

Christopher D. Laughrey
Senior Petroleum Systems Analyst

Christopher D. Laughrey is a Senior Petroleum Systems Analyst with Weatherford Laboratories' OilTracers® Interpretive Services Group. His thirty-nine years of professional experience is international in scope with specializations in isotope and petroleum geochemistry, clastic and carbonate reservoir petrology, basin analysis, and geophysical log analysis. He consults for both private industry and government, working on integrated interpretive projects involving exploration, development, and operational problems in both unconventional and conventional plays, including stray gas and oil contamination issues. Recent work includes regional geochemistry of sweet and sour gases in the Western Canadian Sedimentary Basin, the origin of nonhydrocarbon gases (CO₂, N₂, and H₂S) in the Denver-Julesburg, Greater Green River, Appalachian, and South Texas subsurface basins, gas studies associated with North American gas storage projects, rock and fluid geochemistry of Paleozoic reservoirs in the Volga-Ural basin province, integrated petrologic and geochemical efforts in the Woodford Shale of the Anadarko and Arkoma basins, and both gas and rock geochemistry/petrology investigations of Marcellus and Utica formation reservoirs in the Appalachian basin. Much of this recent work has included applying noble gas geochemistry to solving problems concerning natural gas migration and accumulation in the DJ and Appalachian basins. In addition to technical consulting duties, Christopher teaches workshops on both unconventional and conventional reservoir geology and geochemistry, and collaborates with other Weatherford scientists on research and business development efforts within the company. Prior to joining the Oil Tracers Group, Christopher consulted with the Dolan Integration Group in Boulder, Colorado, worked five years as a Senior Geosciences Advisor for Weatherford Laboratories in Golden, Colorado, conducted Carbonate Petroleum Reservoir workshops and field seminars for Petro China through Geologic Mapping and Resource Evaluation (GMRE) Inc. in State College, Pennsylvania, and worked as a Senior Geological Scientist for the Pennsylvania Geological Survey. During his thirty year tenure with the Survey, he also taught graduate courses in sandstone and carbonate petrology, and undergraduate geochemistry, at the University of Pittsburgh, and conducted short courses and workshops on carbonate reservoirs, applied sequence stratigraphy, and petroleum geochemistry for AAPG, SPE, and PTTC. Christopher began his career in 1977 as a geologist and geophysical analyst for the Marine Seismic Exploration Department at the Western Geophysical Company in Houston, Texas.

EDUCATION

B.S. Geology and Natural Sciences, University of Pittsburgh at Johnstown (1977).

University of Pittsburgh, 1980 – 1984: 24 graduate credit hours in isotope, petroleum, and organic geochemistry, sandstone and carbonate petrology, sedimentology, micropaleontology, advanced structural geology, economic geology, and petroleum engineering.

INDUSTRY EXPERIENCE

Weatherford Laboratories (OilTracers® Group), Evergreen, CO

Senior Petroleum Systems Analyst: 2016 –

Continuation of natural gas geochemical studies in the deeper portions of the WCSB.

Dolan Integration Group, Boulder, CO

Senior Geosciences Advisor: March 2015 – March 2016

Completed a regional natural gas geochemistry survey of 125 producing wells in the northeast British Columbia portion of the Western Canada Sedimentary Basin. The Montney Formation was the focus of the effort, but the well data base included unconventional and conventional reservoir gases spanning Devonian to Cretaceous-age rocks. Forty-two of the samples were sour gases, and the purpose of analyzing this subset was to define the origin of H₂S in the producing areas. Laughrey also worked on determinations of the origin of nonhydrocarbon gases (CO₂ and N₂) in the Denver-Julesburg and Greater Green River basins, gas storage, and combined rock and fluid geochemistry studies of Paleozoic reservoirs in the Volga-Ural basin province in Russia,

Weatherford Laboratories, Golden, CO

Senior Geosciences Advisor: November 2009 – February 2015

Work focused on unconventional resources in the Rocky Mountain, Mid-continent, Gulf of Mexico, and Appalachian regions. Laughrey also completed a considerable amount of international work in various basins in Canada, Australia, China, Argentina, Colombia, the Middle East, Russia, and new plays in the UK. He was involved in several research and development efforts including quantitative natural gas isotope applications in the petroleum geosciences, high-resolution SEM imaging and 3-D modeling of low-permeability fine-grained clastic and carbonate reservoirs with an emphasis on the evolution of organic and inorganic pore systems, biomarker applications in petroleum resource systems, interpretation of well site geochemical data, and high-temperature programmed pyrolysis of organic matter in unconventional shale-gas and tight-oil reservoirs. While at Weatherford, he conducted professional workshops and short courses in applied shale petrology and petroleum geochemistry for the Petroleum Technology Transfer Council (PPTC), the AAPG Education Department, and numerous private oil and gas companies including Cabot, Chevron, Colombian Petroleum Institute, El Paso, EQT, ExxonMobil, Hess, Petro China, Repsol, Shell, and Talisman.

