Leon Thomsen

Resume

February 2022

Contacts:

+1 281 630-1111

Leon.Thomsen@DeltaGeophysics.net
LAThomsen@UH.edu

Education:

Ph.D. (1969) Columbia University (geophysics)
B.S. (1964) California Institute of Technology (geophysics)

Experience:

Delta Geophysics: (2008-) Chief Scientist

University of Houston: (2008-) Research Professor

Lawrence Berkley National Laboratory: (2008-) Visiting Scientist

SEG Advanced Modeling Corporation: (2015- 2018) Board of Directors
(2017-2018) Chair

KMS Technologies (2008-2010) Executive Advisor

Amoco → BP :

(2001-2008) Senior Advisor, Exploration and Production Technology
(1999-2008) Principal Geophysicist, Upstream Technology, Houston
(1998-1998) Principal Geophysicist, Strategic Exploration, Houston
(1995-1998) Senior Geophysical Associate, Strategic Exploration, Houston
(1991-1995) Special Research Associate, Tulsa Research Center
(1986-1991) Research Associate, Tulsa Research Center
(1982-1986) Staff Research Scientist, Tulsa Research Center
(1980-1982) Senior Research Scientist, Tulsa Research Center

State University of New York, Binghamton

(1977-1980) Associate Professor of Geophysics (with academic tenure)
(1972-1977) Assistant Professor of Geophysics

Temporary appointments:

(1970-1972) Research Fellow, California Institute of Technology, Pasadena
(1969-1970) Chargé de Recherche, Centre Nationale de la Recherche Scientifique, Paris

Accomplishments

The challenge of an *industrial scientist* is to find and develop ideas that are useful to corporate strategy. During my industry career, I helped to lead 4 major paradigm-shifts in exploration geophysics. In chronological order:

Polar anisotropy. When I joined Amoco in 1980, seismic anisotropy was hardly recognized in exploration (despite the obvious anisotropy of all sedimentary rocks), due to its mathematical complexity. The appropriate approximation was found in Thomsen (1986a), which has become the most frequently cited paper in the history of **Geophysics**. The parameterization established there has become the universal basis for analysis of seismic anisotropy; a typical Google search of the term "Thomsen parameter" returns hundreds of thousands of hits. Now, 20+% of the presentations at SEG meetings involve seismic anisotropy.

> As a late outgrowth of these ideas, I and a colleague found (Thomsen and Dellinger, 2003) the approximation needed to solve an exotic anisotropic problem first posed over 100 years ago. This discovery may turn out someday to be actually useful.

Azimuthal anisotropy. In 1980, most geophysicists understood the term "anisotropy", to mean *polar* anisotropy, because of the layered structure of sedimentary rocks. But the presence of oriented fractures in the subsurface removes the azimuthal symmetry, and invalidates the assumption. Such fractured reservoirs may be detected from the surface using the seismic signatures of azimuthal anisotropy: P-wave AVOAz and S-wave splitting. We discovered these in early 1981, but kept them secret until we introduced the critical concepts to the industry in a now-famous "Amoco Anisotrophy Session" at the SEG convention (*c.f.* Thomsen, 1986b). Now, these ideas have become implemented throughout the industry, especially since wide-azimuth marine acquisition has become feasible. Further, these ideas lie at the heart of current research on shale gas prospects, since the shales are seismically and hydraulically anisotropic, fractured or not.

> In 1981, I was the Amoco inventor of using isotropic (and polar anisotropic) P-AVO to detect hydrocarbons directly. This work has underlain countless Amoco/BP discoveries since then. But, this was research inspired by rumors that Mobil had discovered this phenomenon, so I don't count this among my own inventions.

Converted-Wave imaging. In 1995, I left Amoco's Research center to join its worldwide Exploration department, to better *implement* these ideas. However, I and a few colleagues quickly fell upon new ideas, utilizing converted waves (from the newly-invented 4C Ocean Bottom Seismometers) in novel ways to image, for the first time, Amoco's Valhall reservoir through the cloud of gas in the overburden which had long precluded conventional P-wave imaging. Anisotropy turned out to be crucially important to this advance; and all previous converted-wave analysis had been isotropic. The ideas that I developed in Thomsen (1999) (C-waves, γ_{eff}, diodic velocity, vector fidelity, vector reciprocity) are now the universal basis for analysis of converted-wave seismics.

Electromagnetic exploration. In late 2003, I began to think about using seismic-style impulses of EM energy to directly detect hydrocarbons at depth. In late 2004, it became public knowledge that ExxonMobil and Statoil had built up large staffs of specialists and had spent large sums to successfully use *continuous*-source EM for the same purpose. BP assembled a small "skunk works" EM team, and acquired the world's first successful

field-scale impulsive-source marine EM ("ISEM") survey in late 2006 (*c.f.* Thomsen, *et al,* 2007). Since it is clearly better to detect the weak subsurface signal while the source is *off*, it is my prediction that this mode of EM exploration will replace the continuous-source methods, as this technology matures.

The challenge of a *post-industrial scientist* is to continue to make useful contributions, despite the restrictions of ongoing obligations to former employers, and the absence of corporate financial support. I retired from BP in April 30, 2008, and founded **Delta Geophysics**, a consultancy helping clients worldwide to create and apply advanced geophysics (cf. http://www.deltageophysics.net/). I also joined the **University of Houston** as Research Professor. In these roles, I have continued to challenge conventional thinking:

Rock Physics: For many years, exploration geophysicists have understood the effects of variable fluid content on seismic velocities through the work of Biot (1941) and Gassmann (1951). Their formulae are applied many times daily, for example to understand the effects of time-lapse changes in seismic data. However, the experimental support for the theory is very thin, and Thomsen (2010, 2018) shows that the theory is not quite correct either, even within its own assumptions. Recently, this discrepancy was traced to a logical error in the work of Gassmann (Thomsen, 2020ab). As a result, every fluid-substitution calculation done in the last 69 years should be re-thought. A new generation of rock physics experimentation will be required to understand the expected values of the new parameter introduced in this refinement.

