BIOGRAPHICAL MEMOIRS

Adam Marian Dziewonski

November 15, 1936–March 1, 2016
Elected to the NAS, 1995

A Biographical Memoir by
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Adam Dziewonski was a towering figure in solid-earth geophysics and a pioneer of global seismic tomography. He was a major contributor to our knowledge of the Earth's internal structure and a relentless advocate for the needed infrastructure in support of research.

Early Years

Adam Dziewonski was born on November 15, 1936, in Lwów, then part of Poland and now the city of Lviv, Ukraine. During World War II, caught in the complex population migrations of that time, his family first moved to Kraków, then finally settled in Wroclaw. Adam studied at the University of Warsaw and earned a master's degree in geophysics in 1960. During that time, he participated in the Polish I.G.Y. (International Geophysical Year) Scientific Expedition to Vietnam (1958–59), where he was in charge of operating a remote geomagnetic observatory for almost a year. The harsh conditions in the field gave him a keen appreciation for observatory science. After earning a doctorate from the Academy of Mines and Metallurgy in Kraków in 1965, he left for the United States, where he worked as a research associate at the Southwest Center for Advanced Studies in Dallas, Texas. In 1969, he was hired as an assistant professor there when it was renamed the University of Texas at Dallas, and Anton Hales became his cherished mentor.

During his time there, Adam worked on the quantification of seismic surface wave dispersion. In collaboration with Mark Landisman and others, he developed the "multiple filter technique" to extract single-mode group velocity dispersion and other properties by moving window analysis, an approach that completely replaced the classical "peak and trough" method used until then, and it is still used today. From the dispersion data they obtained, he cut his teeth at developing models of upper mantle structure. Early on in Dallas, he met Freeman Gilbert, with whom he collaborated on the measurement and analysis of normal mode eigenfrequencies from records of the 1964 Alaska earthquake, obtaining the first direct proof of the solidity of Earth's inner core.[1] The digitization of the Alaska dataset took two years, something young

Figure 1 Adam Dziewonski gives a presentation at the International Seismological Centre's fiftieth anniversary (ISC-50) session of the International Union of Geodesy and Geophysics General Assembly. *Courtesy of Dmitry Storchak (on behalf of the ISC); photo taken at the ISC-50 scientific session in Prague on June 27, 2015.*

researchers entering the field today would find hard to conceive. In 1972, Adam moved to Harvard University and would spend the rest of his career there. He chaired the Department of Geological Sciences from 1982 to 1986.

Global Earth Models and Preliminary Reference Earth Model (PREM)

The rich normal mode dataset (84 modes) derived from the 1964 Alaska earthquake led Adam and Freeman Gilbert to ponder different aspects of the construction of global models of the Earth's mechanical structure. The addition of other mode data collected by Freeman, as well as, notably, the original overtone dataset generated by the deep 1970 Columbia earthquake, from which Adam was proud to have digitized the long time series by hand (with the help of an assistant), led to the construction of a series of spherically symmetric Earth models. Notable are the 1066a and 1066b models,[2] based on measurements of 1064 normal mode frequencies plus mass and moment of inertia of the Earth, and the attempt at parametric Earth models incorporating constraints from travel time data (PEM-C and PEM-O),[3] which showed that the departure from adiabaticity in the lower mantle should be very small.

Adam was well poised to accept the challenge, given to him and Don L. Anderson in 1977 by the International Union of Geodesy and Geophysics, to construct a reference Earth model for the benefit of the community. The result was the 1981 Preliminary Reference Earth Model (PREM), which for the first time included radial anisotropy and depth-dependent attenuation, met with resounding success. It was called "preliminary" because, as Adam says in his tribute to Don Anderson, "we thought it would be improved in a few years."[4] Unique features of the PREM model are that it includes radial anisotropy in the upper mantle down to 220 kilometers in depth, which is necessary to reconcile measurements of toroidal and spheroidal fundamental mode frequencies (or Love and Rayleigh wave dispersion data). Don Anderson's expertise prevailed on this topic, as well as on depth-dependent attenuation in shear and compression, a topic on which Adam had worked in particular with then-Ph.D. student Richard Sailor. Almost fifty years later, the PREM model is still a reference of choice for many low-frequency seismological studies and is widely used by the mineral physics community to test composition and properties of mantle and core material candidates (more than 12,000 citations to date). Its main downside is the presence of a discontinuity at 220 kilometers, marking the bottom of the depth range in which anisotropy is present but which is not globally observed.

