# GeoNeurale

Presents:

*Leon Thomsen and Robert Garotta*

Hybrid Course

# 3D Seismic Anysotropy and 3D Seismic Multi-Component

# Leon Thomsen & Robert Garotta

## The event of the Year

3D Seismic Multi-Component is the most sensitive measurement to seismic Anisotropy.

A complete treatment of the two subjects and their implications and the latest developments in the scientific research are presented and discussed together from two world scientists who are behind a great part of the development of this technology.

The course starts with 3D Seismic Anisotropy (2,5 Days) and continues with 3D Seismic Multi-Component (2,5 Days). Both scientists are avaliable during the course for questions, feed-back and interactive discussion with the audience.

# GeoNeurale

MUNICH

at the

*GATE – Garchinger Technologie und Gründerzentrum*

5 – 9 December 2011

5 DAYS COURSE

- INSTRUCTORS: Robert Garotta, Leon Thomsen
- LEVEL: Advanced / Specialistic
- AUDIENCE: Seismic Interpreters, Processors, and Imagers, Geophysicists
- Reservoir Engineers.

- COURSE FEES: 3800 Euro + VAT (19%)
- REGISTRATION DEADLINE : 5 November 2011
- ONLINE REGISTRATION: www.GeoNeurale.com

- **SEISMIC ANISOTROPY in EXPLORATION and EXPLOITATION (Leon Thomsen)**

- PROGRAM

- Course Description

- All rock masses are seismically anisotropic, but we generally ignore this in our seismic acquisition,
- processing, and interpretation. The anisotropy nonetheless does affect our data, in ways that limit the
- effectiveness with which we can use it, so long as we ignore it. In this short course, we will understand
- why this inconsistency between reality and practice has been so successful in the past, and why it will
- be less successful in the future, as we acquire better seismic data (especially including vector seismic
- data), and correspondingly higher expectations of it. We will further understand how we can modify our
- practice so as to more fully realize the potential inherent in our data, through algorithms, which recognize
- the fact of seismic anisotropy.

3D SEISMIC MULTI-COMPONENT (Robert Garotta)

- The first two days of the course will be devoted to the presentation of the basic theory of elastic propagation and its consequences about the acquisition and the processing of multi-component data, then to the presentation of 2D and 3D examples of results.
- During the third day more details will be given to particular topics:
- - shear mode static corrections,
- - derivation and use of the Vp/Vs ratios,
- - simultaneous combined PP and PS mode inversion,
- - detection and compensation of azimuthal anisotropy.

# 3D Seismic Anisotropy

- 1.Physical principles (Day 1, morning)
- 2.P-waves: imaging (Day 1, afternoon)
- 3.P-waves: characterization (Day 2, morning)
- 4.S-waves: (Day 2, afternoon)
- 5.C-waves: (Day 2, afternoon)Epilogue: (Day 2, afternoon)

- **SEISMIC ANISOTROPY in EXPLORATION and EXPLOITATION**
- Detailed Program
- INTRODUCTION
- Course Outline
- Support Materials
- End Presentation
- PART 1
- Definition
- Physical Principles
- Most Sediments are Not
- Most Sediments Are
- Inhomogeneities
- Massive Shales
- Small Scale
- Mother Nature
- Core Expand
- Different Fabrics
- Physical Anisotropy of all types
- Electrical Anisotropy (1)
- Electrical Anisotropy (2)
- Electrical Anisotropy (3)
- Anisotropy as a Function of Scale

- Consider Vertical and Horizontal
- Elasticity and Symmetry
- The Role of Ekastic Tensor 1,2,3
- Hooke´s Law
- Symmetry of the Medium
- How bad could it be 1,2,3,4,5,6
- In the survey coordinate system
- Polar Anisotropy
- Solution
- The Velocity of Plane Waves
- A careful Inspection
- The exact Velocity of Plane Waves
- Weak polar Anisotropy 1,2,3,4
- AP Wave front 1,2,3,4
- P Slownesses ia a WA-VSP
- Alternative Formulations
- Example
- Card Tricks
- Comparison of P -Anisotropies
- Azimuthal Anisotropy
- Azimutal Variation 1,2
- The Power of Notation
- End of Presentation

