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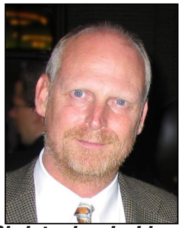
Biography


Christopher L. Liner

Christopher L. Liner joined the faculty of the University of Houston Department of Earth and Atmospheric Sciences in January 2008 and is now professor and associate director of the Allied Geophysical Laboratories industrial consortium. He earned a bachelor of science degree in geology from the University of Arkansas in 1978, a master of science in geophysics from the University of Tulsa in 1980, and a Ph.D. in geophysics from the Center for Wave Phenomena at Colorado School of Mines in 1989. He began his career with Western Geophysical in London as a research geophysicist, followed by six years with Conoco. After working a year with Golden Geophysical, he served as a faculty member of the University of Tulsa Department of Geosciences from 1990 to 2004. From 2005 through 2007, Liner worked as research geophysicist with Saudi EXPEC Advanced Research Center, Dhahran, Saudi Arabia.

Liner's research interests include petroleum reservoir characterization and monitoring, CO_2-sequestration geophysics, advanced seismic-interpretation methods, seismic data analysis and processing, near surface, anisotropy, and seismic wave propagation. He served as editor of GEOPHYSICS in 1999–2001 and contributing editor to World Oil in 2010 and is an editorial board member for the Journal of Seismic Exploration. Liner has written many technical papers, abstracts for scientific meetings, the "Seismos" column in THE LEADING EDGE (since 1992), the "Seismos Blog," and the textbook Elements of 3D Seismology, now in its second edition. Liner is a member of SEG, AAPG, AGU, the Seismological Society of America, and the European Academy of Sciences. In 2011, he was named an honorary member of the Geophysical Society of Houston.

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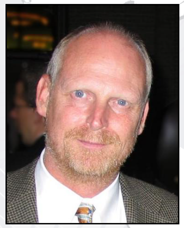
Elements of Seismic Dispersion: A somewhat practical guide to frequency-dependent phenomena



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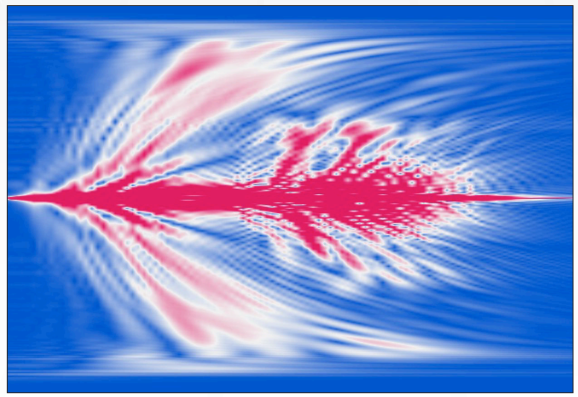

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Elements of Seismic Dispersion: A somewhat practical guide to frequency-dependent phenomena

Abstract

Overview

The classical meaning of the word dispersion is frequency-dependent velocity. Here we take a more general definition that includes not just wave speed but also interference, attenuation, anisotropy, reflection characteristics, and other aspects of seismic waves that show frequency dependence. At first impression, the topic seems self-evident: Of course everything is frequency dependent. Much of classical seismology and wave theory is nondispersive: the theory of P- and S-waves, Rayleigh waves in a half-space, geometric spreading, reflection and transmission coefficients, head waves, and so forth. Yet when we look at real data, strong dispersion abounds. This course is a survey of selected frequency-dependent phenomena that routinely are encountered in reflection-seismic data.

1) Time and frequency

The Fourier transform (FT) is a standard frequency-analysis tool, but it yields little information about combined time-frequency content. We will review the FT and its extension to short-time FT and continuous wavelet transform as representative examples of a broad class of time-frequency decomposition methods.

2) Vibroseis harmonics

The vibroseis source injects a long, slowly varying signal into the earth. We commonly find that new frequencies, or harmonics, that are not present in the sweep are present in the earth response. This interesting phenomenon is discussed in relation to a more familiar process, that of human hearing. Those harmonics are illustrative of a general property of nonlinear waves and interaction.

3) Near surface

Velocity dispersion generally is considered not to be an issue in seismic data processing. This is nearly true for seismic body waves (P-, S-, and mode-converted) that propagate in the deep subsurface. In the near surface, however, velocities often show strong dispersion, and the description is considerably inaccurate. This is especially the case in marine shooting over shallow water where, even in the 10- to 100-Hz band, velocities are observed well above and below the speed of sound in water. This paradox arises because shallow water over an elastic earth forms a waveguide whose characteristics we will examine.

4) Anisotropy

In this section, we consider seismic-velocity anisotropy and how it depends on frequency. We will restrict our comments here to velocity variation with respect to the vertical axis (VTI) in a horizontally layered earth. Of the sedimentary rock types, only shale is seen to be significantly anisotropic at the core, or intrinsic, scale. The question is how to calculate apparent anisotropic parameters of a layered medium as seen by very long waves. Backus (1962) solved this problem, and his method can be applied to standard full-wave sonic data. So where does dispersion come into all this? It is buried in the thorny question of the Backus averaging length.

5) Attenuation

The distinction between intrinsic and apparent frequency-dependent seismic properties is nowhere greater than in attenuation. Constant Q and viscous theories of intrinsic attenuation are developed and compared with experimental intrinsic scattering-attenuation data. Intrinsic attenuation is found to be compatible only with the viscous theory, while constant Q yields a better explanation of scattering attenuation caused by layering.

6) Interference

The preceding sections have explored frequency-dependent phenomena related to acquisition and wave propagation, effects that would be seen and dealt with on prestack data. Data processing will remove or correct for those effects and will be unseen by the interpreter. However, dispersion effects (in our broad meaning) remain in the realm of final imaged data. First and foremost is the fundamental, unavoidable phenomenon of interference. We will discuss selected topics in this broad field, including the thin bed, bandwidth effect on reflectivity, single-frequency isolation, and reflection from a vertical transition zone.

7) Biot reflection

Many of the dispersion effects discussed previously contain information about the subsurface, but none as direct and important as the problem of reflectivity dispersion resulting from a poroelastic contact in the earth. We will review the nature of body waves in porous media and the characteristics of Biot reflection from an isolated interface and will end with an introduction to Biot reflections in layered porous media.

Learning goals

- gain a broad understanding of dispersive phenomena and related investigation tools
- understand the fundamental difference between intrinsic and apparent dispersion phenomena
- improve knowledge of the reflection process beyond the classic model
- provide an appreciation of historical development and a deep guide to the literature for self-study

Who should attend

The course is framed along the lines of acquisition, processing, and interpretation to contain material of interest to the entire spectrum of seismic geophysicists. The mathematical level of the course is generally on the advanced undergraduate level, but deeper aspects often are included for advanced readers. Familiarity with the Fourier transform and related topics will be beneficial. In all cases, theoretical developments are illustrated by examples or case histories.