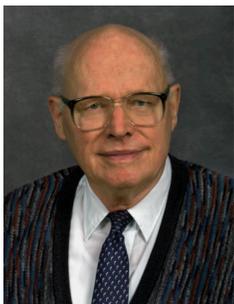




Paul Witherspoon's Legacy: A Tribute to a Brilliant Scientist and Inspiring Teacher, and an Introduction to AGU's Paul A. Witherspoon Mid-Career Lecturer in Hydrologic Sciences Award

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In his long life and career within the Earth Sciences community, Paul A. Witherspoon (1919–2012) left a legacy as one of the world's leading hydrogeologists [Duncan and Voss, 2013; Freeze et al., 2015a, 2015b]. Paul's influence on advancing our science and

empowering the next generation of hydrogeologists runs much deeper than we can know. Working with Paul was a life-enhancing experience for his many graduate students and colleagues. He was supportive, available, optimistic, and fun. His students and colleagues fondly recall the many dinner parties and events that Paul and his late wife Elizabeth hosted at their home, and the lively, wide-ranging and stimulating discussions that marked those occasions.

Paul was a role model in his ability to foster a research environment of cooperation, excitement, and friendship. His students who stayed in academia inevitably attempted to create a similar setting. In the contemporary scientific world, Witherspoon is still widely acknowledged as having possessed an unusual gift for identifying really important problems, finding the resources to work on them, communicating clearly, and making friends and trusted colleagues across disciplinary and geographic boundaries.

Moreover, Paul had a seminal influence on the development of ideas and methodologies related to the hydrogeology of fractured rock. His interest in the topic originated from his early studies on caprock integrity for underground gas storage, grew through his mid-career emphasis on the role of aquitards in hydrogeological systems, and then flourished in his later work on thermohydrologic and hydromechanical couplings in geothermal systems and nuclear waste isolation. Never one to shy away from difficult topics, Paul tackled the seemingly most intractable and difficult research problems and inspired his colleagues to do the same.

As just one example, Paul and several of his students wrote an acclaimed article on the cubic law, entitled "Validity of cubic law for fluid flow in a deformable rock fracture" [Witherspoon *et al.*, 1980]. Arguably, this has been the most influential paper on the topic of fluid flow in a single rock fracture, with over 1000 citations to date (Google Scholar, 21 November, 2015).

Paul was widely honored for his work. He was awarded the Horton Medal from the American Geophysical Union and both the Meinzer Award and the Distinguished Service Award from the Geological Society of America. In 1989, he was elected to the U.S. National Academy of Engineering for "pioneering work in geothermal energy, underground storage, hydrogeology, and the flow of fluids in fractured and porous rocks." In 1992, Paul initiated a collaboration between U.S. and Ukrainian scientists to develop a program of hydrological studies on contaminant transport at Chernobyl and its surroundings; subsequently, he was elected as a Foreign Member to the National Academy of Sciences of Ukraine. In 2001, he was elected Fellow of the World Innovation Foundation.

Paul's greatest legacy is his many students and colleagues, who benefited from his generous mentorship and lifelong friendship. Not surprisingly,

Paul's former students became key scientists throughout the world, including many outstanding hydrogeologists in the United States, Canada, UK, and other countries. To show their appreciation, they honored him over the years with several memorable research conferences and symposia at Lawrence Berkeley National Laboratory (LBNL), on the occasions of his 60th, 70th, 80th, and 85th birthdays [Narasimhan, 1982; Faybishenko, 1999; Faybishenko and Witherspoon, 2004]. Two monographs stemming from these events were published by the American Geophysical Union [Faybishenko *et al.*, 2000, 2005]. The monograph resulting from the presentations given in the fall 2012 AGU session devoted to the memory of Paul was recently published by AGU and Wiley [Faybishenko *et al.*, 2015].

Paul always reveled in his international coterie. He knew a few words in more languages than anyone you will ever meet, and always relished greeting people in their native language. He also developed close ties with scientists and organizations in China, Russia, France, Sweden, Ukraine, and many other countries, and traveled widely to give talks and courses.

Paul had a most attractive quality: the ability to explain, to anyone of any age or social group or background, difficult scientific problems in very simple terms. As an example, one of his colleagues recalled how he succinctly explained the problem of water movement at Yucca Mountain to a taxi driver in Nevada. He clearly had the knack of raising scientific questions and explaining difficult scientific topics to anybody. His goal, always, was to make students and colleagues feel at ease in his interactions with them. For this reason, he was never short of appreciative comments. Paul knew the secrets of effective conversation, had the skill of asking questions that promoted conversation, and encouraged innovative research. He also knew how to listen and to put others at ease, so that they would be inspired to express their ideas. His presence, encouragement, words of wisdom, and feedback really motivated his students and colleagues to excel and perform at their best.

In 1977, working from his faculty position at the University of California, Berkeley, Paul initiated and organized the Earth Sciences Division (ESD), and was the first Director of this new division at LBNL. Since then, ESD has developed into one of the most prestigious and respected Earth sciences institutes in the world. This division has recently been expanded to become the Earth and Environmental Sciences Area

(<http://eesa.lbl.gov>). This expansion is intended to position Berkeley Lab's programs so that they will have an even greater impact on environmental sciences, climate sciences, and subsurface energy resources worldwide. This vision all started with Paul. He would have been delighted and proud.