Anisotropic AVO: Since 1980, AVO has been an important technology for risk reduction in the exploration for hydrocarbons. It is almost universally conducted using the assumption of isotropy. But: does it make sense to analyze the Amplitude Variation with Angle while ignoring the Velocity Variation with Angle? Thomsen (1993) concluded: probably not, since the (neglected) anisotropic term is potentially as large as the (retained) isotropic terms. But for all this time, there has been no feasible method for estimating the required parameter. In 2013, Lin and Thomsen (2013) discovered such a method, implying that every AVO analysis done in the last 35 years should be re-thought. UH has applied for a patent based on this work.

Seismic-style EM exploration: The 2006 survey mentioned above was inconclusive, but the need to respect BP's proprietary information stymied further progress after I retired. However, in the research environment at UH, Thomsen (2014) and Neese and Thomsen (2014, 2015) showed how to use seismic-style processing to directly estimate apparent resistivity in the subsurface from ISEM moveout, without mathematical inversion of the data. This work will Disrupt the billion-dollar EM exploration industry. UH has received a patent based on this work.

Honors:

Member, National Academy of Engineering, 2022.

Best Paper Award, SEG Annual Meeting**,** 2020. This award recognized Thomsen (2020a), which had just previously been *rejected for publication* by SEG because it contradicts well-accepted theory. It may be that Thomsen is the oldest recipient of this award.

Maurice Ewing Medal, 2020. This is the highest award given by the Society of Exploration Geophysicists, given for lifetime achievement.

Honoree, SEG-GSH Symposium, March 2015**.**

President, Society of Exploration Geophysicists, 2006-2007. The SEG is the international society of applied geophysicists, with over 33,000 members in 130 countries; the SEG President is the *defacto* head of the profession, worldwide.

Kapitsa Medal and **Foreign Member,** Russian Academy of Natural Sciences, 2004.

Honorary Member, European Association of Geoscientists and Engineers, 2003.

AAPG's Beydoun Memorial Award: Best International Poster, Cairo 2002, presented to P. Heppard, D. Ebrom, M. Mueller, T.Harrold, and L. Thomsen

The Milton Dobrin Memorial Lecturer, U. Houston, March 2001.

Thomsen (1999) was selected by **GEOPHYSICS** as one of its best three papers for 1999.

Geophysical Society of Houston, **Honorary Member**, 1999.

European Association of Exploration Geoscientists, **Best Paper**, 1997 Annual Meeting.

Reginald Fessenden Award, SEG,1993.

Lynn and Thomsen (1990) was selected by **GEOPHYSICS** as one of its best eleven papers for 1990.

Thomsen (1988) was selected by **GEOPHYSICS** as one of its best eight papers for 1988.

Thomsen (1986a) was elected by **GEOPHYSICS** as one of its best eight papers for 1986. (This paper was identified in 2004 as the single most-cited manuscript in the history of **GEOPHYSICS**.)

GEOPHYSICS Golden Anniversary issue: Thomsen (1985) (the first of my work released for publication by Amoco).

SEG Foundation Scholarship (1960-64); partial tuition at Caltech.

Patents

Neese, J. W. and L. Thomsen, System and method for processing electromagnetic survey data, filed U.S. Pat. Off. October 2014, issued July 30 2019 (U.S. Patent 10,365,390 B2).

Thomsen, L. and R. Lin, System and method for estimating seismic anisotropy with high resolution, filed U.S. Pat. Off. September 2013, issued Sept. 2016 (U.S. Patent 9,488,744).

Martinez Y.; N. Allegar]; L. Thomsen; C. Stoyer, Method for Determining Electromagnetic Survey Sensor Orientation , filed February 2009, issued April 2010 (US 2010102820, WO 2010047885).

Thomsen, L. A., Allegar, N. C., Dellinger, J. A., Jilek, P., Johnson, D. T., Xia, G., System and Method for Using Time-Distance Characteristics in Acquisition, Processing, and Imaging of t-CSEM Data, issued February 18, 2009 (U.S. Patent 7,502,690, 7941273).

Smith, M. J., B. D. Ritchie, and L. Thomsen, System and Method for CSEM exploration in polar regions, filed July 2005, issued May 2008 (U.S. Patent 7,376,515).

Strack, Kurt M.; Reuter, H., and Thomsen, Leon A.; Integrated earth formation evaluation method using controlled source electromagnetic survey data and seismic data, filed 2006, issued February 5, 2008 (U.S. Patent 7328107).

Strack, Kurt M.; Thomsen, Leon A.; Reuter, H., Method for acquiring transient electro-magnetic survey data, filed 2005, issued April 10, 2007 (U.S. Patent 7203599)

Strack, Kurt M.; L. A. Thomsen, and C. H. Stoyer,, Method for identifying subsurface features from marine transient controlled source electromagnetic surveys, filed 2005, issued 2006 (U. S. Pat. 11,064,063).

Thomsen, L. and J. A. Delinger, High resolution determination of polar anisotropy, issued 2005 (U.S. Patent 6,944,094).

Thomsen, L., Vector Recomposition of Seismic 3D Converted-Wave Data, filed 1999, issued 2001 (U. S. Pat. 6,292,754) (Azeri Pat. i2003 0239).

Crider, R. and L. Thomsen, Selection of Seismic Modes through Amplitude Characteristics, filed 1999, issued 2001 (U. S. Pat. 6,263,284).

Thomsen, L. Converted-Wave Processing in Many-layered Anisotropic Media, filed 1998, issued 2000 (U. S. Pat. 6,128,580).

Mueller, M. C., L. A. Thomsen, and I. Tsvankin Reflected Shear Wave Seismic Processes, filed 1995, issued 1998 (U. S. Pat. 5,835,452).

Thomsen, L., K. E. Hanson, and M. V. Brumbaugh, Detecting and Resolving Azimuthal Anisotropy from Nonpolarized Sources (Method of Geophysical Exploration), issued 1992 (U.S. Pat. 5,136,554).

Scott, D. R. and L. Thomsen, Methods for Estimating Burial Conditions of Sedimentary Materials, filed 1988, issued 1992 (U. S. Pat. 5,081,612).

