# 2016 SEG® DISTINGUISHED INSTRUCTOR SHORT COURSE

*3C Seismic and VSP: Converted Waves and Vector Wavefield Applications*

**Presented by James Gaiser**

## WHO SHOULD ATTEND

The course is intended for geophysicists, geologists and engineers. The emphasis is on practical understanding and application of vector wavefields, thus a basic prerequisite knowledge of P-waves is assumed. The course would be most relevant to those currently involved with, or considering the use of AVO/A inversion, fracture/stress characterization analyses, or interpretation in gas-obscured reservoirs.

## OVERVIEW

The course will give an overview of 3C seismic theory and practical application: from fundamentals of PS-waves and VSPs, through to acquisition and processing including interpretation techniques. The emphasis will be on unique aspects of vector wavefields, anisotropy, and the important relationships that unify S-waves and P-waves. Various applications and case studies will demonstrate image benefits from PS-waves, elastic properties from joint inversion of amplitude variations with offset/angle (AVO/A), and VSP seismic methods for improved reservoir characterization.

## BIOGRAPHY

James (Jim) Gaiser received an MS (1977) in geophysics from the University of Utah and PhD (1989) in geophysics from the University of Texas at Dallas. In 1977 he joined ARCO in the geophysical analysis and processing group before moving to research and development in 1981, where he worked on vertical seismic profiling, elastic wave imaging, and seismic anisotropy. He worked with Western Geophysical/Schlumberger from 1992 to 2007 conducting research in coherent-noise suppression, depth migration and multicomponent processing, and with ION Geophysical – GXT Imaging Solutions from 2007 to 2009 where he worked on interferometry, and 3D converted wave imaging. After several years as senior scientist with Geokinetics Inc., where his research activities were 3D imaging and velocity model building in anisotropic media, and converted waves, he joined CGG as R&D Manager of multicomponent research in 2013. He is currently Principal Research Advisor for Gaiser Geophysical Consulting. Jim has authored numerous patents and articles, shared the award for SEG best presentation in 1981, received SEG honorable mention for his presentation in 1993, shared SEG honorable mention for his TLE article in 2003, and received the SEG Life Membership award in 2007. He served on the SEG Development and Production committee from 1993 to 1997, was District 2 Representative for the SEG council from 1994 to 1997. He served as vice president of the Denver Geophysical Society (DGS) in 2004 and president in 2005. He is active with EAGE organizing committees for workshops, and is currently

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a member of the SEG Research committee (2007 to present) and a lecturer for the SEG Continuing Education program. He is a member of SEG, DGS, GSH, CSEG, EAGE, RAS, AAPG and SPE.

## COURSE OBJECTIVES

Students will obtain an understanding of theoretical and practical aspects of 3C seismic and VSP, including how to use PS-wave and vector wavefield data to improve rock property applications, as well as:

- Basics of PS-wave registration, velocities and birefringence (S-wave splitting).
- Elastodynamic processes that generate converted waves and how they relate to elastic rock properties.
- Issues of PS-wave asymmetry and illumination, and how 3C surface and VSP wavefields are related.
- Unique characteristics of PS-wave processing: time registration with P-waves, S-wave splitting, VP/VS analyses, velocities, and conversion-point gathering.
- Identifying and accounting for potential vector infidelity effects.
- Interpretation of converted-wave and VSP wavefields.
- Applications of 3C seismic and VSP data for migration and elastic impedance inversion, imaging through gas, fracture/stress characterization, and timelapse.

## SUMMARY

Definitions and wavefield properties of 3C seismic and VSP data are covered, including anisotropy, coordinate systems, vector wavefields, and S-wave applications. Challenges our industry has faced in the development of S-wave technology are reviewed to obtain a perspective of the current PS-wave emphasis.

S-waves and VSP in the 20th century: An overview of the history and development of S-wave and VSP technology in the 20th century is discussed, including S-wave source development, the influence from P-wave AVO, and the emphasis on vertical transverse isotropy (VTI) and azimuthal anisotropy. Also, the early development of PS-wave and VSP technology is reviewed.

Fundamentals: A tutorial of the elastodynamic theory of PS-wave generation is described, along with reflection and transmission coefficients, coordinate systems, and polarity standards. Conversion-point illumination, modeling and interpretation of 3C seismic and VSP, NMO velocity in anisotropic media, and the resolution of PS-waves are also reviewed.

Acquisition: Basic source radiation patterns, free surface and seabed responses to P- and S-wave arrivals are described as well as source, receiver, and VSP systems. Various 3C acquisition configurations are examined in terms of PS-wave illumination, minimal datasets, and common-offset vector (COV) gathers, including VSP geometries.

Processing and Analysis: Unique 3C processing steps such as rotation, S-wave statics and splitting analyses are emphasized in addition to noise attenuation, vector infidelity corrections, elastic-wavefield decomposition, common conversion-point gathering, and VP/VS analyses. Essentials of VSP wavefield separation, anisotropic velocity analyses, and conventional processing are described along with interferometry application.

Imaging and Inversion Applications: Applications of PS-wave seismic demonstrating anisotropic imaging, velocity model building, and tomography are presented in addition to case studies imaging through gas, and imaging with VSP. Also, various inversion applications are presented: layer stripping for fracture/stress properties and joint AVO/A for rock properties, including unconventional reservoir, microseismic imaging, and timelapse applications. Current research directions of 3C seismic and VSP include investigations using reverse-time migration, AVAz and full-waveform inversion, near surface velocity model building, distributed acoustic sensing, and rotational sensors. Business model considerations are discussed along with improving the economic viability of 3C seismic and VSP to increase productivity, and to reduce processing costs and turn around times.