Geologic Mapping and Resource Evaluation, Inc. (GMRE), State College, PA

Instructor: 2008 - 2009

Laughrey developed and conducted dedicated Carbonate Petroleum Reservoir workshops and field seminars specifically designed for Petro China earth scientists and engineers. Formal classroom training was conducted at the Pennsylvania State University. Field exercises were carried out in the central Appalachian Ridge and Valley province.

Pennsylvania Geological Survey, Pittsburgh, PA

Senior Geological Scientist: January 1980 – December 2009

Laughrey conducted and published applied research in tight-gas sands, fractured carbonate reservoirs, applied sequence stratigraphy, shale petrology, source rock geochemistry of the Marcellus and Utica shales, and natural gas isotope geochemistry throughout the Appalachian basin. While at the Survey, he served as principal investigator for two Appalachian Oil and Natural Gas Research Consortium projects sponsored by the U. S. Department of Energy and private petroleum industry consortia:

- Contract Number DE-FC26-03NT41856, *A Geologic Playbook for Trenton – Black River Appalachian Basin Exploration*, DOE/NETL – 2007/1258, July 1, 2006 (Principal Investigator for both Petrology and Geochemistry) .
- Contract Number DE-FC26-03NT41856, *Measuring and Predicting Reservoir Heterogeneity in Complex Deposystems*, September 1990 to December 1993 (Principal Investigator Petrology and Geochemistry).

As a scientific diver at the Survey, Laughrey conducted underwater sediment transport and deposition observations for the Environmental Geology Division as part of their Great Lakes coastal geoscience efforts.

University of Pittsburgh, Pittsburgh, PA

Instructor: 2005 - 2007

Adjunct position teaching graduate courses in sandstone and carbonate petrology, and undergraduate geochemistry.

Western Geophysical Company of America, Houston, TX

Geophysical Analyst: 1977 - 1980

Laughrey began his career in 1977 as a geologist and geophysical analyst for the Marine Seismic Exploration Department at the Western Geophysical Company (now Western Geco) in Houston, Texas. He worked on projects in the Gulf of Mexico, the offshore western Atlantic margin, the Bering and Beaufort seas, Alaska's North Slope, and Fiji's offshore basins in the southwest Pacific.

ADDITIONAL CREDENTIALS AND EXPERIENCE

Laughrey is the author or coauthor of forty technical papers, books, and articles on the application of integrated geochemistry, petrology, and stratigraphy to petroleum exploration and production, the application of isotope geochemistry to petroleum systems analysis, the mitigation of stray natural gas environmental problems, the history of geology, and submerged cultural resources. His most relevant publications are listed below.

Professional Organizations:

Geological Society of America; European Association of Organic Geochemists; The Geochemical Society; Society of Economic Paleontologists and Mineralogists ; The Society for Organic Petrology; European Association of Geologists and Engineers; American Geophysical Union; American Association of Petroleum Geologists; Rocky Mountain Association of Geologists; Pittsburgh Association of Petroleum Geologists;; Pittsburgh Geological Society; National Speleological Society – Cave Diving Section; National Association of Underwater Instructors (Technical Diving Course Director).

Awards:

Ralph R. Miller Best Energy Minerals Division Paper, Eastern Section, American Association of Petroleum Geologists, September 2015.

Pittsburgh Geological Society Best Presentation on Appalachian Geology Award, Eastern Section, American Association of Petroleum Geologists, September 2015.

A. I. Levorsen Memorial Award for Best Paper, Eastern Section, American Association of Petroleum Geologists, September 2010.

Scientific Achievement Award, Pennsylvania Geological Survey, April 2000.

Vincent E. Nelson Memorial Award for Best Poster, Eastern Section, American Association of Petroleum Geologists, September 1998.

Recognition Award for Teamwork, Natural Gas Migration Investigations, Pennsylvania DEP/DCNR Southwest Region, June 1997.

Outstanding Service Award, Eastern Section, American Association of Petroleum Geologists, September 1984.