- PART 2
- Canonical Anisotropic Reflection Problem
- Ray Greater than Wavefront 1,2
- Thin Layer
- Thin Isotropic Layers
- Thin Anisotropic Layers 1,2
- NM Stacks
- Anisotropic Movement Velocity
- Taylor Series Coefficients
- Yields the Moveout Velocity
- Short Spread 1,2
- Reflection Problem 1,2,3
- Fuggy Images
- Hyperbolic Moveout Analysis 1,2
- A Single Polar-Anisotropic Layer 1,2,3
- Hockey Stricts Straightened
- Anisotropic DMO
- The DMO Operator 1,2
- Isotropic and Anisotropic 1,2
- Various Constant Velocities
- Beds and Faults
- Anisotropic Time Migration
- Two Problems
- Imaging Errors
- Benefit of Anisotropic Time Migration
- Anisotropic Depth Migration
- A Synthetic Anisotropic Model
- Anisotropic Depth Migration 1,2,3,4

Determining the Parameters
2-Parameters Semblance Plots 1,2,3
NMO Velocity
Slowness Ellipses
Azimuthal Variation of Moveout Velocity 1,2
Parameter Semblance Plots
Gathers are not flat
Determined from Residual Moveout
The total Slowness
Azimuthal Anisotropy
Some beds dip
Elasticity Tensor 1,2
Scattering Problems
Dipping Anisotropy 1,2
Expensive Mis-Imaging 1,2
Isotropic Mislocate the Faults
Correctly Images the Fault
Orthorhombic Anisotropy
3-D Geometry 1,2
Anisotropy fro Real Formations 1,2
9 Equations  9 Unknowns
For all Directions
End of Presentation

- PART 3
- Polar Anisotropy
- Lithology from Velocity Ratio
- Laboratory Data on Dry Shales
- Estimation of Lithology
- N-Estimation of Lithology
- Pore Pressure Prediction
- Amplitudes
- Angle-Dependent Effects
- Linearized Isotropic Half-Space
- Quantitative AVO 1,2,3
- Wavefront Angle
- Qualitative AVO 4
- Crossplot 1,2,3
- Azimuthal Variation of Velocity
- Stacking Velocity
- Anomalies from coherent zones
- Zone of High Anisotropy
- Clair: World Largest Uneconomic Field
- Multi-Azimuth
- P-Wave and S-Wave Velocity Analysis
- 2D Surface Seismic Lines
- Apparent Velocity Correlated with Production 1,2
- Azimuthal AVO: Fracture Detection
- Amplitude Variations in Transmission
- Two-Term Anisotropic P-AVO 1,2

- PART 4
- Isotropic Shear Waves
- The Theory Behind
- Inline and Crossline Polarizations
- Polar Anisotropy 1,2
- Weak Polar Anisotropy
- Card Tricks: Polar Anisotropy
- Horizontal Propagation
- Cusps and Triplications
- Wavefront-Velocity
- Ray-Velocity
- Strong Anisotropy
- This complicated Behaviour occurs only if..
- But this can be simplified to 1,2
- The approximation is good
- VSP´s
- Polar Anisotropy in an Offset VSP Survey
- Schematic Illustration of S-ave Anisotropy 1,2
- Afford Rotation
- Devil´s Elbow Pennsylvania
- Principal Modes Propagate down
- As Recorded on Receivers 1,2
- The Spike-Seismogram Vector: Crossline Source
- The Spike-Seismogram Vector: Inline Source
- 2cx2c Data Matrix 1,2,3,4
- Principal coordinate System
- Alford Rotation Is..

