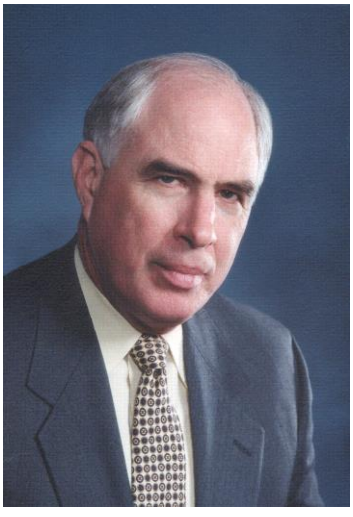
Leon Thomsen



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B. S. Geophysics, 1964, California Institute of Technology

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Research Interests

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

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 (1986), 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.

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. 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.

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 early 2004, 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 survey in late 2006. 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. I retired from BP in 2008, and joined the **University of Houston** as Research Professor. I also founded **Delta Geophysics**, a consultancy helping clients worldwide to create and apply advanced geophysics (*c.f.* http://www.deltageophysics.net/). In these roles, I have continued to challenge conventional thinking:

Seismic Fluid Substitution. Since 1951, exploration geophysicists have understood the effects of variable fluid content on seismic velocities through the work of Biot and Gassmann. 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) shows that the theory is not quite correct either, even within its own assumptions. As a result, every fluid-substitution calculation done in the last 60 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 (1992) 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, we (Lin and Thomsen, 2013) demostrated such a method, implying that every AVO analysis done in the last 30 years should be re-thought.

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, Neese and Thomsen (2014) showed how to use seismic-style processing to directly estimate resistivity in the subsurface, without inversion of the data. This work will disrupt the billion-dollar EM exploration industry.

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 served (2001-04) on the Advisory Board to the Associate Director for Geosciences, National Science Foundation.

Experience

University of Houston
(2008-) Research Professor of Geophysics

Delta Geophysics:
(2008-) Chief Scientist

Lawrence Berkley National Laboratory
(2008-) Visiting Scientist

KMS Technologies:
(2008-2010) Executive Advisor

Amoco → BP
(1980-2008) Senior Research Scientist → Principal Geophysicst

State University of New York, Binghamton
(1977-1980) Associate Professor of Geophysics (with academic tenure)
(1972-1977) Assistant Professor of Geophysics

NASA Goddard Space Flight Center
(1979) Visiting Research Fellow (sabbatical leave from SUNY)

Australian National University
(1978) Visiting Research Fellow (sabbatical leave from SUNY)

International Business Machines
(1970-71) Consultant

California Institute of Technology
(1970-71) Research Fellow

Centre Nationale de la Recherche Scientifique
(1969-1970) Chargé de Recherche

Selected Publications

Thomsen, L. and D. L. Anderson, 2015. Weak elastic anisotropy in global seismology, accepted for publication in The Don L. Anderson Tribute Volume, Eds. Foulger, Lustrino, and King, American Geophysical Union and Geologic Society of America.

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

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More at: Google Scholar ; ResearchGate .