Harry Fielding Reid Medal Citation for Paul Richards

It is a great honor and great pleasure for me to present the citation for Paul Richards to receive the Reid Medal of the Seismological Society of America, our highest honor. I suppose in general the qualifications required for receiving our medal are that the recipient be outstandingly talented and use that talent outstandingly well. In the case of this year's medalist there is no question. His great talents were recognized early on, and his subsequent career is powerful testimony to his dedicated and elegant use of that talent. To quote from his nominators: "Paul Richards has been one of most influential contributors to theoretical and observational seismology over the past three decades."

Paul was born in Cirencester, Gloucestershire, England, an undergraduate of Peterhouse, University of Cambridge, and he was a State Scholar. He won the college Mathematics prize and the Essay prize in Physics. He obtained his B.A. in Mathematics from the University of Cambridge. From 1965 to 1970 Paul was a graduate student at the Seismological Laboratory of the California Institute of Technology, obtaining an M.S. in Geology and a Ph.D. in Geophysics. His thesis was titled "A contribution to the theory of high frequency elastic waves, with applications to the shadow boundary of the Earth's core." From 1970 to 1971 he was an Assistant Research Geophysicist at the Institute of Geophysics and Planetary Physics, University of California at San Diego. In 1971 he went to Lamont-Doherty Geological Observatory of Columbia University, becoming professor in 1979, and Mellon Professor of the Natural Sciences in 1987.

Recognition of Paul's contributions has come from many organizations. To cite a few:

- He was a Sloan Foundation Research Fellow, American Editor of the Geophysical Journal of the Royal Astronomical Society, recipient in 1977 of the James B. Macelwane Award of the American Geophysical Union, and a MacArthur Fellow in 1981. He was a member of the Red Team advising the U.S. Arms Control and Disarmament Agency on capability of the U.S. to verify compliance with the Comprehensive Test Ban Treaty.
- He was honored as Harold Jeffreys Lecturer of the Royal Astronomical Society in 1999 on the subject: Earth's Inner Core—Discoveries and Conjectures, and recipient of the 2006 Leo Szilard Lectureship Award from the American Physical Society for work on seismic monitoring of a test ban treaty.
- In 2008 he was elected Fellow of the American Academy of Arts and Sciences.
- In our Society he has served on the Board of Directors from 2002 to 2009.

I have known Paul since he was a graduate student at Cal Tech. We overlapped from 1965 to 1970 when, after getting a Masters in Geology, he completed his Ph.D. After Cal Tech he spent a post-doc with me at IGPP-UCSD, where I got to appreciate his abilities even further. He worked on, and quickly solved a problem relative to using sonobouys to record earthquakes in the ocean. Paul seemed to me humbly surprised by his own abilities—in quantitative, analytical, and mathematical insight, and in physical intuition. I was so impressed with Paul's abilities that when, on a visit to Lamont in 1970, I was asked for an evaluation of possible candidates for a position that had just opened up, I unhesitatingly recommended Paul as the most promising seismologist. I am happy to say that Paul has more than satisfied my expectations for his future.

Paul has made numerous outstanding contributions to quantitative seismology, seismological aspects of the Comprehensive Test Ban Treaty, the structure of the earth's inner core, earthquake and explosion source physics, national and international political aspects of arms control, and highest quality scientific reviewing and professional service—all clearly documented with his many publications in his Curriculum Vitae. His work on the Comprehensive Test Ban has been outstanding. He did not suffer easily any attempts to distort the science for political reasons. His widespread cooperation with other scientists is clearly indicated by the number of high-level co-authors on his publications. He has not hesitated to work constructively with others when that was to the advantage of the science, and, because of his unselfish personality, students and colleagues have been eager to work with him.

I quote again from nominators: "Important insights developed in [h]is work include the detailed effects of frequency dependence and tunneling of waves at grazing incidence to discontinuities, exhib-

ited in the strong frequency dependence of compressional waves in the outer core multiply reflected from the core-mantle boundary. In 2005, using high quality waveform doublets, Paul and co-authors confirmed the temporal change of waves through the inner core by about a tenth of a second per decade. The discovery has been dubbed as one of the most important discoveries in the last century and thrust deep earth research into the front pages of the world-wide media and the views of the general public."

▲ SSA Medal awardee Paul Richards.