- The Fast-Slow Dealy
- Seismically-Detected Fractures
- Principal Sections showing Split-Shear
- The Slow-Mode Amplitudes are Variable
- Slow-Mode Zones Correspond to Fravtures 1,2,3
- These Fast-Slow Differences are Magnified 1,2
- The previous Derivation does not work
- if the Azimuth of Ansotropy changes..
- Time Lapse
- The Argument for Sensing..
- The Stress-Cracks-Anisotropy Connection 1,2
- Time-Lapse Changes in Shear-Wave Splitting 1,2,3
- Chages in Overburden Shear-Wave Splitting 4
- VSP´s
- An Example of Coarse-Layer Variation
- Crossed Dipole Sonic Data
- Conventional Logging uses a Monopole Source
- In a slow S-Formation
- The Crossed-Dipole Tool
- Crossed-Dipole Log
- End of Presentation

- PART 5
- C-Wave Basics
- Isotropic Waves at a Plane Interface
- C-Waves in ocean bottom Seismic 1,2,3
- The canonical C-Wave Problem
- Homogeneous and Isotropic Case 1,2,3
- Velocity
- The partially Realistic C-Wave Problem
- C-Wave Moveout Velocity 1,2,3
- Non-Hyperbolic Movement
- The more Realistic C-Wave Problem
- C-Wave Nonhyperbolic Moveout 1,2
- Diodic Movement
- Asymmetric Inline CMP
- If you Pick the Slow Mode you Get..
- The Gather was Centered about a Point
- Common conversion Point Gathers
- The minimally realistic C-Wave problem 1,2,3
- An approximate computation
- The Effective Velocity Ratio 1,2
- An Approximate Computation
- Anisotropic Prestack Depth Migration
- C-Wave 2d Section at Valhall 1

- Conventional P-Wave
- The Moveout Ellipse for C-Waves is Off-Center 1
- C-Wave 2d Section at Valhall 2
- The Moveout Ellipse for C-Waves is Off-Center 2
- Valhall: DMO/Post Stack Time Migration 1,2
- Anisotropic Prestack Depth Migration
- Valhall: Anisotropic Pre-Stack C-Wave
- Anisotropiy Required to focus Image
- Amplitudes
- Linearized Anisotropic Half-Space 1,2
- The Anisotropy combined with Shear
- A C-Wave Split-Spread Gather
- Such Data must be Described
- Vector Infidelity
- Azimuthal Anisotropy 1,2,3
- Alignment of Split C-Waves
- Quotation
- Acknowledgements
- End Presentation
- EXERCISES

## 3D SEISMIC MULTI-COMPONENT (Robert Garotta)

- **<u>Section 1 Historical overview</u>**
-
- - Scientists
- - Earthquake seismologists
- - Civil engineers
- - Exploration geophysicists
-
- **<u>Section 2 Why use shear waves</u>**
- -
- - When compressional mode fails
- - When lithological information is required
- - When fluid contend is important
- - When confirmation is needed
- - When shallow to medium depth resolution is required

- **<u>Section 3  Theoretical basis</u>**
- -
- - Elastic wave propagation in homogeneous media
- - Reflection, transmission and conversion of elastic waves
- - Boundary and surface waves
- - Wave attenuation
- - Modelling
-
- **<u>Section 4   Shear wave acquisition</u>**
- -
- - Shear wave sources
- - Land multi-component receivers
- - Shear wave land acquisition
- - PS mode land acquisition specifics
- - Shear wave marine and shallow water acquisition