Thomsen, L., Detecting and Resolving Formation Anisotropy from Seismic Data, filed 1986, issued 1990 (U.S. Pats. 4,888,743, and 4,933,913).

Hanson, K., L. Thomsen, C. Sondergeld, and C. Rai, Means for Obtaining Shear-wave Velocities, filed 1986, issued 1988 (U.S. Pat. 4,754,439).

Hanson, K., and L. Thomsen, A Method of Seismic Exploration Including Processing and Displaying Shear Wave Seismic Data, issued 1988 (U.S. Pat. 4,755,972).

Hanson, K. E., T. J. Taylor, and L. Thomsen, Shear Wave Velocity Estimation, filed 1989, issued 1993 (U. S. Pat. 5,265,016).

Hanson, K., C. Crowe, A. Frisillo, C. Sondergeld, and L. Thomsen, A Method for Identifying and Separating the Effects of Elastic and Anelastic Formation Properties in Seismic Data, filed 1985, issued 1988 (U.S. Pat. 4,729,101).

Bodine, J. H., J. Bork, R. Alford, H. Wright, and L. Thomsen, A Method of Seismic Exploration including Processing and Displaying Seismic Data to Quantitatively Distinguish among Seismic Events, filed 1984, issued 1987 (U.S. Pat. 4,646,239).

Alford R., H. B. Lynn, and L. Thomsen, Seismic Surveying Technique for the Detection of Azimuthal Variations in the Earth's Subsurface, filed 1984, issued 1989 (U.S. Pat. 4,817,061).

Books

Thomsen, L., 2014. Seismic Anisotropy in Exploration and Exploitation, the SEG/EAGE Distinguished Instructor Short Course #5 Lecture Notes, 2nd Edition, Soc. Expl. Geoph., Tulsa.

Committee on Fracture Characterization and Fluid Flow, National Research Council, Rock Fractures and Fluid Flow: Contemporary Understanding and applications, Nat. Acad. Press, Washington, D. C., 1996.

Thomsen, L., On the Fourth-Order Anharmonic Equation of State of Solids, Ph.D. Thesis, Columbia University, 1969.

Refereed Publications (not including numerous Amoco/BP proprietary publications)

ORCID: 0000-0002-5093-0498 .

Thomsen, L., 2021a. The Logical Error in Gassmann Poroelasticity: Consistency with Effective Medium Theory, **Soc. Expl. Geoph. Expnd. Absts., 91,** 2303-2307.

Thomsen, L., 2021b. The Logical Error in Gassmann Poroelasticity: Derivations and Data, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 82**.

Thomsen, L., 2020a. A Logical Error in Gassmann Poroelasticity, **Soc. Expl. Geoph. Expnd. Absts., 90**, 2429-2933.

Thomsen, L., 2020b. A Logical Error in Gassmann Poroelasticity, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 81**. doi: https://doi.org/10.3997/2214-4609.202010055

Lin, R. and L. Thomsen, 2019. Validation of Digital Rock Physics Algorithms, **Minerals, 9**, 669; doi:10.3390/min9110669. https://www.mdpi.com/2075-163X/9/11/669.

Thomsen, L., 2019. Geophysics and the Shale Revolution: The anisotropy connection, **Geophys. Prosp., 67**, 2266–2268.

Neese, J. W., D. R. Jackson, Y. Zheng, and L. A. Thomsen, 2018. TE_z/TM_z scalar potentials due to an arbitrarily-oriented dipole in 3D space in the presence of an infinite dielectric cylinder, **Radio Science, 53(4),** pp. 509-524. https://doi.org/10.1002/2017RS006483 .

Thomsen, L., 2018. On the Fluid Dependence of Seismic Anisotropy: Beyond Biot-Gassmann, **J. Earth Sciences**, https://doi.org/10.1007/s12583-017-0806-9 .

Li, J., Y. Zheng, L. Thomsen, T. J. Lapen, and X. Fang, 2018. Deep earthquakes in subducting slabs hosted in highly anisotropic rock fabric, **Nature Geoscience 11,** 696–700. https://www.nature.com/articles/s41561-018-0188-3

Hu, B., L. Thomsen, and D. Reynolds, 2017. Statistical analysis of the parameterization in azimuthal anisotropic seismic processing, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts., 87,** 416-420. https://doi.org/10.1190/segam2017-17749210.1

Thomsen, L., 2017. On the Fluid Dependence of Rock Compressibility: Beyond Biot-Gassmann, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts., 87**, pp. 3690-3694.

Li, J., Y Zheng, and L Thomsen, 2017. In situ seismic anisotropy around deep earthquakes in Japan subduction slabs using Japan Meteorological Agency moment tensors, **Am. Geoph. Union Fall Meeting**, abstract #DI43B-0360.

Neese, J. W. and L. Thomsen, 2015. Robustness of the EM-Radon Transform, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 76,** Madrid.

Thomsen, L. and D. L. Anderson, 2015. Weak elastic anisotropy in global seismology, The Interdisciplinary Earth: A Volume in Honor of Don L. Anderson, Eds. G. R. Foulger, M. Lustrino, and S. King, Geol. Soc. Am. Spec. Paper 514 and Am. Geophys. Union Spec. Pub. 71, pp. 39-50.

Neese, J. W. and L. Thomsen, 2014. Seismic processing of numerical EM data, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts**., 84.

Thomsen, L., 2014. Electromagnetics and seismics: the deep connections, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts.**, 84.

Thomsen, L., and R. Lin, 2014. High-Resolution Anisotropy from AVO, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 75**, We102-15. Also presented at Stanford, TUDelft.

Lin, R. and L. Thomsen, 2013d. Extracting Polar Anisotropy Parameters From Seismic Data And Well Logs, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts., 83,** 310-314.

Thomsen L,, 2013b. Can we use Conventional Seismics in Unconventional Resource Plays?. **ASEG Extended Abstracts**,1–2, dx.doi.org/10.1071/ASEG2013ab363

Far, M. E., L. Thomsen, C. M. Sayers, 2013a. Seismic Characterization of Reservoirs with Asymmetric Fractures, **GEOPHYSICS**, **78**, N1–N10.

