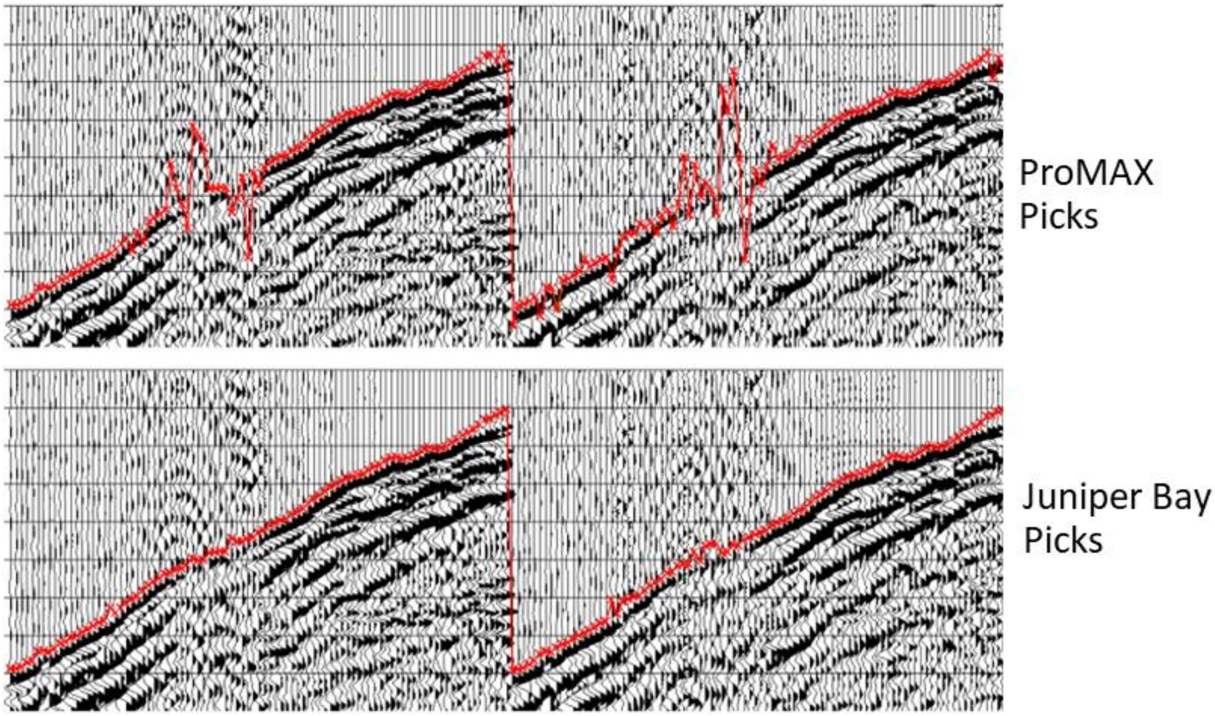
First-Break Noise Removal



First-breaks can be extremely noisy, and this problem is getting worse with the advent of single-point Vibroseis sources. Removing this noise is a difficult problem, as the noise is often strong and short-wavelength statics must be preserved. Juniper Bay's novel solution (see my 2019 paper "Cleaning up first arrivals in the cross-spread domain" listed at the end of this document) exploits the "locally surface-consistent" property of cross spreads and the power of robust statistics. It has the following features:

- Works on cross-spread ensembles. Source and receiver lines need not be orthogonal, so parallel-line, slant, 2D, and swath surveys can all be handled.
- Removes random noise, and coherent noise when it's not surface-consistent.
- Preserves short-wavelength statics.
- Does not alter those first breaks that are already clean.
- Handles (but does not correct for) reverse-polarity traces.
- Parameters are few and easy to select (principally a rough estimate of first-break times).
- Executes quickly.
- Can be run in parallel.
- Has a quality-control mode that shows the flattened first breaks, the cleaned-up first breaks, and the difference, all in one trace.

Spatially Continuous First-Break Picking

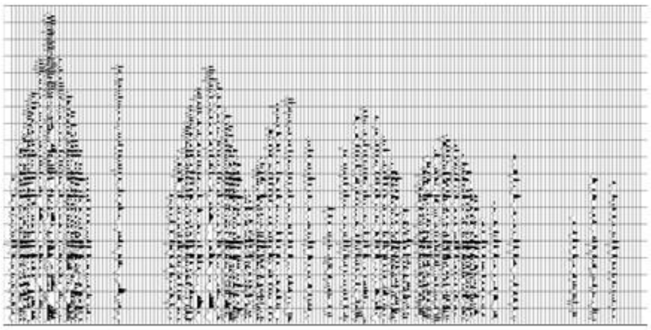


Many automatic first-arrival pickers, including ProMAX's module ***First Break Picking***, determine picks on a trace-by-trace basis, meaning each trace is picked independently of the others. Such pickers generally try to find a time point where some trace attribute or group of attributes changes abruptly in character. The most common and successful of these attributes is the energy level of the samples, but more exotic ones like fractal dimension can be used as well.