Outstanding Service Award, Contributions to Technical Diving, National Association of Underwater Instructors, 2005.

Professional Contributions:

Christopher has taught, and continues to teach, short courses, workshops, and Webinars on carbonate reservoirs, applied sequence stratigraphy, and applied geochemistry for industry clients, Weatherford, the Petroleum Technology Transfer Council (PTTC), AAPG, and SPE. He has presented papers at three AAPG Hedberg Conferences:

1. *Natural Gas Geochemistry: Recent Developments, Applications, and Technologies* in Beijing, China (May 9-12, 2011);
2. *Critical Assessment of Shale Resource Plays* in Austin, TX (December 10-15, 2010);
3. *Sequence Stratigraphic and Allostratigraphic Principals and Concepts*, Dallas, TX (August 26-29, 2001).

And he is scheduled to present at a fourth AAPG/SEPM Hedberg Research Conference in Santa Fe, New Mexico October 16 to 19, 2016 – *Mudstone Diagenesis*.

Laughrey has presented lectures at five AAPG Geoscience Technology Workshops:

1. *Success in the Marcellus and Utica Shales: Case Studies and New Developments*, Baltimore MD (May 23-25, 2011);
2. *U. S. Shale Plays*, Fort Worth, TX (August 2-4, 2011);
3. *Shale Plays: An Integrated Approach*, Houston, TX (November 12-14, 2012);
4. *Marcellus and Utica/Point Pleasant*, Pittsburgh, PA (June 17 –18, 2014);
5. *Revitalizing Reservoirs – Rocky Mountains, Midcontinent, Canada, International Focus*, Golden, CO (August 11 – 12, 2015).

Finally, he has presented overviews of respective rock and gas isotope geochemical techniques at the prestigious AAPG Division of Professional Affairs Playmaker Forums in Houston and Midland, TX (January 23, 2014 and January 14, 2015).

Additional Industry Training and Experience:

Weatherford Laboratories Industry Workshop, *Sedimentary Geochemistry and Biogeochemistry: A Guide to Interpreting Organic-Rich Mudstones, Their Solid-Phase Components, and Organic Carbon Preservation* (Dr. Wesley Ingram), July 16, 2014, Golden, CO.

Tectonics of the Rocky Mountain Region (Dr. Chuck Kluth), Colorado School of Mines, April 4, 2013.

Weatherford Laboratories Industry Workshop, *Liquids Rich Reservoirs: Characterization and Optimization* (Dr. Richard Thomas), January 29 – 31, 2013, Houston, TX (emphasis on integrated PVT and fluids geochemistry applications).

Source-Rock Kinetics: New Methods of Determining Them, and Novel Applications to Hydrocarbon Exploration, Especially Unconventional (Dr. Douglas Waples), January 24, 2013, Denver, CO.

Pore-Scale Imaging and Computation: Applications to Evaluation and Development of Mudrock Reservoirs, Colorado School of Mines, October 4, 2012.

Hydrothermal Dolomite Reservoir Facies: Global and Western Canada Perspectives Short Course (Dr. Graham Davies), London, Ontario, September, 2000.

Organic Geochemistry of Sediments and Sedimentary Rocks, SEPM Certification Course (Indiana University Biogeochemistry Division – Drs. Pratt, Brassell, and Schimmelmann), Cincinnati, OH, October, 1992.

Carbonate Petroleum Reservoirs, Certification Course (Dr. Gerald Friedman, RPI), Pittsburgh, PA, October, 1990.

Clay Minerals for Geologists and Engineers, SEPM Certification Course, Houston, TX, September, 1988.

Certification Course: *Water Quality Chemistry, Field and Laboratory Methods*, Stockton State College, Stockton, NJ, Fall Semester, 1978.

Isologica software expertise with interpreting gas isotope and other geochemical data.

Experience with *Zetaware* and *BasinMod* software and geochemical modeling in basin analysis.

Experience with *Petra* and *Geo Graphix* mapping software packages.

Summer/Fall 1977: Core analysis and well site geology, Core Laboratories, Dallas and Houston, Texas (summer employment).

1991 – 1993: Field Team in Underwater Archaeology, Cultural Resource Management Program, University of Pittsburgh.

1991 – 2000: Instructor, Aquatics Program at the University of Pittsburgh, developed and supervised the academic scuba diving program at the Johnstown, Pennsylvania campus and taught diving at the main campus in Pittsburgh, Pennsylvania.