Far, M. E., L. Thomsen, and C. M. Sayers , 2012b. Inversion of asymmetric fracture parameters using synthetic AVOA data, **Soc. Expl. Geoph. Annl. Mtg. Expnd. Absts.**, **82,** 1-5.

Far, M. E., C. M. Sayers, L. Thomsen, D. Han, and J. P. Castagna, 2012a. Seismic Characterization of Naturally Fractured Reservoirs Using Amplitude Versus Offset and Azimuth Analysis**, Geop. Prospg., 61**(2), 427-447.

Thomsen, L., 2012b. On the use of isotropic parameters $\lambda, E, \nu,$ to understand anisotropic shale behavior, **Istanbul International Geophysical Conference and Oil & Gas Exhibition,** September**, Soc. Expl. Geoph. Conv. Expnd. Absts**.(2013), **83,** 320-324.

Thomsen, L., 2012a. On the Fluid Dependence of the Parameters of Anisotropy**, Soc. Expl. Geoph. Conv. Expnd. Absts., 82**. Also in **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 74,** and **Proc. 15 Intl. Wkshp. Seis. Anisotropy, Bahrain,** April.

Strack, K.M., Hanstein, T., Stoyer, C.H., and Thomsen, L., 2011, Time Domain Controlled Source Electromagnetics for Hydrocarbon Applications, in The Earth's Magnetic Interior, IAGA Special Sopron book series, Petrovský, E., Herrero-Bervera, E.; Harinarayana, T. and Ivers, D. (Eds.), 101- 115

Thomsen, L. 2010d. Anisotropy in the 21st Century: Resolution and Symmetry". **Soc. Expl. Geoph. Conv. Expnd. Absts., 80**.

Thomsen, L. 2010c. On the Fluid Dependence of Rock Compressibility: Biot-Gassmann Refined. **Soc. Expl. Geoph. Conv. Expnd. Absts., 80**, 2447-2451.

Tsvankin, I., J. Gaiser, V. Grechka, M. van der Baan, and L. Thomsen, 2010. Anisotropy, Ch. 2 in **Geophysics Today**, pp. 15-31. Soc. Expl. Geoph, Tulsa.

Tsvankin, I., J. Gaiser, V. Grechka, M. van der Baan, and L. Thomsen, 2010b. Seismic

anisotropy in exploration and reservoir characterization: An overview, **GEOPHYSICS**, **75**(5), 75A15-75A29.

Thomsen, L., 2010a. Weakly Anisotropic Elastic Compliance, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 72**. Also in Proc. 14 Intl. Wkshp. Seis. Anisotropy, Perth, April 2010.

Dellinger, J., F. Muir, B. J. VerWest, I. Tsvankin, L. Thomsen, T. Alkhalifah, K. Larner, C. M. Sayers, G. Ball, P. R. Williamson, P. A. Sexton, S. Xu, R. W. Vestrum, D. C. Lawton, R. Schmid, K. Hawkins, R. Leggott, G. Williams, H. Kat, I. F. Jones, M. L. Bridson, and N. Bernitsas, 2008., Incorporating Anisotropy, Ch. 8 in Prestack Depth Migration and Velocity Model Building, Soc. Expl. Geoph., Tulsa, 689-836.

Xia, G., L. Thomsen, and O. Barkved, 2007. Fracture Detection from Seismic P-wave azimuthal AVO analysis – application to Valhall LoFS data, **Proc. Intl. Symp. In-situ Rock Stress, Intl. Soc. Rock Mech.,** Trondheim, 2006. Also: 12IWSA Proceedings, **J. Seis. Expl.**

Helbig, K., and L. Thomsen, 2005. 75-plus years of anisotropy in exploration and reservoir seismics: A historical review of concepts and methods, **GEOPHYSICS**, **70**(6), pp. 9ND-23ND.

Bouska, J., T. Lyon, R. Johnston, D. Buddery, D. Howe, M. Mueller, L. Thomsen, D. Ebrom, 2005. Acquisition Design of the First 4 Component 3D Ocean Bottom Seismic in the Caspian, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 67**, B003.

Ebrom, D., P. Heppard, M. Albertin, S. Viceer, P. Garossino, L. Thomsen, 2005. Vp/Vs from Two Different Mode Converted Arrivals**, EAGE/SEG Research Workshop - Multicomponent Seismic - Past, Present and Future**, A33.

Barkved, O.I., J.H. Kommedal, and L. Thomsen, 2004.The role of multi-component seismic data in developing the Valhall Field, Norway, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 66**.

Lyon, T., J. Bouska, R. Johnston, M. Mueller, L. Thomsen, 2004. Reducing structural uncertainty on the Azeri Field using Ocean Bottom Seismic: Offshore Azerbaijan, **Soc. Expl. Geoph. Expdd Absts 23**, 468-471.

Johnston, R., J. Bouska, T. Lyon, A. Ashby, R. Walters, P. Whitfield, R. Crompton, D. Ebrom, M. Mueller, L.Thomsen, 2004. Azeri 4C: Processing the first 3D OBS survey in the Caspian Sea, **SEG Expdd. Absts. 23**, 845-848.

Bouska, J., T. Lyon, R. Johnston, D. Howe, M.C. Mueller, L. Thomsen, and D. Ebrom, 2004. Acquisition Design of the First Four-Component 3D Ocean Bottom Seismic in the Caspian, **Soc. Expl. Geoph. Conv. Expnd. Absts., 74**.

Ebrom, D., P. Heppard, L. Thomsen, M. Mueller, T. Harrold, L. Phillip, and P. Watson, 2004. Effective stress and minimum velocity trends, **Soc. Expl. Geoph. Conv. Expnd. Absts., 74**, 1815-1618.

Ebrom, D., P. D. Heppard, M. Tompkins, and L. Thomsen, 2004. Compaction, Stresses, and Velocity in High Overpressure. **AAPG Annual Meeting**.