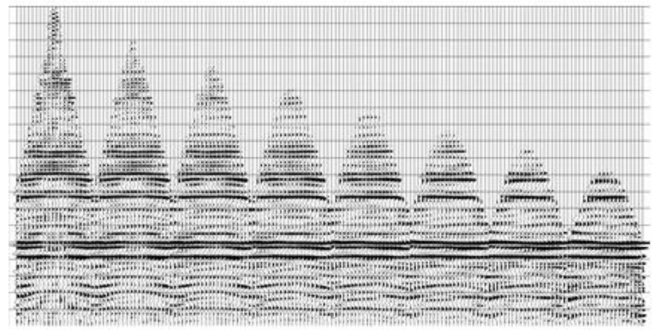
Trace-by-trace pickers work fairly well for dynamite data where the first arrivals tend to be clean and there is an abrupt onset of source energy on each trace. But on Vibroseis data these pickers often work poorly. This is because Vibroseis first arrivals tend to be noisier and have a broader and non-causal seismic wavelet, resulting in a less abrupt change in trace attributes near the first-arrival time.

To pick Vibroseis data well, a picker must consider more than one trace simultaneously. One strategy is to encourage spatially continuity of the picks – that is, after linear-moveout correction, there should be few or no large time differences between nearby traces. There are surprizingly few papers that describe such strategies. Juniper Bay's picker uses a shortest-path algorithm to select final picks from numerous candidate picks for each trace. Attributes such as energy ratio are incorporated into the distances used in the shortest-path algorithm.

Rank-Reduction-Based 5D Interpolation



CMP gather



5D interpolated gather

A seismic trace has four spatial dimensions describing its geographical location. An ideal 3D seismic survey is densely and evenly populated in all four dimensions, but this is almost never acquired due to physical and economic constraints. 5D interpolation takes a prestack seismic data set that is sparsely populated in four spatial dimensions, and increases the trace density by interpolating in the four dimensions simultaneously. This can bring the following benefits:

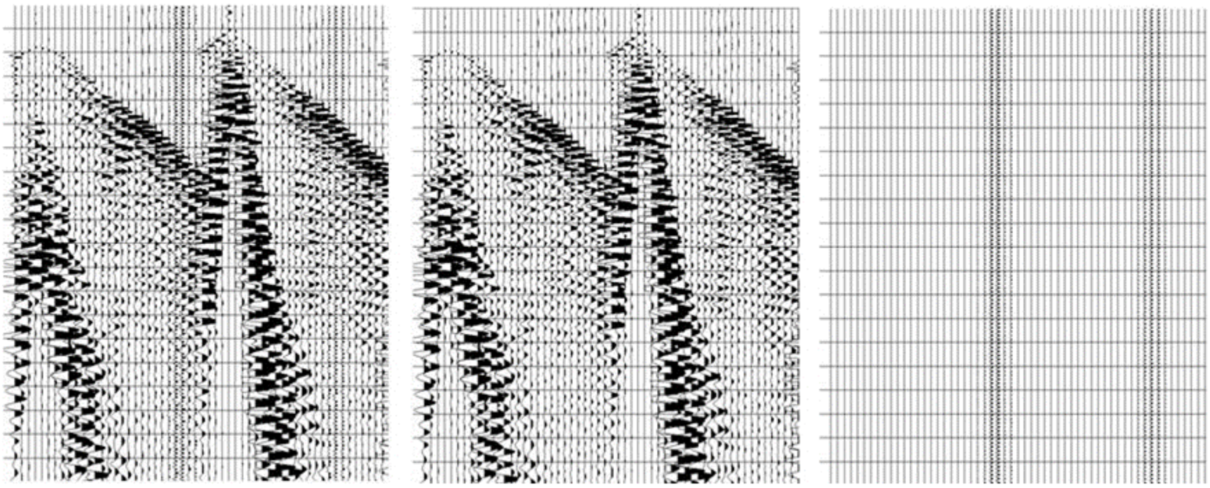
- Improved multiple removal, prestack migration, AVA / AVO analysis, and inversion.
- Less random noise.
- Reduced acquisition footprint.
- More continuous reflectors, particularly up shallow.

