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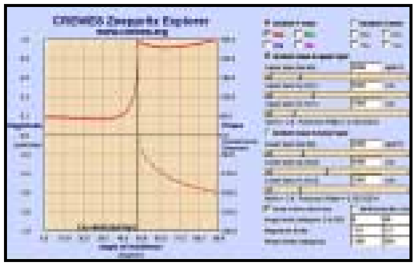
CREWES NEWS

The Consortium for Research in Elastic Wave Exploration Seismology

In This Issue...

CREWES Introduces Zoeppritz Explorer

CREWES is pleased to announce a useful web-based applet, Zoeppritz Explorer. The applet, which requires a Java-enhanced browser, can be found on the new "Interactive Demos" page on the CREWES website. The source code is available to sponsors only from the Software Download page.



This Explorer utility allows one to view the angle dependence of any reflection or transmission coefficients for any combination of earth properties. Both magnitude and phase are displayed, and critical angles are clearly annotated. Exact solutions and the Aki-Richards approximation are currently available, and graph scales are all interactively adjustable. This visual representation of the varied behaviour of the Zoeppritz Equations should be very useful in any exploration of their properties.

Comments, queries and suggestions regarding this utililty can be sent to Chuck Ursenbach at ursenbach@crewes.org.

Amplitude within Fresnel zone for zero-offset

Shuang Sun

Reflection energy from a linear reflector comes from the integral over an aperture often described as the Fresnel zone. Within the Fresnel zone, the diffraction energy interferes constructively to yield the reflection energy. To get true reflection amplitude in poststack migration, a migration aperture that is twice the Fresnel zone size must be considered. We have derived the size of the Fresnel zone for the prestack case as a function of half the source-receiver offset (Sun & Bancroft, submitted to SEG, 2001).

A Fresnel zone is defined as the intercept when a spherical wave penetrates a plane to a depth of one half of a wavelength (Claerbout,1985). The Fresnel zone identifies the area that contributes energy to a migrated trace. Using Claerbout's definition above and the DSR (double square root) equation, I have derived the Fresnel zone size for a horizontal reflector as a function of half the source-receiver offset in an offset section.

The result is shown in the equation below, where τ is the period of the wavelet and h is the half source-receiver offset. We have further evaluated how the size of the migration aperture affects the migration result, and then established an acceptable minimum migration aperture for horizontal reflectors. For both zero offset and offset data, twice the Fresnel zone size is the minimum migration aperture to preserve true amplitude; as a migration aperture that is larger does not improve the migration result, this is also the optimum aperture.

$$x_f = \sqrt{\frac{\tau v^2 \sqrt{t_0^2 + \frac{4h^2}{v^2}}}{4 - \frac{h^2}{v^2 t_0^2 + 4h^2}}}$$

CREWES NEWS Expands

Readers will notice an expanded CREWES NEWS this month, with the introduction of two new regular features, and the re-introduction of a third.

The first feature is **In Focus**, a series of articles exploring the various research projects that CREWES is involved in. Kicking off the series is an update on the Pikes Peak lake-bottom cable survey.

The second regular feature introduces readers to current research being conducted by graduate students. Shuang Sun and Marco Perez help us inaugurate this section.

Finally, we resume our series of profiles of CREWES students. In the spotlight this month, former M.Sc. and current Ph.D. student from Thailand, Chanpen Silawongsawat.

We hope you enjoy the newsletter’s expanded coverage and welcome your comments and suggestions. These can be sent to the editor, Mark Kirtland at kirtland@crewes.org

In Focus: The Pikes Peak lake-bottom cable seismic survey

Dr Robert R. Stewart

The CREWES Project and AOSTRA, in collaboration with Husky Energy Inc., conducted a detailed study of Husky's Pikes Peak heavy oil field near Lloydminster, Saskatchewan. As part of this study, a unique experimental "lake-bottom seismic cable" survey was acquired in September, 2000. The lake-bottom cable (LBC) was Schlumberger Canada's five-level, VSP tool. This 60m downhole tool had 3-C receivers separated at 15m intervals with a flexible cable between sensor levels. The purpose of the experiment was to determine whether coherent seismic energy could be recorded by seismic sensors lain under water (a 1m deep slough in this case). If successful, this type of recording could assist land-seismic exploration in summer months and might be beneficial to marine surveying using a VSP tool as an ocean-bottom cable (OBC).

Figure 1: Deployment of the wireline across the "lake".

To conduct the lake-bottom survey, we first floated and pulled the wireline from the VSP recording truck across the slough (Figure 1). With the wireline at the far side of the slough, the 5-level, 3-C VSP tool was attached and winched back, stopping at 29 receiver locations to provide different receiver positions. We offer special thanks to the Schlumberger engineers who were extremely helpful and patient during this procedure. A vertical vibrator was walked away from the slough edge to give 10 source positions.

