

# Milo M. Backus

## Professional Summary

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### Academic Background

B.S. Geology and Geophysics, Massachusetts Institute of Technology, 1952  
Ph.D. Geophysics, Massachusetts Institute of Technology, 1956

### Areas of Expertise

A. Quantitative interpretation of geophysical data applied to petroleum exploration.

### Professional Work Experience

A. Present Position: Senior Research Geophysicist, Bureau of Economic Geology, The University of Texas at Austin (1998 - Present).

B. Present Position: Shell Oil Companies Foundation Distinguished Chair in Geophysics Emeritus, The University of Texas at Austin (1998 - Present).

C. Shell Oil Companies Foundation Distinguished Chair in Geophysics, The University of Texas at Austin (1991 - 1998).

D. Dave P. Carlton Centennial Professor in Geophysics, The University of Texas at Austin (1982 - 1991).

E. Wallace E. Pratt Professor of Geophysics, The University of Texas at Austin, Department of Geological Sciences (1975 - 1982).

F. Independent geophysical consultant, self-employed (1974 - 1975).

G. Vice-President, Geophysical Service Inc., Dallas, TX (1965).

H. Director of Research, Geophysical Service Inc., Dallas, TX (1962).

I. Research Geophysicist, Geophysical Service Inc., Dallas, TX (1955 - 1974).

## Professional Societies

Society of Economic Geologists

## Awards and Honorary Societies

Best Paper in The Leading Edge, High-Resolution Multicomponent Seismic Imaging of Deepwater Gas-Hydrate Systems, 2007

Hollis Hedberg Award, Institute for Study of Earth and Man, SMU, 2000

Society of Exploration Geophysicists, Special Commendation Award with RJ Graebner and ME Trostle: 3D Seismic, 1998

Offshore Energy Center, Offshore Pioneer - Technology Hall of Fame (1998): Marine Exploration, 1998

Midland Reporter-Telegram, 1996 Energy Award with RJ Graebner, ME Trostle: 3D seismic, 1996

Offshore Technology Conference, Individual Achievement Award: Digital and 3-D Seismic, 1992

Society of Exploration Geophysicists, Maurice Ewing Gold Medal: Digital and 3-D Seismic, 1990

Society of Exploration Geophysicists, Honorary Member, 1988

Society of Exploration Geophysicists, Distinguished Lecturer: The fourth dimension—offset-dependent reflectivity, 1985

Society of Exploration Geophysicists, President, 1979 - 1980

European Association of Exploration Geophysicists, Conrad Schlumberger Award: Flat spot exploration, 1975

Society of Exploration Geophysicists, Best Paper Award: Water reverberations, 1959

## Publications

### Articles

#### Peer Reviewed

Zeng, Hongliu, and Backus, M. M., 2005, Interpretive advantages of 90°-phase wavelets: Part 1—modeling: *Geophysics*, v. 70, no. 3, p. C7–C15.

Zeng, Hongliu, and Backus, M. M., 2005, Interpretive advantages of 90°-phase wavelets: Part 2—seismic applications: *Geophysics*, v. 70, no. 3, p. C17–C24.

Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1998, Stratal slicing, part I: realistic 3-D seismic model: *Geophysics*, v. 63, no. 2, p. 502–513.

Simmons, J. L., Jr., and Backus, M. M., 1996, A matched-filter approach to impedance estimation: *Geophysics*, v. 61, no. 2, p. 484–495.

- Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1996, Facies mapping from three-dimensional seismic data: potential and guidelines from a Tertiary sandstone-shale sequence model, Powderhorn field, Calhoun County, Texas: AAPG Bulletin, v. 80, no. 1, p. 16–46.
- Simmons, J. L., Jr., and Backus, M. M., 1994, AVO modeling and the locally converted shear wave: Geophysics, v. 49, no. 8, p. 1237–1248.
- Simmons, J. L., Jr., and Backus, M. M., 1992, Linearized tomographic inversion of first-arrival times: Geophysics, v. 57, p. 1482–1492.
- Dobbs, S. L., Wilson, J. L., and Backus, M. M., 1990, Accounting for limited spatial aperture in the waveform inversion of p-tau seismogram: Geophysics, v. 55, p. 452–457.
- Coltrin, George, Backus, M. M., Cloos, Mark, and Shipley, T. H., 1989, Seismic reflection imaging problems resulting from a rough surface at the top of the accretionary prism at convergent margins: Journal of Geophysical Research, v. 94, no. B12, p. 17485–17496.
- Backus, M. M., and Huston, Dan, 1989, Offset dependent mis-tie analysis at seismic line intersections: Geophysics, v. 54, no. 8, p. 962–972.
- Backus, M. M., and Nepomoceno, F., 1982, The reflection seismogram in a solid, layered earth: Geophysical Prospecting, v. 5, p. 406–410.
- Backus, M. M., 1981, The continuing challenge and opportunity for exploration geophysics: Geophysics, v. 46, no. 3, p. 343–346.
- Backus, M. M., 1980, Geophysical exploration is just beginning: AAPG Bulletin, v. 64, no. 5, p. 673.
- Backus, M. M., 1980, President's page—Exploration cost effectiveness: Geophysics, v. 45, no. 12, p. 1739–1740.
- Backus, M. M., 1980, President's page—Education in exploration geophysics: Geophysics, v. 45, no. 9, p. 1349–1350.
- Backus, M. M., 1980, President's page—Case histories: Geophysics, v. 45, no. 7, p. 1129–1130.
- Backus, M. M., 1980, President's page—Mandatory standard format reprints: Geophysics, v. 45, no. 6, p. 1015–1016.
- Backus, M. M., 1980, President's page—Quality control: Geophysics, v. 45, no. 2, p. 195–196.
- Backus, M. M., 1980, President's page—Fifty years: Geophysics, v. 45, no. 1, p. 1–2.
- Backus, M. M., and Chen, L., 1975, Flat-spot exploration: Geophysical Prospecting, v. 23, no. 3, p. 533–577.
- Schneider, R. L., and Backus, M. M., 1968, Dynamic correlation analysis: Geophysics, v. 33, no. 1, 105–126.
- Laster, S. J., Backus, M. M., and Schell, R., 1967, Analog model studies of the simple refraction problem, *in* Musgrave, A. W., ed., Seismic refraction prospecting: Society of Exploration Geophysicists, p. 15–66.
- Backus, M. M., 1965, Seismological signal processing: AAPG Bulletin, v. 49, no. 7, p. 1079.
- Schneider, W. A., and Backus, M. M., 1964, Ocean-bottom seismic measurements off the California coast: Journal of Geophysical Research, v. 69, no. 6, p. 1135–1143.
- Schneider, W. A., Lerner, K. L., Burg, J. P., and Backus, M. M., 1964, A new data-processing technique for the elimination of ghost arrivals on reflection seismograms: Geophysics, v. 29, no. 5, p. 783–805.
- Backus, M. M., Burg, J. P., Baldwin, D., and Bryan, E., 1964, Wide-band extraction of mantle P-waves from ambient noise: Geophysics, v. 29, no. 5, p. 672–692.
- Embree, P., Burg, J. P., and Backus, M. M., 1963, Wide-band velocity filtering—the pie-slice process: Geophysics, v. 28, no. 6, p. 948–974.

- Gilbert, Freeman, Laster, S. J., Backus, M. M., and Schell, R., 1962, Observation of pulses on an interface: *Bulletin of the Seismological Society of America*, v. 52, no. 4, p. 847–868.
- Backus, M. M., 1959, Water reverberations, their nature and elimination: *Geophysics*, v. 24, no. 2, p. 233–261.
- Backus, M. M., Hurley, N. F., and Stetson, Henry Crosby, 1953, Relationships of radioactive elements in three cores from the Gulf of Mexico: *Geological Society of America Bulletin*, v. 64, no. 12, Part 2, p. 1391.