- **<u>Section 5   Processing of shear wave data</u>**
- -
- - Generalities about Shear mode processing in VTI environment
- - Static corrections
- - Normal moveout corrections
- - Generalities about PSv mode processing in  VTI environment
- - Processing sequence of PSv mode in VTI environment
- - Particulars of marine processing
- - S and PSV mode processing in an orthorhombic environment
- - Correlation of P and S data
- 
- **<u>Section 6  Results of shear waves surveys</u>**
- 
- - Poisson’s ratio derivation from P and SH surveys
- - Poisson’s ratio derivation from P and PSV surveys
- - Example of gas detection
- - Wave mode comparisons
- - Improving the seismic image
- - 3Dx3C and 2Dx3C azimuthal anisotropy surveys
- 
- <u>Conclusions</u>

# DISCUSSION

# BIOGRAPHY

- *Leon Thomsen*
- Leon. Thomsen holds degrees in geophysics from Caltech (B.S. 1964) and Columbia (Ph.D. 1969).
- His academic career began with post-doctoral appointments at CNRS in Paris, and at Caltech, followed by faculty appointments at the State University of New York in Binghamton (1972-80).
- Thomsen's industrial career began with 14 years at Amoco, at its famous Tulsa Research Center.
- Following the change of its mission in 1994, he joined Amoco's worldwide exploration department in Houston.
- Following the recent merger, he serves in BP Amoco's Upstream Technology Group in Houston, as Principal Geophysicist.
- For his work in seismic anisotropy, Thomsen was given the Fessenden Award in 1994 by the SEG.
- He served as the SEG Distinguished Lecturer in 1997, and was Chairman of the Research Committee in 1998-2000.
- He and his colleagues received the EAGE's Best Paper Award in 1997 for their converted-wave analysis at Valhall. Thomsen was given Honorary Membership in the GSH in 1998.

- During 28 years at Amoco, BP-Amoco, and BP, Thomsen lead the exploration community in four major paradigm-shifts in seismic exploration:
- · Seismic polar anisotropy (His 1986 paper establishing key concepts is the most-frequently cited paper in the history of **Geophysics**.)
- · Seismic azimuthal anisotropy (He discovered the phenomenon in 1980; his 2006 paper establishes that the P-wave seismic signature corresponds to real subsurface fracture patterns.)
- · Converted-wave seismic (His 1999 paper established numerous key concepts, such as C-waves, $\gamma_{eff}$, diodic velocity, vector fidelity, vector reciprocity, and event registration.)
- · Electromagnetic imaging, seismic style (with KMS personnel)
- This work was realized in 60 refereed papers, 2 books, 16 patents (plus 3 others in process), and many presentations and interviews. He retired from BP in 2008, as Principal Geophysicist and Senior Advisor.

- Awards
- Thomsen is a Foreign Member of the Russian Academy of Natural Sciences, and holder of their Kapitsa Medal. He is an Honorary Member of the European Association of Geoscientists and Engineers, and also of the Geophysical Society of Houston. He holds a Fessenden Award (1993) from the SEG, and numerous best-paper awards from various societies.
- Service
- Leon served the worldwide Society of Exploration Geophysics as President in 2006-07; in this role he was the *de facto* head of the international profession of applied geophysics. Prior to that, he held several elected SEG positions, and chaired several important committees. He also served as SEG/EAGE Distinguished Instructor (2002) and SEG Distinguished Lecturer (1997). He serves on the Advisory Boards to the Director, Lamont-Doherty Geological Observatory, and to the Dean of Natural Sciences and Mathematics, University of Houston. He served on the Advisory Board to the Associate Director for Geosciences, National Science Foundation.

- **BIOGRAPHY**

- **Robert Garotta**
- Robert Garotta, graduated of the Faculté des Sciences in Paris (DES), began his career at the geophysical department of the French National Centre of Scientific Research (CNRS).
- He joined CGG as a field geophysicist, first in the gravity method then as a seismologist.
- He was involved in various fields of research and development such as vibroseismic, velocity analysis, static corrections, 3D survey design, shear wave experimentation and processing.
- He concluded his career at CGG as Senior Vice President of the company.
- Robert is still advising the CGGVeritas group in the area of Multi-Component seismic.