Coherent data were recorded on all three of the VSP geophones' components. The raw VSP "Z" component became the in-line or radial receiver, while the "X and Y" components were in the vertical plane perpendicular to the line direction. We rotated the "X and Y" components to give effective vertical and crossline channels. We then processed the vertical channel into a PP section and the radial channel into a PS section. Although we were processing only a few end-on shots, we were delighted to be able to construct credible sections. The frequency spectrum of a previous seismic section (shot in Winter 2000) showed a very high frequency content (up to 150 Hz). To compare with the LBC section, the previous section was bandpass filtered (6-11-30-40 Hz). The LBC stacked section is clearly low frequency, though quite promising considering all of its limitations. The frequency content may have been compromised for a number of reasons: the receivers were simply lain on the slough bottom and there was poor source coupling, due to the vibrator operating in a muddy area; a water-surface ghost could have attenuated the received data. We had very low fold, and only a basic processing sequence was used.

We processed the radial component with a Vp/Vs value of 3.0. The resultant PS stacked section also matched a low-pass filtered version of the winter shooting 3-C survey reasonably well. We conclude that the lake-bottom cable technique, using a VSP tool, is a promising method to acquire multi-component data in lakes. We also suggest that this would be a viable technique offshore.

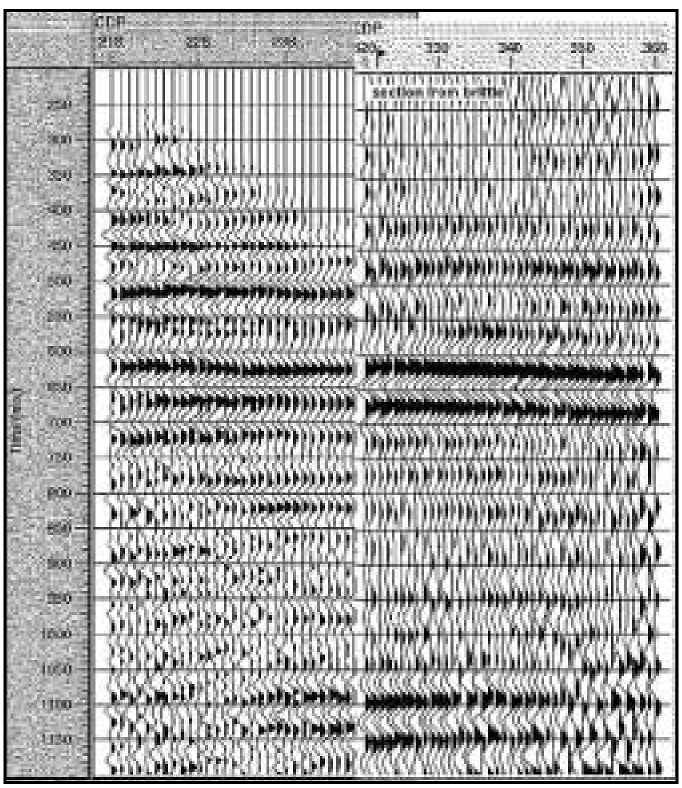


Figure 2: The lake-bottom cable stacked section (left) and low-pass filtered Winter 2000 section (right).

Tomography in Isotropic and TI Media

Marco Perez

This work aims to develop effective methods for performing tomographic velocity analysis for a variety of recording geometries in both isotropic and transversely isotropic media. Tomography is a process that extrapolates a velocity field from known wave propagation traveltimes. A method involving the finite-difference eikonal traveltime solver is employed to compute traveltimes. The solver is described in a paper by Perez & Bancroft (CREWES Research Report, 2000).

In this technique, traveltimes and ray paths are first computed from an initial velocity model. Using a method of least squares, the difference between these modeled traveltimes and the known traveltimes are minimized through an iterative process of velocity adjustment. Due to the non-linearity of raypaths, various iterations may be required to converge to a solution. Such a tomographic computation is displayed in the following figures. In the case of transmission tomography between two boreholes (see Figure 1), traveltime maps based on an estimated velocity field are first constructed for each source. The principle of reciprocity is invoked to determine the ray path from the receiver to the source. The normals of the constant traveltime wavefronts correspond to the minimum traveltime and delineate the ray path. As the ray approaches the source, the plane wave approximation made in the eikonal traveltime solver breaks down, thereby invalidating the ray path approximation. One of the optimum ways to reduce error from the plane wave approximation involves reducing the velocity grid size.

Traveltime maps are similarly constructed for source and receiver locations in reflection tomography (Figure 2). The minimum of the summation of the maps along the reflector indicates the point of reflection. The location of reflectors and the calculation of reflector depth derivatives are necessary to determine the location of the reflector.

The author has implemented various methods to solve the least squares problem in tomography, including the conjugate gradient scheme (CGS) and singular value decomposition (SVD). Well log information can also be incorporated into the tomographic inversion to constrain some velocities.

Future direction of this research involves the more complex task of determining ray paths in transversely isotropic media from known traveltimes. In the case of anisotropy, the direction of ray propagation is dependent upon the ray angle, which is not normal to the wavefront. Once again, the principle of reciprocity can be used to trace the ray from the receiver back to the source. To test this inversion method, the velocity field obtained can be used in migration of the data, and the results compared with the original input model.