In 2015, AGU established the Paul A. Witherspoon Mid-Career Lecturer in Hydrologic Sciences. The award is intended to promote and reward excellence and outstanding achievements by a mid-career scientist (within 10 to 20 years postdoctoral) in advancing the field of hydrologic sciences. As the scientific community enlarges the scope of hydrological science, not only on the fundamental disciplinary level but also by including more interfaces with other disciplines and society at large, this award is very much needed. While obviously honoring its recipients, the Paul A. Witherspoon award will also honor Paul's great accomplishments—in advancing the science of hydrology, its application to socially important problems, and Paul's inspired and dedicated mentoring of young hydrologists. Some of his former students and colleagues recall that Paul himself very much valued mid-career professionals, who often developed significant expertise in one or more areas, and who were ambitious and constantly looking for new research challenges and directions.

As one of Paul's former students said, "Paul's notes for Mineral Engineering 282 formed the starting point of my own course notes. Over the years, about half of my research has involved fluid flow in porous or fractured media. All of this work owes a great debt, in many direct and indirect ways, to Paul Witherspoon—a brilliant scientist and inspiring teacher."

To learn first-hand about Paul Witherspoon's perspective in research and community building, view the videotaped interview that he gave in 2007, posted on the website of the International Association of Hydrogeologists (IAH) (timecapsule.iah.org). A biographical article based on the interview was also published by IAH [Freeze and Javandel, 2008]. As expressed in his obituary [Freeze et al., 2012], "to enter Paul's orbit was to experience a stimulating mix of high intelligence, deep curiosity, and love of life."

*Witherspoon's biography at the LBNL EESA website
<http://esd.lbl.gov/profiles/paul-a-witherspoon/>.

References

- Duncan, S. M., and C. I. Voss (2013), Editors' Message: Eminent hydrogeologists profiled in 20 years of Hydrogeology Journal (1992–2012), *Hydrogeol. J.*, 21(7), doi:10.1007/s10040-013-1009-9.
- Faybishenko, B. (Ed.) (1999), *Proceedings of the International Symposium on Dynamics of Fluids in Fractured Rocks: Concepts and Recent Advances (in Honor of Paul A. Witherspoon's 80th Birthday)*, LBNL 42718, Lawrence Berkeley Natl. Lab., Berkeley, Calif.
- Faybishenko, B., and P. A. Witherspoon (Eds.) (2004), Dynamics of fluids in fractured rock, in *Proceedings of the International Symposium on Dynamics of Fluids in Fractured Rocks: Concepts and Recent Advances (in Honor of Paul A. Witherspoon's 85th Birthday)*, LBNL-54275, Lawrence Berkeley Natl. Lab., Berkeley, Calif.
- Faybishenko B., P. A. Witherspoon, and S. M. Benson (Eds.) (2000), *Dynamics of Fluids in Fractured Rock*, *Geophys. Monogr. Ser.* vol. 122, AGU, Washington, D. C.
- Faybishenko, B., P. A. Witherspoon, and J. Gale (Eds.) (2005), *Dynamics of Fluids and Transport in Fractured Rock*, *Geophys. Monogr. Ser.*, vol. 162, AGU, Washington, D. C.
- Faybishenko, B., J. Gale, and S. Benson (Eds.) (2015), *Fluid Dynamics in Complex Fractured-Porous Systems*, *Geophys. Monogr. Ser.*, vol. 210, AGU, Washington, D. C.
- Freeze, R. A., and I. Javandel (2008), An interview with Paul Witherspoon, distinguished hydrogeologist from the USA, *Hydrogeol. J.*, 16(5), 811–815, doi:10.1007/s10040-008-0308-z.
- Freeze, R. A., I. Javandel, and S. P. Neuman (2012), Paul A. Witherspoon (1919–2012), *Eos*, 93(31), 304.
- Freeze, R. A., I. Javandel, and S. P. Neuman (2015a), Paul A. Witherspoon 1919–2012, in *Memorial Tributes*, vol. 19, pp. 334–338, Natl. Acad. Press, Washington, D. C.
- Freeze, R. A., I. Javandel, and S. P. Neuman (2015b), Paul Witherspoon and the birth of contemporary fractured rock hydrogeology, in *Dynamics of Fluids and Transport in Complex Fractured-Porous Systems*, *Geophys. Monogr. Ser.*, vol. 210, edited by B. Faybishenko, S. M. Benson, and J. E. Gale, pp. 1–3, AGU, Washington, D. C.
- Narasimhan, T. N. (1982), Recent trends in hydrogeology, *Geol. Soc. Am. Spec. Pap.*, 189, 1–448.
- Witherspoon, P. A., J. S. Y. Wang, K. Iwai, and J. E. Gale (1980), Validity of cubic law for fluid flow in a deformable rock fracture, *Water Resour. Res.*, 16(6), 1016–1024.