Juniper Bay Software's 5D interpolation is based on matrix rank reduction on constant-frequency slices (see my 2010 paper listed near the end of this document). It has the following features:

- Excellent at interpolating across small gaps.
- Can interpolate multiples, curving events, and diffractions.
- Preserves AVO and AVA effects.
- Strong random noise attenuator.
- Interpolates better than MWNI in regions of low signal-to-noise.
- Only a few easy-to-choose parameters.
- Built-in easy-to-use quality controls such as a signal leakage test.

Absolute Imaging specializes in 5D interpolation, and has been using Juniper Bay's rank-reduction method exclusively for more than three years now.

Powerline Noise Removal



Powerline noise, sometimes called highline, harmonic, sinusoidal, monofrequency, or monochromatic noise, appears as a constant-amplitude sine wave running through the entire trace. The usual causes are 50 or 60 Hz electrical currents such as powerlines near geophones or cables. This noise can cause the following problems:

- Hard-to-pick first breaks.
- Amplitude and phase distortion in the seismic wavelet after minimum-phase deconvolution.
- Poor residual and trim statics.
- Noisy stack, especially after spectral whitening.

Removing powerline noise properly seems like a minor step, but can have a profound effect on the final results. Juniper Bay's powerline remover has the following features:

- Parameters are few and easy to select. Parameter testing is rarely required.
- It searches for the optimal frequency over a given frequency band. The accuracy depends on the trace length, but is typically within .025 Hz. Such accuracy is essential, as even a small error in frequency can degrade the results.
- Little or no damage is done to the underlying signal at the powerline frequency. In particular, ***there is no spectral notching.***
- If no significant powerline noise is found in a trace then it is left untouched. Typically, only a fraction of the traces gets altered. Some surveys might have no powerline noise removed.
- Harmonics of the fundamental frequency are optionally removed if they have significant amplitude.
- Multiple passes can be requested. In other words, if powerline noise is removed from a trace then the altered trace is searched again for a new fundamental frequency, and removed if detected. This is equivalent to running the tool two or more times in sequence, but at only slighter greater computational cost than running it once.
- You can optionally output the difference (the removed noise) rather than the noise-filtered data.
- It writes a report at the end summarizing the results, including the number of traces altered and a histogram showing what powerline frequencies were found within the search band.

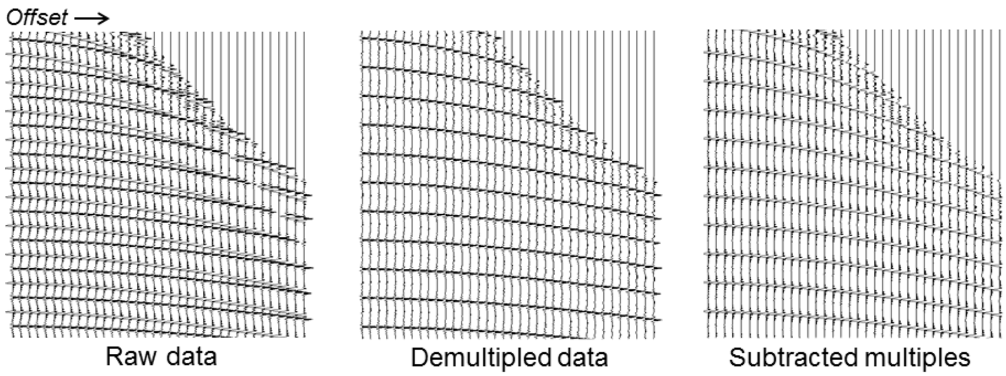
Surface-Consistent Scaling

Surface-consistent scaling, otherwise known as true-amplitude or AVO-compliant processing, tries to equalize trace amplitudes due to acquisition and near-surface effects while preserving amplitude differences due to geology. It is considered critical in bright-spot analysis, AVO analysis, and waveform inversion, where trace-by-trace scaling can mask geological effects.

The ProMAX system has a surface-consistent scaling module called ***Surface Consistent Amps***. The Juniper Bay version offers numerous improvements, including:

- Easier to use. In particular, there are fewer parameters and they are easier to select. The meaning of some of the ProMAX parameters are not clear.
- Fast and fully runnable in parallel. There are some ProMAX steps that can not all be run in parallel, and one of the steps (COMPUTE) can be terribly slow for certain parameter selections.
- Statistically robust, meaning insensitive to erratic noise. This robustness is found in both individual trace scaling measurements and the surface-consistent solution.