Another quote: "Paul's service contributions have been as outstanding as those in research. He has been intensively committed to serving the cause of nuclear disarmament and non-proliferation, serving on national committees advising on the monitoring of the Comprehensive Test Ban Treaty, serving as a visiting fellow at the U.S. Arms Control and Disarmament Agency, and contributing to national reports on treaty verification problems. Paul's continuing commitment in this area has included seminar visits to many universities and colleges and the establishment of a regular course on Weapons of Mass Destruction at Columbia University."

Last, but definitely not least, the Aki and Richards textbook *Quantitative Seismology* has been, to quote from nominators: "truly a bible for seismology. It has been one of most authoritative references and textbooks for researchers and students worldwide."

In summary, based on his contributions in science, education and public service, Paul eminently deserves being awarded the Reid Medal of the Seismological Society of America.

James N. Brune
21 April 2010

Harry Fielding Reid Medal Response

To President Rick Aster, to members of the SSA, and guests: I express my amazement, and my sincere thanks, for the honor bestowed on me today.

This was a total surprise to me when I first heard of it, at the icebreaker last year; one that brings me great pleasure—to have the work I have done in my professional life be recognized in this way.

I thank Jim Brune, not just for a generous citation, but for the guidance he has given me since 1965, when we began a student-advisor relationship at Caltech. I had just arrived with a pure mathematics degree from England and knew almost nothing about geology or geophysics. He and Clarence Allen put me to work reading seismograms, in a project that looked for unusual microseismicity on the San Andreas. But we didn't find it. Then Jim suggested what became a thesis topic, with help from Charles Archambeau—the behavior of *P*-waves and *S*-waves near the core shadow boundary. I looked at hundreds of seismograms, but every patch of the core-mantle boundary seemed to behave differently, so it was a theoretical study. No data. And then, as a another great service, as a representative of the Pasadena Quaker Meeting, Jim Brune signed the legal papers recognizing my marriage in 1968 to Jody—who is here, with our daughter Gillian, and son-in-law Grisha.

During the ups and downs of my professional life, the good days and the difficult ones, my family has provided a sanity check, and the frame of reference for what I try to do. I thank you, my beloved ones.

After Caltech, in a junior research job at U.C. San Diego, Freeman Gilbert encouraged me to tackle something different from my thesis, and I solved a self-similar problem in shear crack theory. But still I wasn't using data.

In 1971, Jody and I left San Diego with our three-week-old son Mark for what has been a career at Columbia University—at Lamont, a place that has a formidable reputation for data gathering, and where at last I learned to grapple with observations.

I was in the right place at the right time when John Filson wanted help running the American office of what was then the Geophysical Journal of the Royal Astronomical Society. That editorial work for seven years was a terrific education.

Another piece of good fortune was being asked in 1975 by Kei Aki to co-author a textbook, which was blessed with his insight and good timing, as seismology moved in the 1980s to new levels of quantitative capability—with the spread of digital broadband high-dynamic-range stations. Our book is still in print, now as a paperback that came out last year.

It was through students including John Anderson, George Choy, Vernon Cormier, and Bill Menke, that I learned about

practical realities of strong ground motion, of tunneling, and whispering galleries. It was through Won-Young Kim, Vitaly Khalturin, and Tanya Rautian, that progress was made using regional seismograms to discriminate between explosions and earthquakes—with opportunities to apply these new methods especially to events in Central Asia and East Asia.

In the mid-1990s Xiaodong Song came as a post-doc to Lamont, and our discovery of seismological evidence that the inner core of the Earth rotates faster than the mantle and crust was the most exciting time of my professional life. I'd been thinking about it for years, with no progress. But then everything came together in a three-week period in early 1996, from having the right idea—to use transmitted waves—through Xiaodong's finding the data and making the measurements, to sending off a manuscript to *Nature*. The inner core is a Moon-sized object at the center of our planet, but it's almost 60 times nearer to us than the Moon. And whereas the Moon keeps the same face to us, the inner core does not—it rotates with respect to us at a rate that can be detected in a human lifetime. Xiaodong was able to document a systematic change in the 20-minute travel-time of a *P*-wave traversing the Earth via the inner core. The change was about one part in a hundred thousand, per year. Ken Creager improved on our original interpretation of the observations; and my student Jian Zhang—and others, including Xiaodong—found doublets that provided evidence a hundred times stronger than we had in our original paper, though due to Xiaodong's careful work we had obtained the right rate of travel-time change for the path we studied in 1996.