Johnston, R., J. Bouska, T. Lyon, A. Ashby, R. Walters, P. Whitfield, R. Crompton, D. Ebrom, M. Mueller, and L. Thomsen, 2004. Azeri 4C: Processing the first 3D OBS Survey in the Caspian Sea, **Soc. Expl. Geoph. Conv. Expnd. Absts., 74**.

Ebrom, D., P. Heppard, M. Mueller, and L. Thomsen, 2003. Pore pressure prediction from S-

wave, C-wave, and P-wave velocities, **Soc. Expl. Geoph. Conv. Expnd. Absts., 73**.

Gretener, P. and L. Thomsen, AVO and Poisson's Ratio, 2003. **The Leading Edge**, **22**(1), 70-72.

Thomsen, L, and J. Dellinger, 2003. On shear-wave triplication in polar-anisotropic media, **J. appl. Geoph., 54,** 289-296.

Holmes, G. M., and L. Thomsen, 2002. Seismic fracture detection at a Middle East offshore carbonate field, **Abu Dhabi International Petroleum Exhibition and Conference**, SPE-78507.

Heppard, P. D., D. Ebrom, M. Mueller, L. Thomsen, and T. Harrold, 2002. Using Shear and Vp/Vs to Predict Overpressure in Petroleum Basins, **AAPG Datapages: Search and Discovery.**

Sava, P., J. Etgen, and L. Thomsen, 2002. "Wave-equation MVA applied to 4-D seismic monitoring, **Stanford Exploration Project**, **112**, 15–21.

Dellinger, J., R. Clarke, and L. Thomsen, 2002: Alford rotation after tensor migration**, Soc. Expl. Geoph. Conv. Expnd. Absts., 72**, 982-985, https://doi.org/10.1190/1.1817432

Ebrom, D., Heppard, P., and Thomsen, L., 2002. Numerical modeling of PS moveout as a function of pore pressure, **Soc. Expl. Geoph. Conv. Expnd. Absts., 72**,1634-1637.

Ebrom, D. A., M.C. Mueller, P.D. Heppard, H.M. Shah, L.A. Thomsen, 2002. VSP-Derived Vp/Vs Ratios for Pressure Prediction ahead of the Bit**, Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts.**, **64,** F-21.

Thomsen, L., 2001. Seismic Anisotropy, **Geophysics**, **66**(1), 40-41.

Arnaud, J., J. Dellinger, L. Ikelle, H. Lynn, C. MacBeth, L. Thomsen, and I. Tsvankin, 2001. SPECIAL SECTION: The Ninth International Workshop on Seismic Anisotropy (91WSA), **GEOPHYSICS, 66**, 1294-1312.

Thomsen, L., O. I., Barkved and B. O. Rosland, 1999. The 3D/4C OBS Survey at Valhall. Offshore Technology Conference. doi:10.4043/10937-MS.

Arnaud, J., K. Helbig, P. Rasolofosaon, and L. Thomsen, 1999. The Eighth International Workshop on Seismic Anisotropy (81WSA), **GEOPHYSICS,** 64(6),1949.

Jack, I. and L. Thomsen, 1999. Recent advances show the road ahead for the electric oilfield very clearly, **Soc. Expl. Geoph. Conv. Expnd. Absts., 69**, 1982-1983.

Dellinger, J, R. Clarke, S. Brandsberg-Dahl, and L. Thomsen, 1999. Alford rotation after *Tensor* Migration, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 61**, 6-43. Also: **Soc. Expl. Geoph. Conv. Expnd. Absts., 72**, 982-985, 2002.

Wilson, D. C., L. Thomsen, 1999. C-Wave Moveout - Using Isotropic Homogeneous Algorithms for Anisotropic Inhomogeneous Data**, Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 61**, 1-46.

Mueller, M. C., O.I. Barkved, L. Thomsen, 1999. A Strategy for Vector Interpretation of Multicomponent Ocean Bottom Seismic Data**, Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 61**, P-067.

Barkved, O. I., M.C. Mueller, L. Thomsen, 1999. Vector Interpretation of the Valhall 3D/4C OBS Dataset**, Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 61**, 6-42.

Thomsen, L., 1999. Converted-Wave Reflection Seismology over inhomogeneous, anisotropic media, **GEOPHYSICS**, **64**(3), 678-690.

Thomsen, L, I. Tsvankin, and M. Mueller, 1999. Coarse-Layer Stripping of Azimuthal Anisotropy from Reflection Shear-wave data, **Geophysics**, **64**(4), 1126-1138.

Brzostowski, M., X. Zhu, S. Altan, L.Thomsen, O. Barkved, and B. Rosland, 1999. 3D converted-wave processing over the Valhall field, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 61**, 6-43, 1999a. Also: **Soc. Expl. Geoph. Conv. Expnd. Absts., 69**, 695-698.

Thomsen, L., 1998. Converted-Wave Reflection Seismology over inhomogeneous, anisotropic media, **Soc. Expl. Geoph. Conv. Expnd. Absts., 68**, 2048-2051.

Thomsen, L., 1998. Optimizing 3D Seismic Surveys: Off-the-Shelf? Or Out-of-the-Box?, **Offshore Technology Conference**, OTC 8720.

Thomsen, L., 1998. Optimizing 3D Seismic Surveys, **Sea Technology**, 39(8), 98-101.

Kommedal, J., O. Barkved, and L. Thomsen, 1997. Acquisition of 4-component OBS data - a case study from the Valhall Field, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 59**, B047.

Thomsen, L., O. Barkved, W. Haggard, J. Kommedal, B. Rosland, 1997. Converted Wave Imaging of Valhall Reservoir, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts.**, **59**, B048.

Thomsen, L., Barkved, O., Haggard, B., Kommedal, J., and Rosland, B., 1997b. A study of the dependence of OBS data-quality on seafloor equipment: Dragged versus cable data: Presented at 67th Ann. Internat. Mtg., Soc. Expl. Geophys., Research Workshop on 4C Applied Technology.