#### Non-Peer-Reviewed

- Hardage, B. A., Murray, Paul, Sava, Diana, Backus, M. M., Remington, R. L., Graebner, R. J., and Roberts, H. H., 2006, Evaluation of deepwater gas-hydrate systems *The Leading Edge*, v. 25, no. 5, p. 572–577.
- Backus, M. M., Murray, Paul, Hardage, B. A., and Graebner, R. J., 2006, High-resolution multicomponent seismic imaging of deepwater gas-hydrate systems *The Leading Edge*, v. 25, no. 5, p. 578–598.
- De Angelo, M. V., Backus, Milo, Hardage, B. A., Murray, Paul, and Knapp, Steve, 2003, Depth registration of P-wave and C-wave seismic data for shallow marine sediment characterization, Gulf of Mexico: *The Leading Edge*, v. 22, no. 2, p. 96–105.
- Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1995, Three-dimensional seismic modeling and seismic facies imaging: *Gulf Coast Association of Geological Societies Transactions*, v. 45, p. 621–628.
- Castagna, J., and Backus, M. M., eds., 1993, Offset-dependent reflectivity theory and practice of AVO analysis: *Society of Exploration Geophysicists, Investigations in Geophysics No. 8*.
- Backus, M. M., Garcia, A. I., and Huston, Dan, 1987, On deconvolution and inversion in a one-dimensional earth (abs.), *in* Worthington, M., ed., *Proceedings, 1986 EAEG-SEG Workshop on Deconvolution and Inversion: Blackwell*, p. 208–225.
- Backus, M. M., and Simmons, J. L., Jr., 1984, Multiple reflections as an additive noise limitation in seismic reflection work: *Proceedings, IEEE*, v. 72, no. 10, p. 1370–1384.
- Backus, M. M., and Landwehr, Martha L., ed., 1980, The expanding role of the seismic reflection method in exploration and development: new ideas, new methods, new developments: *Exploration and Economics of the Petroleum Industry*, v. 18, p. 109–178.
- Gregory, A. Ray, Backus, M. M., Dorfman, Myron H., and Fisher, W. L., eds., 1979, Geopressured formation parameters, geothermal well, Brazoria County, Texas, *in* *Proceedings, Geopressure Geothermal Energy Conference 4*, v. 1, p. 235–311.
- Backus, M. M., 1970, The estimation of interval velocity from seismic data, *in* *Searching the seenties, from Moho to Mars*, p. 60–61,
- Backus, M. M., 1966, Teleseismic signal extraction, *Proceedings of the Royal Society of London, Series A: Mathematical and Physical Sciences*, v. 290, no. 1422, p. 343–367.

#### Abstracts

- Backus, M. M., Murray, Paul, Graebner, R. J., and Hardage, B. A., 2007, OBC sensor response and calibrated reflectivity (abs.), *in* *SEG/San Antonio Annual Meeting*, p. 1044–1048.
- Fomel, Sergey, Backus, Milo, Fouad, Khaled, Hardage, Bob, and Winters, Glenn, 2005, A multistep approach to multicomponent seismic image registration with application to a West Texas carbonate reservoir study (exp. abs.), *in* *SEG/Houston 2005 Annual Meeting*, p. 1018–1021.