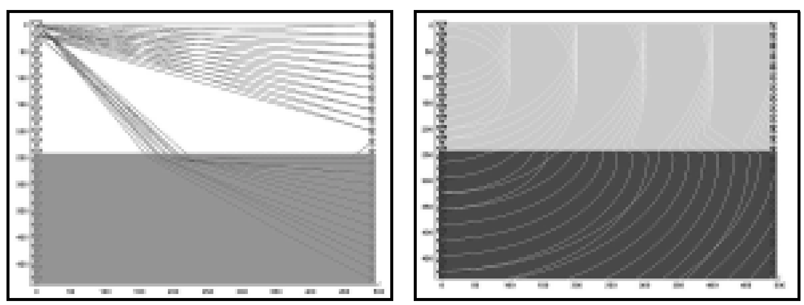


Fig. 1: Transmission tomography rays (left) and traveltime maps (right).

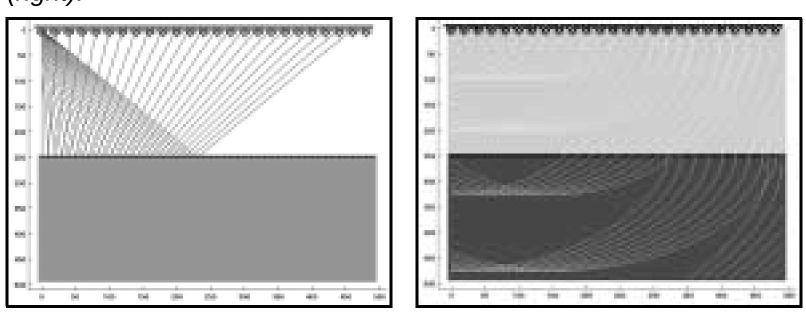


Fig. 2. Reflection tomography rays (left) and traveltime maps (right).

Presentation by CREWES Visiting Scholar

CREWES sponsors are welcome to attend a talk entitled 'Using NMO for Amplitude Preserving Migration' to be given by Dr Dirk Gajewski. The talk will be presented at 10:00 a.m., June 21, in room 136, Earth Sciences building, University of Calgary.

Dr. Gajewski is working with CREWES until October. He is on sabbatical leave from his position as Associate Professor of Applied Geophysics in the Applied Geophysics Group of the Institute of Geophysics, University of Hamburg, Germany. Dirk is also associate editor, anisotropy section, of Geophysical Prospecting.

Dirk's interests include high-frequency asymptotics, seismic modelling, and processing of seismic data from isotropic and anisotropic media.

CREWES Student Profile - Chanpen Silawongsawat

Returning to our series of student profiles, we turn the spotlight on Chanpen Silawongsawat, one of CREWES' most senior students.

Chanpen Silawongsawat joined us in 1995 as an M.Sc. student straight from her native Thailand. Having overcome the challenges of language, culture, and Canadian winters, Chanpen completed her M.Sc thesis, 'Elastic Wavefield Modeling by Phase Shift Cascade' in 1998. She then took a year out, travelling and working as an intern research geophysicist with Geco-Prakla Schlumberger UK, which inspired her with the idea of up/down-going waves separation. She then modified the elastic modelling program she had written to test her ideas. Chanpen returned to CREWES in 1999 to study for her Ph.D. Unocal has allowed her to use a set of OBS data acquired from the Gulf of Thailand for her Ph.D. research.

Prior to joining CREWES, Chanpen attended Chiang Mai University, Thailand, where she studied nuclear physics on a Science and Technology Development scholarship. Upon graduation, she became interested in the exploration geophysics international graduate programme that had just become available. It was through this programme that Chanpen made contact with the University of Calgary and CREWES.

When not pursuing her studies, Chanpen is an active member of the University of Calgary Ballroom Dance club, a student liaison volunteer and teaching assistant. At the end of her first year, Chanpen was selected as the Most Improved Teaching Assistant. She finds dancing entertaining, good exercise and a great way to meet new people from around the world, in addition to helping improve her English. She also enjoys cycling, hiking and mountain biking. She has enjoyed reading since childhood and she still visits libraries and bookstores often, though now they are all in English rather than her native Thai.

Newsletter Delivery Options

We would like to remind CREWES NEWS readers that there are several options available for receiving the newsletter.

As well as being available via fax, we also make the newsletter available as a PDF file, which can be sent as an email attachment.

For those who wish to no longer receive the newsletter via fax, yet who cannot or do not wish to receive attachments, we offer the CREWES NEWS notification service. This takes the form of an email containing a direct link to the latest issue of the newsletter when it is placed on the website.

To make a request for any of these options, please send an email to Louise Forgues at louise@crewes.org.

Revised Contact Details

Readers wishing to contact staff and students should note that all CREWES usernames are attached to the @crewes.org domain.

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