Selected Publications

Laughrey, C. D. and P. F. Purrazzella (in preparation), *Petroleum geochemistry and mudstone diagenesis of the Woodford Shale, Anadarko basin, USA – an integrated approach*, SEPM/AAPG Hedberg Research Conference, Santa Fe, New Mexico, in W. Camp, N. Fishman, and P. Hackley (eds.), *Mudstone Diagenesis*, AAPG Memoir.

Laughrey, C. D. (in review), *Geochemical characterization of post mature gases from Middle Devonian Marcellus Formation, Northern Appalachian basin, USA*, American Association of Petroleum Geologists Bulletin.

Laughrey, C. D., T. R. Ruble, K. Hooghan, P. Purrazzella, K. Washburn, and J. Beuthin (in review), *Dual mineral matrix and organic pore textures in the Niobrara Formation and Colorado Group (Upper Cretaceous) USA and Canada – Implications for tight-oil reservoir evaluation and modeling*, Rocky Mountain Association of Geologists Special Publication, Rocky Mountain Source Rock Compendium.

Laughrey, C. D., H. Lemmens, T. E. Ruble, A. R. Butcher, G. Walker, J. Kostelnik, J. Barnes, and W. Knowles (2013), *Black shale diagenesis: Insights from integrated high-definition analyses of post-mature Marcellus Formation rocks, northeastern Pennsylvania*, in J-Y Chatellier and D. M. Jarvie (eds.), *Critical Assessment of Shale Resource Plays*, AAPG Memoir 103, CD ROM materials.

Laughrey, C. D. and J. A. Harper (2012), *Upper Cambrian Gatesburg Formation of central and western Pennsylvania*, in J. R. Derby, R. D. Fritz and others (eds.), *The Great American Carbonate Bank: The Geology and Petroleum Potential of the Cambrian-Ordovician Sauk Sequence of Laurentia*, AAPG Memoir 98, p. 1 – 30.

R. C. Burruss and **C. D. Laughrey**, (2010), *Carbon and hydrogen isotopic reversals in deep basin gas: evidence for limits to the stability of hydrocarbons*, *Organic Geochemistry*, v.41, p. 1285 – 1296.

Birdwell, J. E., T. E. Ruble, **C. D. Laughrey**, D. R. Roper, and G. Walker (2010), *Differentiating organic carbon residues in spent oil shales*, 30th Oil Shale Symposium, Colorado School of Mines, October 18 – 20, 2010, Golden, CO, 21 p.

Laughrey, C. D., J. Kostelnik, J. A. Harper, and K. M. Carter (2009), *The Pennsylvania petroleum source rock database*,
http://www.dcnr.state.pa.us/topogeo/econresource/oilandgas/marcellus/sourcerock_index/index.htm

Laughrey, C. D. and Kostelnik, J. (2007), *Petrography of the Trenton Limestone and Black River Group carbonate rocks in the Appalachian basin*, in Patchen, D. G., Hickman, J. B., Harris, D. C., Drahovzal, J. A., Lake, P. D., Smith, L. B., Nyahay, R., Schulze, R., Riley, R. A., Baranoski, M. T., Wickstrom, L. H., Laughrey, C. D., Kostelnik, J. Harper, J. A., Avary, K. L., Bocan, J., Hohn, M. E. and McDowell, R., 2006, *A geologic playbook for Trenton-Black River Appalachian basin exploration*, U. S. Department of Energy Final Report DE-FC26-03NT41856, DOE/NEWTL – 2007/1258, pp. 64 – 100. This paper is supplemented by

Appendix E, a full-color, 101-page atlas of Trenton and Black River carbonate petrography.

Laughrey, C. D. and Kostelnik, J. (2007), *Geochemistry of natural gases from Trenton and Black River Formation (Middle Ordovician) carbonate reservoirs, Appalachian basin*, in Patchen, D. G., Hickman, J. B., Harris, D. C., Drahovzal, J. A., Lake, P. D., Smith, L. B., Nyahay, R., Schulze, R., Riley, R. A., Baranoski, M. T., Wickstrom, L. H., Laughrey, C. D., Kostelnik, J. Harper, J. A., Avary, K. L., Bocan, J., Hohn, M. E. and McDowell, R., 2006, *A geologic playbook for Trenton-Black River Appalachian basin exploration*, U. S. Department of Energy Final Report DE-FC26-03NT41856, DOE/NEWTL – 2007/1258, pp. 161 – 210.