- Fouad, Khaled, Hardage, B. A., Backus, M. M., Graebner, R. J., Fomel, S. B., Sakurai, Shinichi, Abd El Naser, M. H., Mounir, M. H., and Kortam, A. M., 2005, Targeting stratigraphic traps using multicomponent seismic: case study from clastic and carbonate reservoirs (abs.), *in* Official program and conference highlights, Second International Petroleum Conference and Exhibition, under the patronage of H. E. Eng. Sameh Fahmy, Minister of Petroleum, Cairo, Egypt, p. 68.
- Backus, M. M., Murray, Paul, Hardage, B. A., and Graebner, R. J., 2005, Enhanced PS-wave images of deep-water, near-seafloor geology from 2-D 4-C OBC data in the Gulf of Mexico (exp. abs.), *in* 75th Annual International Meeting of the SEG, Expanded Abstracts, Houston, CD-ROM [4 p.]
- Murray, Paul, Backus, Milo, DeAngelo, Michael, Fomel, Sergey, Graebner, Robert, Hardage, Bob, and Wood, Lesli, 2004, Evaluating marine gas hydrates with 4-C OBC seismic data (abs.): American Association of Petroleum Geologists Annual Convention Abstracts Volume, v. 13, p. A102.
- Fomel, S. B., and Backus, M. M., 2003, Multicomponent seismic data registration by least squares (exp. abs.), *in* 73rd Annual International Meeting, Society of Exploration Geophysicists, Expanded Abstracts, p. 781–784.
- Fomel, S. B., Backus, M. M., DeAngelo, Michael, Murray, Paul, and Hardage, B. A., 2003, Multicomponent seismic data registration for subsurface characterization in the shallow Gulf of Mexico (ext. abs.), *in* Offshore Technology Conference, OTC Paper No. 15117, 4 p.
- Murray, Paul, DeAngelo, Michael, Backus, M. M., Hardage, B. A., Graebner, R. J., and Fomel, S. B., 2003, Interpreting multicomponent seismic data in the Gulf of Mexico for shallow sedimentary properties (ext. abs.), *in* Offshore Technology Conference, OTC Paper No. 15118, 5 p.
- Simmons, J. L., Jr., Backus, M. M., Graebner, R. J., and Hardage, B. A., 1999, Case history: 3-D shear wave processing and interpretation in radial-transverse (SV-SH) coordinates (abs.), *in* Annual Meeting Abstracts: Society of Geophysics, p. 792–795.
- Simmons, J. L., Jr., and Backus, M. M., 1999, Shear-wave splitting: Tutorial, issues, and implications for 9-C 3-D seismic reflection data (abs.), *in* Annual Meeting Abstracts: Society of Exploration Geophysicists, p. 788–791.
- Simmons, J. L., Jr., and Backus, M. M., 1999, Radial-transverse (SV-SH) coordinates for 9-C 3-D seismic reflection data analysis (abs.), *in* Annual Meeting Abstracts: Society of Exploration Geophysicists, p. 728–731.
- Teagan, A. C., Shipley, T. H., Bangs, N. L., and Backus, M. M., 1996, Post-stacking migration velocity analysis of 3-D seismic reflection data from the Barbados accretionary prism (abs.): Eos, Fall Meeting Supplement, v. 77, no. 46, p. 315.
- Simmons, J. L., Jr., and Backus, M. M., 1996, Waveform-based AVO inversion and AVO prediction error (abs.): Geophysics, v. 61, no. 6, 1575–1588.
- Simmons, J. L., Jr., and Backus, M. M., 1996, AVO inversion and direct hydrocarbon detection (abs.): Society of Exploration Geophysicists, Annual Meeting Abstracts, p. 960–963.
- Teagan, A. C., Shipley, T. H., Bangs, N. L., Backus, M. M., and Moore, G. F., 1994, Migration velocity analysis using 3-D seismic data from the northern Barbados ridge complex (abs.): Eos (Supplement), v. 75, no. 44, p. 672.
- Backus, M. M., Zeng, Hongliu, and Simmons, J. L., Jr., 1993, Displaying 3-D data cube and its perturbations (abs.), *in* 3-D seismology: integrated comprehension of large data volumes: SEG Summer Research Workshop, Technical Program and Abstracts, p. 266–269.

- Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1993, Facies-guided 3-dimensional seismic modeling, part 1 (abs.), *in* SEG 63rd Annual International Meeting: p. 938–941.
- Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1993, Facies-guided 3-dimensional seismic modeling, part 2 (abs.), *in* SEG 63rd Annual International Meeting: p. 1253–1256.
- Backus, M. M., 1993, Basic considerations for fluid anomaly seismic signal detection, and mapping reservoir properties (exp. abs.), *in* 3rd International Congress of the Brazilian Geophysical Society, expanded abstracts, p. 1485–1491.
- Zeng, Hongliu, Backus, M. M., Barrow, K. T., and Tyler, Noel, 1992, On the expected signals from pore fluids and facies: an example from Powderhorn field, Texas (abs.), *in* How useful is amplitude-versus-offset (AVO) analysis?: SEG/EAEG Summer Research Workshop, Technical Program and Abstracts, p. 278–288.
- Backus, M. M., 1992, On sensitivity, detectability, and ambiguity (abs.): 1992 SEG-EAEG Summer Research Workshop Abstracts, p. 178–188.
- Backus, M. M., 1992, On sensitivity, detectability, and ambiguity: 1992 SEG-EAEG Summer Research Workshop Abstracts, p. 178–188.
- Backus, M. M., 1992, Reflection amplitude versus angle and direct hydrocarbon detection: 1992 SEG-EAEG Summer Research Workshop Abstracts, p. 191–193.
- Huston, D. C., Wood, Leigh, Simmons, J. L., Jr., Todd, C.P., Chang, J. Y., Catto, A. J., and Backus, M. M., 1992, A young offshore oil and gas field: 1992 SEG-EAEG Summer Research Workshop Abstracts, p. 53–60.
- Finn, C. J., and Backus, M. M., 1991, Maximum-likelihood traveltimes inversion for a 3-D velocity-depth model (exp. abs.): SEG Expanded Abstracts, Sixty-First Annual Meeting: Society of Exploration Geophysicists, p. 897–900.
- Wang, D. L., and Backus, M. M., 1991, Resolution of P-wave velocity and density in linearized inversion (exp. abs.): SEG Expanded Abstracts, Sixty-First Annual Meeting: Society of Exploration Geophysicists, p. 879–882.
- Bernitsas, Nikolaos, and Backus, M. M., 1990, Finite difference modeling of fault surface reflections: SEG Expanded Abstracts, Sixtieth Annual Meeting: Society of Exploration Geophysicists, p. 996–999.
- Wang, D. L., and Backus, M. M., 1989, Resolution of low-frequency velocities in linearized least-squares inversion (exp. abs.), *in* Fifty-Ninth Annual Meeting, Society of Exploration Geophysicists: SEG expanded abstracts, p. 501–504.
- Backus, M. M., and Simmons, J. L., Jr., 1988, First arrival times and diving wave tomography (exp. abs.), *in* Society of Exploration Geophysicists, Fifty-Eighth Annual Meeting: SEG expanded abstracts, p. 1239–1243.
- Wood, Leigh, and Backus, M. M., 1988, Signal and noise in picked reflection times from partial-stack seismic data (exp. abs.): *in* Society of Exploration Geophysicists, Fifty-Eighth Annual Meeting: SEG expanded abstracts, p. 775–779.
- Backus, M. M., 1987, Amplitude versus offset—a review (exp. abs.), *in* Society of Exploration Geophysicists Fifty-Seventh Annual Meeting: SEG Expanded Abstracts, p. 359–364.
- Finn, C. J., and Backus, M. M., 1986, Estimation of three-dimensional dip and curvature from reflection seismic data (abs.), *in* Society of Exploration Geophysicists Fifty-Seventh Annual Meeting: SEG Expanded Abstracts,
- Huston, Dan, and Backus, M. M., 1986, Interpretation of seismic signal and noise through line intersection analysis (abs.), *in* Society of Exploration Geophysicists Annual Meeting Abstracts: Session: S10.7,
- Stark, T. J., and Backus, M. M., 1985, Debubbling and calibration of deep water seismic reflection data (abs.): *Earthquake Notes*, v. 55, no. 1, p. 10.