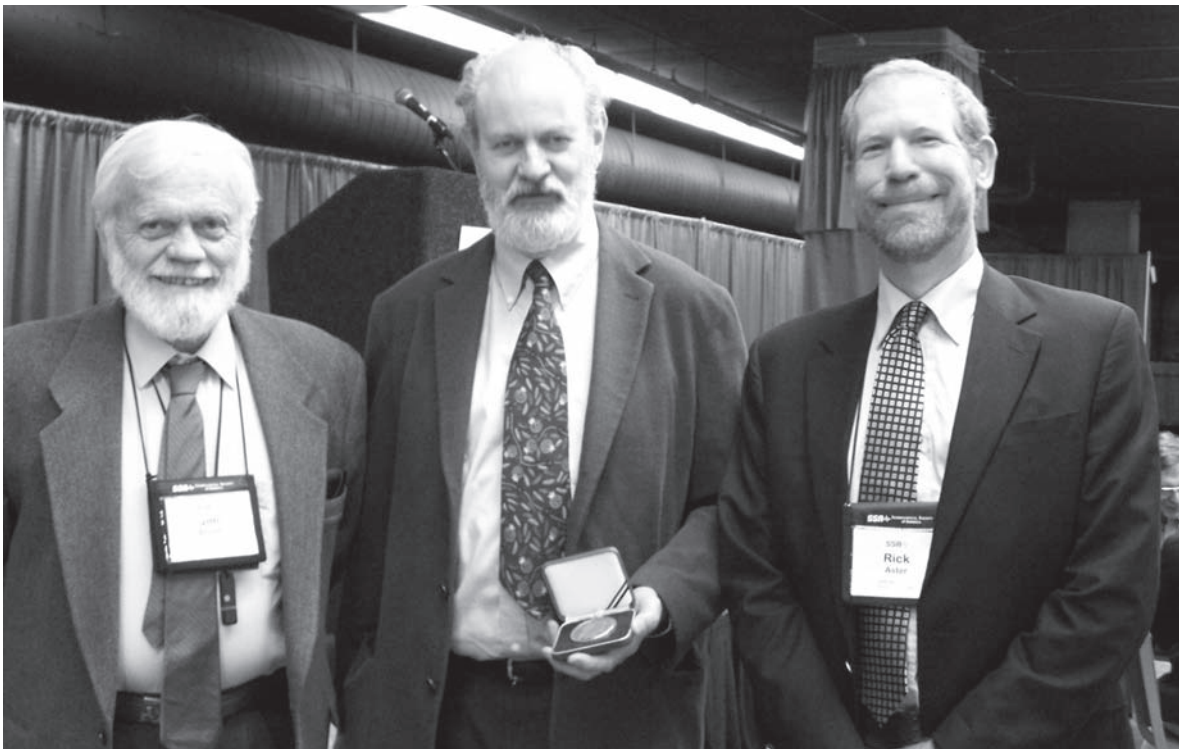
This was "precision seismology," where the scientific payoff came from arrival-time changes measured to better than a hundredth of a second. So, now I'm really wedded to data; and precision seismology is needed too in the hugely effective new methods for locating earthquakes. I've had adventures there with Won-Young Kim, David Schaff, Felix Waldhauser, Mark Fisk, and Relu Burlacu; and Felix and David are now doing what I regard as some of the most important work in all of seismology with their studies of terabyte-sized archives of waveforms, using hundreds of thousands of events in the past, as a resource to locate most of today's events in California, a few minutes after they occur, to within a few hundred meters.

To conclude: I wrote theoretical papers at first, and was then fortunate to find colleagues who got me into practical applications and data analysis. I'm glad that Lynn Sykes and I are now writing together.

In our profession as seismologists, we can be fortunate that there *is* such a range of good work to do: the intellectual challenges of various theories and sorting out important ideas; the terabytes of high-quality data sets to be interpreted; and the applications to hazard mitigation, and (I hope) to nuclear arms control.

I am so glad I was guided into seismology, and the community of seismologists; and I greatly appreciate the company I've found.

Paul Richards
21 April 2010



▲ Jim Brune, Paul Richards, and SSA President Rick Aster. Brune presented the citation for Reid Medal honoree Richards at the annual luncheon.