Mueller, M., O. Barkved, and L. Thomsen, 1997. Dipole Sonic Results (Valhall area): Implications for AVO and OBS interpretation, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 59,** E050.

Mueller, M., L. Thomsen, and W. Chmela, 1997. Dual Dipole Arrivals in Neogene Pay Zones, Nile Delta, Egypt, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 59,** P015,

Beaudoin, G., T. Chaimov, W. Haggard, M. Mueller, and L. Thomsen, 1997. The Use of Multicomponent Seismology in CBM Exploration – a Case Study, **Europ. Assoc. Geosci. Engrs. Conv. Expnd. Absts., 59**, B009.

Thomsen, L., 1996. Poisson was not a *Rock* Physicist, Either!, **The Leading Edge**, **15**(7), 852-855.

Thomsen, L. and Committee on Fracture Characterization, 1996. Ch. 4: Fracture Detection Methods, National Research Council, National Academies Press.

Thomsen, L, I. Tsvankin, and M. Mueller, 1995. Layer-Stripping of Azimuthal Anisotropy from Reflection Shear-wave data, **Soc. Expl. Geoph. Conv. Expnd. Absts.,, 65**, 289-292.

Thomsen, L, I. Tsvankin, and M. Mueller, 1995. Adaptation of Split Shear-wave Techniques to Coalbed Methane Exploration, **Soc. Expl. Geoph. Conv. Expnd. Absts., 65**, 301-304.

Chaimov, T., G. Beaudoin, W. Haggard, M. Mueller, and L. Thomsen, 1995. Shear-Wave Anisotropy and Coalbed Methane Productivity, **Soc. Expl. Geoph. Conv. Expnd. Absts., 65**, 305-307.

Tsvankin, I., and L. Thomsen, 1995b. Inversion of Reflection Traveltimes for Transverse Isotropy, **GEOPHYSICS, 60**(4), 1095-1107.

Thomsen, L., 1995a. Anisotropy due to Aligned Cracks in Porous Rock, **Geoph. Prospg.,43**, 805-829.

Vassiliou, A. A., L.A. Thomsen, S. Treitel, J.H. Queen, W.S. Harlan. 1994. Crosswell tomography in anisotropic media - Case studies, **Europ. Assoc. Expl. Geoph. Expnd. Absts.**, **56**, G038.

Thomsen, L., 1993. The current, direct value of internal research, **The Leading Edge**, **12**(9), 918-921.

Tsvankin, I., and L. Thomsen, 1993f. Joint Inversion of Reflection Traveltimes for Transverse Isotropy, **Europ. Assoc. Expl. Geoph. Expnd. Absts., 55**, C026.

Scott, D., and L. Thomsen, 1993e. A Global Algorithm for Pore Pressure Prediction, SPE25674, **Proc. SPE Middle East Oil Technical Conference** (Bahrain), pp. 645-654.

Tsvankin, I., and L. Thomsen, 1993d. Nonhyperbolic Reflection Moveout, **GEOPHYSICS**, **59**(8), 1290-1304.

Tsvankin, I., and L. Thomsen, 1993c. Joint Inversion of Reflection Traveltimes for Transverse Isotropy, **Europ. Assoc. Expl. Geoph. Expnd. Absts.**, **55**.

Scott, D., and L. Thomsen, 1993b. A Global Algorithm for Pore Pressure Prediction, **Europ. Assoc. Expl. Geoph. Expnd. Absts., 55**, D005.

Thomsen, L. Weak Anisotropic Reflections, 1993a. in Offset-Dependent Reflectivity-Theory and Practice of AVO Analysis, ed. J. P. Castagna, and M. M. Backus, pp. 103-111. Soc. Expl. Geoph.

Castagna, J. P., R. S. Spratt, N. R. Goins, T. J. Fitch, S. K. Dey-Sarkar, S. V. Svatek, H. W. Swan, T. K. Kan, C. Y. Young, and L. Thomsen. Principles, 1993. Ch. 1 in Offset-Dependent Reflectivity-Theory and Practice of AVO Analysis, ed. J. P. Castagna, and M. M. Backus, pp. 1-111. Soc. Expl. Geoph.

Tsvankin, I. and L. Thomsen, 1992b. Nonhyperbolic Moveout in Transversely Isotropic Media, **Soc. Expl. Geoph. Conv. Expnd. Absts., 62**.

Tsvankin, I. and L. Thomsen, 1992a. Inversion of Reflection Traveltime for Transverse Isotropy, **Soc. Expl. Geoph. Conv. Expnd. Absts.**, **62**.

Frisillo, A. L. and L. Thomsen, 1991b. Effect of Fluid Micro-Distribution on Velocity and Attenuation in Porous Rock, **Europ. Assoc. Expl. Geoph. Conv. Expnd. Absts.**, **53**, 246-247.

Sriram, R., J. Disiena, H. Mack, R. Tatham, W. Wiggins, P. Shah, L. Thomsen, and D. Winterstein, 1991a. Recording and Processing Vector Wave Field Data: Review of the 1989 SEG Summer Research Workshop, **The Leading Edge**, **10**.

Thomsen, L., Poisson was NOT a Geophysicist, 1990b. **The Leading Edge, 9(**12**)**, 27-29 (with discussion **10**(4), 44, 1991).

Lynn, H. B. and L. Thomsen, 1990a. Reflection Shear-Wave Data Collected near the Principal Axes of Azimuthal Anisotropy, **Geophysics, 55**(2), 147.

Thomsen, L., 1988. Reply to Discussion by F. K. Levin of "Weak Elastic Anisotropy", **GEOPHYSICS, 53**(4), 558-560.

Thomsen, L., 1988. Reflection Seismology in Azimuthally Anisotropic Media, **GEOPHYSICS, 53**(3), 304-313.

Thomsen, L., Elastic Anisotropy due to Aligned Cracks, 1987. **Soc. Expl. Geoph. Conv. Expnd. Absts., 57**.

Lynn, H. B. and L. Thomsen, 1986d. Reflection Shear-Wave Data Collected near the Principal Axes of Azimuthal Anisotropy, **Soc. Expl. Geoph. Conv. Expnd. Absts., 56**, 468-470.