- Garcia, A. I., and Backus, M. M., 1985, Thin layer response catalog (exp. abs.), *in* Society of Exploration Geophysicists SEG Expanded Abstracts, p. 588–590.
- Garcia, A. I., Backus, M. M., Young, C. Y., Kan, T. K., and Corrigan, K., 1985, Effects of fine layering on reflection seismograms (exp. abs.), *in* Society of Exploration Geophysicists SEG Expanded Abstracts, p. 598–600.
- Todd, C.P., and Backus, M. M., 1985, Offset-dependent reflectivity in a structural context (exp. abs.), *in* Society of Exploration Geophysicists SEG Expanded Abstracts p. 586–588.
- Onstott, G. E., Backus, M. M., Wilson, J. L., and Phillips, J. D., 1984, Color display of offset dependent reflectivity in seismic data (exp. abs.), *in* Society of Exploration Geophysicists: SEG Expanded Abstracts, p. 674–675.
- Backus, M. M., 1983, Research workshop 2—the change in reflectivity with offset (abs.), *in* Annual Meeting Abstracts, Society of Exploration Geophysicists, Session: RW2.1,
- Chang, C. Y., and Backus, M. M., 1982, Emergent angle dependent deconvolution (abs.): *Geophysics*, v. 7, no. 4,
- Backus, M. M., Stoffa, P. L., Tsai, C. J., and Stark, T. J., 1982, Current limitation on deep crustal mapping with marine seismic systems (abs.): *Geophysics*, v. 7, no. 4,
- Backus, M. M., and Nepomoceno, F., 1982, The reflection seismogram in a solid layered earth (exp. abs.), *in* Society of Exploration Geophysicists: SEG Expanded Abstracts, p. 218–220.
- Rosa, A. L. R., Tassini, J., and Backus, M. M., 1982, Seismic data quality in a basalt-covered basin (exp. abs.), *in* Society of Exploration Geophysicists: SEG Expanded Abstracts, p. 64–67.
- Backus, M. M., Castagna, J., and Gregory, A. Ray, 1979, Sonic log waveforms from a geothermal well in Brazoria County, Texas (abs.), *in* Society of Exploration Geophysicists International Meeting abstracts (49), p. 105.
- Scoville, J. M., and Backus, M. M., 1978, Wavelet estimation using water bottom multiples (abs.), *in* Society of Exploration Geophysicists International Meeting abstracts (48), p. 52.
- Pinson, William Hamet, Jr., Backus, M. M., and Herzog, Leonard Frederick, II, 1955, The Rb and Sr content and geologic age of certain lepidolites and their radiogenic Ca (super 40) content (abs.): *Transactions, American Geophysical Union*, v. 36, no. 3, p. 523.

### Contract Reports

- Hardage, B. A., Backus, M. M., DeAngelo, Michael, Fomel, S. B., Fouad, Khaled, Graebner, R. J., Murray, Paul, Remington, R. L., and Sava, Diana, 2006, Elastic wavefield stratigraphy: an emerging seismic technology: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, under DOE contract DE-PS26-02NT15375, 86 p.
- Hardage, B. A., Backus, Milo, DeAngelo, Michael, Fomel, Sergey, Fouad, Khaled, Graebner, Robert, Murray, Paul, and Remington, Randy, 2004, Imaging deep gas prospects using multicomponent seismic technology: The University of Texas at Austin, Bureau of Economic Geology, final project report prepared for Research Partnership to Secure Energy for America, under contract no. GRI-04/0186, 31 p.
- Hardage, B. A., Backus, M. M., DeAngelo, M. V., Graebner, R. J., Laubach, S. E., and Murray, Paul, 2004, Combining a new 3-D seismic S-wave propagation analysis for remote fracture detection with a robust subsurface microfracture-based verification technique: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, under contract no. DE-AC26-00NT40690, 72 p.
- Hardage, B. A., Backus, M. M., De Angelo, Michael, Graebner, R. J., Murray, Paul, and Wood, L. J., 2002, Characterizing marine gas-hydrate reservoirs and determining mechanical properties of marine gas-hydrate strata with 4-component ocean-bottom-

cable seismic data: The University of Texas at Austin, Bureau of Economic Geology, annual report prepared for U.S. Department of Energy, under contract no. DE-FC26-00NT41024, 37 p. + figs.

Hardage, B. A., Backus, M. M., De Angelo, Michael, Fomel, Sergey, Graebner, R. J., Murray, Paul, and Wood, L. J., 2002, Characterizing marine gas-hydrate reservoirs and determining mechanical properties of marine gas-hydrate strata with 4-component ocean-bottom-cable seismic data: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for U.S. Department of Energy, under contract no. DE-FC26-00NT41024, 43 p. + apps.

Graebner, R. J., Backus, M. M., and Hardage, B. A., 1999, Maintenance of borehole geophysics test site: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Society of Exploration Geophysicists Executive Committee and SEG Foundation Board of Directors, 14 p. + attachments.

#### Workshop Workbooks

Hardage, B. A., Backus, M. M., DeAngelo, Michael, Fomel, S. B., Fouad, Khaled, Graebner, R. J., Murray, Paul, and Remington, R. L., 2004, Imaging deep gas prospects using multicomponent seismic technology: The University of Texas at Austin, Bureau of Economic Geology, 52 p.

#### Dissertation

"Mass Spectrometric Determination of the Relative Isotope Abundance of Calcium and the Determination of Geologic Age".