- Awards:
- - Conrad Schlumberger Award from EAEG 1965
- - Prix Charles Bihoreau 1975
- - SEG Distinguished Instructor 2000
- - SEG Honorary Member 2001

- **REGISTRATION FORM**
- Please fill out this form and Fax to +49 89 8969 1117
- or Email to Courses@GeoNeurale.com

- ***3D Seismic Anisotropy and 3DSeismic Multi-Component***
- Munich, 5 – 9 December 2011
- Course Fee: 3800 Euro + 19 % VAT **(VAT Tax is 100% refunded from the German Finance Ministry)**

- Name:
- Company:
- Address:
- Job Title:
- Phone:
- Fax:
- Email:

- SIGNATURE: ____________________________________

## Registration Details

- Course fee:  3800 Euro + 19% VAT
- Registration deadline : 5 November 2011

- **Payment and Registration**
- Tuition fees are due and payable in Euro upon enrollment in the course by bank transfer to the bank account given below
- unless another payment form is agreed
- Unless otherwise indicated, the payment should be received before the date specified in the invoice as payment term to make
- the enrollment effective.

- To register to the course please fill in the registration form and fax or email it along with the confirmation of your bank transfer to:
- GeoNeurale
- Lichtenbergstrasse 8
- D-85748  Munich
- T +49 89 8969 1118
- F +49 89 8969 1117

- ONLINE REGISTRATION:  www.GeoNeurale.com

- **Bank Information:** Genossenschaftsbank EG Muenchen
- Bank Account N.  519618 BIC – Code :   GENODEF 1M07
- BLZ 701 694 64 IBAN :   DE19 7016 9464 0000 5196 18

- Please indicate your name and the purpose:  “Seismic Anisotropy and Multi-Component course fee".

## Provisions

Tuition fees are due and payable in Euro upon enrollment in the course. Unless otherwise indicated, fees do not include student travel costs and living expenses.

Payments are also accepted via personal or company check, traveler's check, credit card, and Company Purchase Orders.

Cancellations by Participant:

All cancellation are subject to a 100 Euro non-refundable cancellation fee.

Cancellation have to be notified to our office, at least 30 days prior to the course start date to receive a refund (less the 100 Euro cancellation fee).

If the participants are unable to cancel prior to the 32 days notification date, they may substitute another person at their place in a course by notifying us prior to the course start date.

Course Cancellations:

GeoNeurale reserves the right to cancel the courses if necessary. The decision to cancel a course is made at least two weeks prior to the course start date. If a course is cancelled, the participant will receive a full reimbursement of the tuition fees ( but not of the plane ticket or hotel expenses or any other costs), or will be enrolled in another course upon his decision ( the cost of the original course will be applied to the cost of the replacement course ).

GeoNeurale can not be responsible for any penalties incurred for cancellation or change of airline or hotel reservations .

Refunds:

GeoNeurale will promptly remit all refunds of tuition fees due to cancellations or annullment (less any appropriate non-refundable cancellation fee) within 30 days of the course cancellation.

Force Majeure:

GeoNeurale can not be responsible for cancellations due to “force majeure” events : airplane or airport strikes, emergency situations, natural catastrophes and all situations and incidents independent or outside the human control that can delay or cancel the course. In case of such events related cancellations the course tuition fees will be refunded to the client .

Geoneurale is not responsible for any delay or absence caused by the training instructor or training instructor company for reasons which are independent or out of the control of GeoNeurale s decisions.

AGREEMENT: Upon enrollment all parts accept the above mentioned provisions. The above specified provisions shall regulate the agreement between GeoNeurale and the participant and the participant company and will enter into force upon enrollment.

**GEOLOGICAL EXCURSION**

- **The course is followed on Saturday by an optional excursion to the carbonates of the local Bavarian Alps "Karwendelgebirge", with stops at the Bavarian Castles of Neuschwanstein and Linderhof.**

PROGRAM and FOTOS