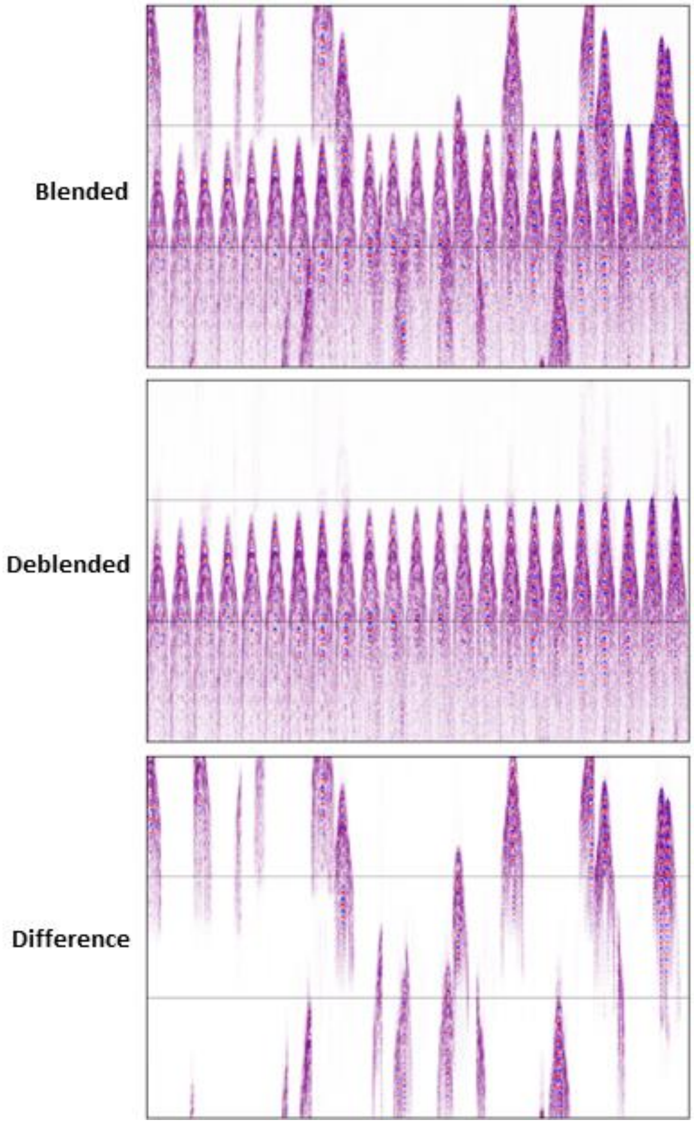
High-Resolution Radon-Transform Multiple Removal



Hyperion removes multiples using a time-domain Radon transform that fits the data using curves having a normal-moveout trajectory. It has the following features:

- Executes quickly.
- Has "primary weighting", a type of high-resolution transform which prevents damage to primary energy.
- Works from non-NMOed data, making it less prone to damage due to NMO stretch than Radon transforms that work from NMO-corrected data. This means that more offsets may be used, increasing the resolution of the transform.
- Works in the time domain, so that it is not distorted by muted zones.
- Parameter selection is easy. No *τ-p* mute picking is required.
- Super gathers are supported. This feature adapts to the fold, so that a super gather might include many gathers at the survey boundaries and few or one gather in the interior.
- Can specifically target water-column multiples, those strong multiples that bounce between the water surface and water bottom without reflecting within the earth.
- Handles higher-order (that is, non-hyperbolic) normal-moveout curves.

Simultaneous-Source Deblending



Seismic data is now often acquired using blended or simultaneous sources – that is, the acquisition crew does not wait until the energy from one source has fully died out before firing the next source. This speeds up acquisition and reduces costs, but it means that energy from one source will often contaminate another. This extraneous-source energy is sometimes referred to as “crosstalk”. One could proceed with conventional processing without worrying about crosstalk, but it’s better to remove it early in the processing, a task called “deblending”. That is the purpose of this tool.

Note that this tool is still in the testing stage!

Resume

Stewart Trickett is the owner, researcher, and developer for Juniper Bay Software Ltd. Stewart has a bachelor's degree in computer science from the University of British Columbia and a master's degree in applied mathematics from the University of Waterloo. He has researched and developed seismic processing software for over forty years, and was the original designer of two commercially successful processing systems: Veritas Seismic's *Sage* and Kelman Technologies' *Kismet*. He was the manager of research and development at Kelman Technologies, and later an R&D manager at Fugro and CGG owing to take overs, for thirteen years. He began Juniper Bay Software in 2016.