R. C. Burruss and **C. D. Laughrey**, (2006), *Stable isotopic constraints on abiogenic hydrocarbon gas contributions to thermogenic natural gas resources in the northern Appalachian basin, USA*, American Geophysical Union, Fall Meeting 2007, U24A-02, Smithsonian/NASA Astrophysics Data System, <http://adsabs.harvard.edu/abs/2006AGUSM.U24A.02B>

Laughrey, C. D., Billman, D. A., and Canich, M. R. (2004), *Petroleum geology and geochemistry of the Council Run gas field, North Central Pennsylvania*, American Association of Petroleum Geologists Bulletin, v. 88, pp. 213 - 239.

Laughrey, C. D. and Baldassare, F. J. (2003), *Some applications of isotope geochemistry for determining sources of stray carbon dioxide gas*, Environmental Geosciences, v. 10, pp. 107 – 122.

Laughrey, C. D. and Baldassare, F. J. (1998), *Geochemistry and origin of some natural gases in the Plateau Province, Central Appalachian basin, Pennsylvania and Ohio*, American Association of Petroleum Geologists Bulletin, v. 82, pp. 317-335.

Laughrey, C. D. (1998), *The origin of oil*, Pennsylvania Geology, v. 29, p. 9 – 14.

Baldassare, F. J., and **Laughrey, C. D.** (1997), *Identifying the sources of stray methane by using geochemical and isotopic fingerprinting*, Environmental Geosciences, v. 4, pp. 85 – 94.

Laughrey, C. D. and Harper, R. M. (1996), *Upper Ordovician Bald Eagle Formation fractured anticlinal play*, pp. 164-167 in Roen, J. B., and Walker, B. J., eds., *The Atlas of Major Appalachian Gas Plays*, West Virginia Geological and Economic Survey Publication V-25, 200 p.

Laughrey, C. D. and Harper, R. M. (1996), *An unusual occurrence of ooids in the Speechley sand of western Pennsylvania*, Pennsylvania Geology, v. 27, no. 3, pp.8-13.

Laughrey, C. D. (1995), *Biomarkers (chemical fossils) in Pennsylvania rocks*, Pennsylvania Geology, v. 26, no. 2, pp.8-14.

Laughrey, C. D. (1994), *Sedimentary evaporites in the Gatesburg Formation of central Pennsylvania*, Pennsylvania Geology, v. 25, no. 2, pp.10-15.

Riley, R. A., Harper, J. A., Baranoski, M. T., **Laughrey, C. D.**, and Carlton, R. W. (1993),

Measuring and predicting reservoir heterogeneity in complex deposystems: The Late Cambrian Rose Run sandstone of eastern Ohio and western Pennsylvania, Appalachian Oil and Natural Gas Research Consortium, West Virginia University, Morgantown, WV, 257 p.

Laughrey, C. D. (1990), *Anomalous sterane maturity indices in bitumen of the Upper Devonian Huron Shale in northwestern Pennsylvania*, The Geochemical Society V. M. Goldschmidt Conference Program and Abstracts, May 2 – 4, 1990, Baltimore, Maryland, p. 60.

Laughrey, C. D. (1988), *Persifer Frazer, Jr.*, Pennsylvania Geology, v. 19, p. 13 – 15.

Harper, J. A., **C. D. Laughrey** (1987), *Geology of the oil and gas fields of southwestern Pennsylvania*, Pennsylvania Geological Survey, 4th Series, Mineral Resource Report 87, 166 p., 8 Plates.

Laughrey, C. D., and Harper, J. A. (1986), *Comparisons of Upper Devonian and Lower Silurian tight formations in Pennsylvania - geological and engineering characteristics*, in C. W. Spencer and R. F. Mast (eds.), *Geology of Tight Gas Reservoirs*, American Association of Petroleum Geologists, Studies in Geology 24, pp. 9 - 43.

Laughrey, C. D. (1984), *Petrology and reservoir characteristics of the Lower Silurian Medina Group sandstones, Athens and Geneva fields, Crawford County, Pennsylvania*, Pennsylvania Geological Survey, 4th series, Mineral Resource Report 85, 126 p.

Laughrey, C. D. (1982), *High-potential gas production and fracture-controlled porosity in Upper Devonian Kane "sand," central - western Pennsylvania*, American Association of Petroleum Geologists Bulletin, v. 66, pp. 477 - 482.

Harper, J. A., **C. D. Laughrey**, and W. S. Lytle (1982), *Oil and gas fields of Pennsylvania*, Pennsylvania Geological Survey, 4th Series, Map 3, scale 1:250,000, 2 sheets.