A Pioneer in Global Seismic Tomography

In his efforts to reconcile normal-mode and travel-time data sets, Adam was keenly aware of the importance of lateral heterogeneity in the Earth's mantle. In 1976–77, Adam spent a year at the Massachusetts Institute of Technology's Lincoln Laboratory, where he was able to access and analyze the unique global travel-time dataset assembled by the International Seismological Centre (ISC), then freshly available on magnetic tapes. Using 700,000 P travel-time residuals and an ingenuous parametrization of the mantle using spherical harmonics and conical blocks, he obtained the first global long-wavelength three-dimensional model of the Earth's lower mantle.[5] He worked with his Harvard colleague Rick O'Connell and then-graduate student Brad Hager to compare the features of this model with that of the geoid, and they discovered the negative correlation between degree 2 and 3 seismic structure in the deep mantle and the geoid. The robustness of this striking deep structure was later confirmed in a higher resolution study,[6] highlighting for the first time the presence, near the core-mantle boundary, of a ring of high velocities surrounding two large antipodal and equatorial low-velocity regions that correlate with the location of most major hotspots. These images, first published in color in *American Scientist,* are now textbook references, and the intriguing low-velocity regions, now awkwardly named LLSVPs (Adam preferred the term "pillars of the Earth"), are still the focus of many deep-Earth studies.[7]

In 1979, John Woodhouse's arrival at Harvard started a decade of fruitful collaborations in which John's theoretical talents and Adam's skills at data analysis and inversion combined to produce some major achievements. These include:

Development of the Centroid Moment Tensor (Harvard CMT) Methodology. Adam used long-period waveforms to infer earthquake source parameters,[8] yielding the widely used catalog for global earthquake source and tectonic studies. It was first produced by Adam and his collaborators at Harvard and recently moved to Lamont Doherty Earth Observatory (LDEO) in Palisades, New York, and now called Global CMT.

Development of the First Global 3D Upper-Mantle Model Based Entirely on Long-Period Teleseismic Waveforms. In 1984, for the first time, time domain observed waveforms could be compared to synthetic ones computed in a 3D model using normal-mode perturbation theory, owing to a theoretical "trick" introduced by John Woodhouse to include the effect of heterogeneity that is not symmetric with respect to the Earth's center.[9] This opened the way to more sophisticated waveform tomographic techniques.

Discovery of Inner-Core Anisotropy. In 1986, with graduate student Andrea Morelli, Adam showed that the differences in the travel times of inner core-sensitive P waves for paths quasi-parallel to the Earth's rotation axis versus paths that are equatorial could be due to anisotropy in the inner core.[10] In back-to-back papers, John Woodhouse and students Domenico Giardini and Xiang-Dong Li showed that a similar interpretation worked for the anomalous splitting of core-sensitive normal modes.[11,12]

This decade was arguably the most intense in Adam's career. A tenacious workaholic, he (and John) would work late at night because "things were most quiet then," chain smoking in the Hoffman lab computer room at Harvard, until Adam suddenly decided to quit on January 16th, 1987, a date he still remembered precisely thirty years later. Still further discoveries were in store, notably that of a region of distinct anisotropy in the central part of the inner core, with graduate student Miaki Ishii.[13]

Over the next decades, Adam and his students perfected several generations of long-wavelength global mantle elastic models. Adam always insisted on the significance for mantle dynamics of "degrees 2 and 3 structure"—the longest wavelength heterogeneity in the mantle. He continued investigating this topic, in collaboration with myself and Ved Lekic, long after retirement. At the time of his death, he was advising us on the construction of a three-dimensional reference Earth model that would include the now robustly resolved long-wavelength structure, a critical step beyond PREM for additional advances in understanding mantle mineralogy and dynamics.