Thomsen, L., 1986c. Elastic Anisotropy due to Aligned Cracks: Theoretical Models, **EOS, Trans. Am. Geoph. Union, 67**(44), 1207

Thomsen, L., 1986b. Reflection Seismology in Azimuthally Anisotropic Media, **Soc. Expl. Geoph. Conv. Expnd. Absts., 56**, 468-470.

Thomsen, L., 1986a. Weak Elastic Anisotropy, **Geophysics, 51**(10), 1954-1966.

Thomsen, L., 1985b. Biot-Consistent Elastic Moduli of Porous Rocks: Low Frequency Limit, **Geophysics, 50**(12), 2797-2807.

Thomsen, L., and M. Joggerst, 1985a. Oil and Gas in Offshore Tracts: Bias in Estimates of Reserves, **Mathematical Geology**, **17**(4), 353-365.

Thomsen, L., and R. Tatham, 1983. The change in reflection coefficient with angle of incidence, **Soc. Expl. Geoph. Conv. Expnd. Absts., 53**, 636,

Thomsen, L, 1980. ^{129}Xe on the Outgassing of the Atmosphere, **J. Geoph. Res., 85**(B8), 4374-4378.

Thomsen, L., 1977. Theoretical Foundations of Equations of State for the Terrestrial Planets, in **Annual Reviews of Earth and Planetary Sciences, 5**, 491-513.

Thomsen, L., 1976. Electronic Band Structures of (Mg,Fe)O and (Mg,Fe)2SiO4, **EOS, Trans. Am. Geoph. Union, 57**(12), 1005.

Thomsen, L., 1975. Towards an equation of state for lower mantle, **Trans. Am. Geoph. Union, 56**(12), 1063-1063.

Thomsen, L., 1975b. The Lower Petrologic Geotherm: A Transitory State, **Science, 188**(4193), 1130.

Wu, F. T. and L. Thomsen, 1975a. Microfracturing of Westerly Granite under Creep Conditions, **Intl. J. Rock Mech. Min. Sci., 12**(5-6), 167.

Thomsen, L., 1973. Structure et constitution du manteaux et du noyau, dans Traite de Geophysique Interne, Tome 1: Sismologie et pesanteur, eds. J. Coulomb et G. Jobert, Edns. Masson, Paris.

Lu, C.P., H. Spetzler, and L. Thomsen, 1973. Holographic determination of thermal and elastic-moduli of rocks and crystals. **Trans. Am. Geophys. Union, 54**(4), 474.

Thomsen, L., and H. Spetzler. 1973. Hot creep observed by holographic interferometry, **Trans. Am. Geophys. Union, 54**(4), 452.

Ahrens, T. J., and L. Thomsen, 1972. Application of the fourth-order anharmonic theory to the prediction of equations of state at high compressions and temperatures." **Phys. Earth Planet Ints, 5**, 282-294.

Thomsen, L., 1972d. On the Implications of Lunar Aseismicity, **Nature, 240**(5376), 94.

Thomsen, L., 1972c. Elasticity of Polycrystals and Rocks, **J. Geoph. Res., 77**(2), 315-327.

Thomsen, L., 1972b. On the Effects of Pressure upon Rock Elasticity, **Phys. Earth Planet. Interiors, 5**,325.

Thomsen, L., 1972a. The Fourth-Order Anharmonic Theory: Elasticity and Stability, **J. Phys. Chem. Solids, 33**, 363,

Duvall, G. E., D J. Pastine, G. R. Barsch, W.A. Bassett, D.L. Decker, D. McWhan, W.J. Carter, C. Beckett, R.H. Wentorf, K, Vedam, M. van Thiel, R. Grover, M. Swerdlow, J.S. Weaver, L Thomsen, S.E. Bahr, E.M. Compy, P.J. Freud, P.L.M. Heydemann, M Klein, D.H.K. Mao, 1971g. Equation-of-State Standards, **Bur. Standards Spec. Publn., 326**, 315.

Caltech GPS, 1971f. Preliminary seismological and geological studies of the San Fernando, California, earthquake of February 9 1971, **Bull. Seismological Soc. Am., 61** (2), 491-495.

Thomsen, L., 1971e. Perfectly disordered polycrystals and rocks, **Trans. Am. Geophys. Union**, **52**, (6), 483.

Thomsen, L., and T. J. Ahrens, 1971d. New Hugoniot calculations and measurements, **Trans. Am. Geophys. Union, 52**,(4), 358.

Thomsen, L., 1971c. Equations of State and the Interior of the Earth, **Proc. Intl. School of Phys. E. Fermi, Corso L**, J. Coulomb and M. Caputo, eds., Academic Press, New York.

Thomsen, L., and O. L. Anderson, 1971b. Consistency in the High-Temperature Equation of State of Solids, **Proc. Symp. Accurate Characterization of the High Pressure Environment, Natl. Bureau Stds. Spec. Publ. 326**, 209.

Thomsen, L., 1971a. Elastic Shear Moduli and Crystal Stability at High P and T, **J. Geoph. Res., 76**(5), 1342.

Thomsen, L., 1970b. On the Fourth-Order Anharmonic Equation of State of Solids, **J. Phys. Chem. Solids, 31**(9), 2003.

Thomsen, L., 1970a. A New Development in the Theory of Equations of State for Solids, **Geoph. J., 21**(4), 409.

Thomsen, L., and O. L. Anderson, 1969. On the High-Temperature Equation of State of Solids, **J. Geoph. Res., 74(**4), 981-991.

Thomsen, L., 1967. On the Distributions of density and temperature in the low-velocity zone, **J. Geoph. Res., 72(**22), 5649-5663.

Unrefereed Publications

Thomsen, L., The Next Great Adventure, **Hart's E&P Supplement**, September 2008.

Thomsen, L. and B. Bouma, A report on SEG's first General Assembly, **The Leading Edge**, **27**(4), 492-492, 2008.

Thomsen, L., Annual Report of the President, **SEG Yearbook,** 2007.