Stewart has published over 50 articles and conference abstracts, primarily on deconvolution, noise attenuation, and interpolation, and has given countless presentations to clients, conferences, and professional societies. Google Scholar lists over 900 citations of his work. He is best known for his development of rank-reduction techniques such as Cadzow filtering, often called Singular Spectrum Analysis, for seismic noise attenuation and interpolation. His talk "Robust rank-reduction filtering for erratic noise" was selected as one of the top thirty papers delivered at the 2012 SEG annual convention. In 2016 he was presented with the Technical Achievement Award of the Canadian Society of Exploration Geophysicists for outstanding technical contributions to the field of Canadian geophysics.

Stewart is a member of the Society of Exploration Geophysicists, the Canadian Society of Exploration Geophysicists, and the European Association of Geoscientists and Engineers. He is an associate editor for *Geophysics*, the world's leading journal in applied geophysics.

Selected Publications

Trickett, S., 2023, *Ordering cross-spread gathers* (submitted to Geophysics).

Trickett, S., 2022, *In search of the vibroseis first arrival*: Geophysical Prospecting **70**, 641-654.

Trickett, S., 2021, *Effective Technical Talks*: CSEG Recorder 46 (02).

Trickett, S., 2021, *Software Correctness*: CSEG Recorder 46 (02).

Trickett, S., 2019, *Cleaning up first arrivals in the cross-spread domain*: 89th Annual International Meeting, SEG, Expanded Abstracts.

Trickett, S. 2016, *Frequency-Domain Rank Reduction in Seismic Processing – An Overview*: GeoConvention, Calgary, Alberta.

Trickett, S., 2015, *Preserving signal: Automatic rank determination for noise suppression*: 85th Annual International Meeting, SEG, Expanded Abstracts, 4703-4707.

Trickett, S., L. Burroughs, and A. Milton, 2013, *Interpolation using Hankel tensor completion*: 83rd Annual International Meeting, SEG, Expanded Abstracts, 3634-3638.

Trickett, S., L. Burroughs, and A. Milton, 2012, *Robust rank-reduction filtering for erratic noise*: 82nd Annual International Meeting, SEG, Expanded Abstracts.

Milton, A., S. Trickett, and L. Burroughs, 2011, *Reducing acquisition costs with random sampling and multidimensional interpolation*: 81st Annual International Meeting, SEG, Expanded Abstracts.

Trickett, S. R., L. Burroughs, A. Milton, L. Walton, and R. Dack, 2010, *Rank-reduction-based trace interpolation*: 80th Annual International Meeting, SEG, Expanded Abstracts, 3829–3833.

Trickett, S., and L. Burroughs, 2009, *Prestack rank-reduction-based noise suppression*: CSEG Recorder, **34**, no. 9, 24–31.

Trickett, S., 2008, *F-xy Cadzow noise suppression*: 78th Annual International Meeting, SEG, Expanded Abstracts, 2586–2590.

Trickett, S., 2007, *Maximum-likelihood-estimation stacking*: 77nd Annual International Meeting, SEG, Expanded Abstracts, 2640-2643.

Hunt, L., S. Trickett, D. Levesque, P. McKenny, B. Link, and S. Jameson, 2003, *The effects of stretch-free stacking on a clastic exploration play in Alberta, Canada*: 73rd Annual International Meeting, SEG, Expanded Abstracts, 321-324.

Trickett, S., 2003, *Stretch-free stacking*: 73rd Annual International Meeting, SEG, Expanded Abstracts, 2008-2011.

Trickett, S. R., J. Grimm, V. Aleksic, and D. McVee, 2003, *Prestack F-xy eigenimage noise suppression*: 73rd Annual International Meeting, SEG, Expanded Abstracts, 1901–190.

Trickett, S. R., 2003, *F-xy eigenimage noise suppression*: Geophysics, **68**, 751–759.

Trickett, S., 2002, *F-x eigenimage noise suppression*: 72nd Annual International Meeting, SEG, Expanded Abstracts, 2166–2169.

Dennis, P., F. Peterson, B. Link, and S. Trickett, 1999, *Geological based seismic deconvolution:*: 69th Annual International Meeting, SEG, Expanded Abstracts, 1315-1317.

Link, B., and S. Trickett, 1997, *Wavelet instability: Issues and risk management strategies:*: 67th Annual International Meeting, SEG, Expanded Abstracts, 1039-1042.

Trickett, S., B. Link, and B. Goodway, 1996, *Improving wavelet stability by turning the deconvolution black box into a glass box*: 66th Annual International Meeting, SEG, Expanded Abstracts, 1599-1602