Adam was a strong and influential voice well beyond the global seismology community. He was always keenly aware of the importance of combining different disciplines, including geodynamics, mineral physics, and geochemistry, to really understand "how the Earth works." He was a key player in the development of the successful CIDER (Cooperative Institute for Dynamic Earth Research) program, born out of the recognition of the need for a concerted effort to improve understanding of the constraints and limitations across disciplines as well as potential opportunities for collaboration across disciplines. He was the first chair of the CIDER Steering Committee, serving from 2004 to 2007.

An Advocate for Broadband Seismology Infrastructure

Adam acquired an appreciation early in his career for the need for high-quality data for global structure research, and he was fortunate to be in the right place at the right time. When broadband digital seismology became a reality in the mid-1970s, he embraced the quest for developing a new generation of state-of-the-art global seismic observatories. He, Don Anderson, and a handful of other enthusiastic mid-career seismologists in academia worked relentlessly on the establishment of the Incorporated Research Institutions for Seismology (IRIS). When IRIS was finally established in 1984, he served on its first executive committee and inspirationally chaired the first Global Seismic Network Standing Committee and later the Planning Committee and the U.S. Array Advisory Committee.

Adam contributed in other ways towards our current seismological infrastructure. In 1986, with graduate student Joe Steim, he initiated and supported the development of the "very broadband seismometer," which became the gold standard for the Global Seismographic Network. That same year, he was a founding member of the Federation of Digital Seismograph Networks, which still coordinates instrument standards and data exchange internationally, and served as its chair from 1989 to 1994. He also was a founding member of the International Ocean Network (ION), which was established in 1992 to extend the deployment of broadband seismic observatories to the ocean floor. Related to this effort, he participated as co-chief scientist in the OSN-1 experiment off Hawaii (1994–98) to compare qualities of installation of broadband seismometers on the ocean floor and in boreholes, towards complementing the uneven land-based distribution of global seismic stations. He also advised the International Seismological Centre (ISC) and served as chair of its governing council from 1998 to 2005.

Adam was a man of relatively few words, which he chose carefully. He defended his vision with a strong and deep voice that made a lasting impact. In the last years before his passing, he proposed the GABBA (Global Array of BroadBand Arrays) as the next ambitious endeavor for global seismology, a concept that is still making its way in the community under different names. Adam retired from teaching in 2009 as the Frank B. Baird, Jr., Professor of Science. He passed away on March 1, 2016, at the age of seventy-nine.

Honors

Adam shared the 1998 Crafoord Prize with Don L. Anderson "for their fundamental contributions to our knowledge of the structures and processes in the interior of the Earth." He received the William Bowie Medal of the American Geophysical Union (AGU) in 2002 and many other honors, among them the Gold Medal of Ettore Majorana Foundation and Centre for Scientific Culture (1999) and the Harry Fielding Reid Medal of the Seismological Society of America (1999). He was elected to the National Academy of Sciences in 1995. In 1999, he received an honorary doctorate from the Academy of Mines and Metallurgy in Kraków, Poland. He was a fellow of the AGU (1982), of the American Academy of Arts and Sciences (1988), and the American Association for the Advancement of Science (1996).

Adam greatly inspired several generations of young researchers and unselfishly supported the careers of those in whom he recognized talent. I had the privilege of closely collaborating with him on many infrastructure endeavors since the mid-1980s, notably FDSN, ION, and most recently CIDER, and enjoyed many stimulating research discussions with him, even as we often sparred. I will miss him as a mentor, collaborator, and close friend.

Acknowledgment

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