Thomsen, L., The state of the Society of Exploration Geophysicists, **The Leading Edge**, **26**(9), 1088-1090, 2007.

Thomsen, L., A year of rapid changes, **The Leading Edge**, **26**(5), 552, 2007.

Thomsen, L., and F. Aminzadeh, User Needs Drive Advances in Geophysical Technology, **The American Oil and Gas Reporter, 50**(1), 91-97, 2007.

Thomsen, L., Executive Committee responsibilities, The President's Page, **The Leading Edge**, **25**(11), 2006.

Thomsen, L, SEG: The worldwide society of applied geophysics, The President's Page, **The Leading Edge**, 25(1), 2006.

Thomsen, L, On continuously learning geophysics, The President's Page, **The Leading Edge**, **23**(1), 10, 2004.

Barkved, O. I., T. Jackson, I. Jack, L. Thomsen, and T. Wood, Life-of-field seismic monitoring arrives, **Hart's E&P, 76**(9), 45-48, 2003.

Thomsen, L, DISC 2002: The Diary, **The Leading Edge**, **22**(5), 434-439, 2003.

Lynn, H., R. R. Stewart, R. Garotta, and L. Thomsen, 2001, 4C-ing the future – a word from the "gurus", **The Leading Edge**, **20**(9), 978--982, 2001.

Thomsen, L, The current, direct value of internal research, **The Leading Edge, 12**(9), 918-921. https://doi.org/10.1190/1.1436978

Interviews:

International Association of Rock Physicists. October 2015:

http://www.rockphysicists.org/rock-physics-influencer-profiles/october-november-2015-leon-thomsen

Dr. Anisotropy, by Rhonda Duey, **Hart's E&P**, April 2015 (http://www.epmag.com/dr-anisotropy-788891)

GSH-SEG 2015 Spring Symposium honors Leon Thomsen, by Isaac Farley, **The Leading Edge**, **34** (4), 438, 2015

The Computer Tutor: An Interview with Leon Thomsen, **The Leading Edge**, **33** (7), 798-800, 2014.

A Conversation with Leon Thomsen, Geophysical Society of Houston Journal, pp. 31-39, 2011.

Skilled labour supply key to hitting Mideast oil and gas production targets, says BP**: Al Bayan**, 11/29/07, **Al Khaleej** 12/1/07, **Al Itihad** 12/2/07, (cf

http://www.ameinfo.com/140094.html , http://www.infopig.com/keywords/Killed.html ,

http://www.ameinfo.com/cgi-bin/arabic/search.cgi?query=bp&sb=Add_Time&so=DESC , http://www.godubai.com/citylife/press_release_page.asp?id=12971&search , http://www.zawya.com/Story.cfm/sidZAWYA20071128082113/SecIndustries/pagMan

ufacturing/chnMiddle%20East%20Manufacturing%20News/obj4469E093-15C5-E7B8-FF9C1010F3AAA468/ ,
http://www.bi-me.com/main.php?id=15372&t=1&c=6&cg=4 ,
http://www.topix.com/com/bp/2007/11/skilled-labour-supply-key-to-hitting-mideast-oil-and-gas-production-targets-says-bp .
http://www.menafn.com/qn_news_story_s.asp?storyid=1093175818)

SEG career enhancement emphasis on education, global outreach, **Oil and Gas Journal**, 2007.

POINT OF VIEW: New SEG chief helped bring vector seismics into practice, **Oil and Gas Journal**, **104**(37), 2006.

Thomsen to Lead Ever More Global Society, E&P Daily News, Oct. 2, 2006.

An interview with Leon Thomsen, **Canadian SEG Recorder**, pp. 26-33, June 2002.

Student Theses Advised, University of Houston:

2015 John W. Neese M.S. Thesis: Seismic-Style Processing of Numerical EM Data (U.S. Patent 10,365,390 B2).
2013 Rongrong Lin M.S. Thesis: Extracting polar anisotropy parameters from seismic data and well logs (U.S. Patent 9,488,744). 2012
Mehdi Eftekhari Far Ph.D. Thesis: Seismic Characterization of Naturally Fractured Reservoirs

Courses Taught:

Seismic Waves and Rays in Hydrocarbon Exploration (UH)
Seismic Waves in Hydrocarbon Exploration (SEG-online course)
Understanding Seismic Anisotropy in Exploration and Exploitation: *Hands On* (AAPG, BGP, BHPB, CGG, CNOOC, CSEG, EAGE, GSH, Noble, NTNU, SEG, Shell, SPG India, TGS, UH)
Electromagnetic methods for Exploration & Production (w/ K. Strack, KMST) (UH, Saudi Aramco)
Modern Seismic Reservoir Characterization (KAUST, GSH)

Professional Society Affiliations:

American Geophysical Union (Lifetime Member)
American Physical Society (Lifetime Member)
European Association of Geoscientists and Engineers (Honorary Member)
Geophysical Society of Houston (Honorary Member)
Sigma Xi
Society of Exploration Geophysicists (Lifetime Member)

Professional Service (partial listing):

2015-18 Board of Directors, SEAM Inc. (Chair, 2017-2018)
2008-10 Advisory Board to Dean of Natural Sciences and Mathematics, UH
2008-10 Board of Directors, SEG Global, Inc. (Treasurer, 2010-11)
2006-07 SEG President
2005-06 SEG President-Elect
2004-08 Advisory Board to Director, Lamont-Doherty Earth Observatory
2004- SEG Foundation Trustee Associate

2003-04 SEG Vice President
2002-05 American Geophysical Union Development Committee
2002 SEG/EAGE Distinguished Instructor
2001-04 National Science Foundation Geosciences Advisory Board
1998- SEG Research Committee. (Chair, 1998-2000)
1997 SEG Distinguished Lecturer
1991- Editorial Board, **Journal of Seismic Exploration**.
1991-96 National Academy of Sciences Committee on Fracture Characterization and Fracture Flow.
1986-88 External Evaluation Committee (Chair, '87), Division of Earth Science, Lawrence Berkeley National Laboratory