NATURE|Vol 435|30 June 2005

OBITUARY

Keiiti Aki (1930–2005)

Seismologist extraordinaire.

USC/SOUTHERN CALIFORNIA EARTHQUAKE CENTER

Everyone called him Kei, the intellectual leader who for 40 years devised new methods to achieve a more quantitative understanding of dynamic processes within the Earth. Kei Aki died on 17 May on Réunion Island, the volcanic 'hot spot' in the Indian Ocean that had been his home since retirement from academic life. He will be known for his many research results in seismology, as well as for his leadership in developing probabilistic estimates of seismic hazard.

Aki was born in Japan, and wrote that "When I was 19 years old, I applied to the Department of Geophysics of the University of Tokyo, partly because of the simplest entrance examination, only on three subjects, English, Mathematics and Physics". He moved on to seismology and was recruited by Frank Press to the faculty of the Massachusetts Institute of Technology in 1966, and thus to an academic career in the United States.

His scientific achievements include some of the earliest studies using seismic surface waves to estimate fault orientation and direction of slip at the earthquake source. In 1966 he showed how to estimate the 'seismic moment' of an earthquake from seismograms. This measure, equal to the product of fault area ruptured, average fault slip and rigidity, became recognized as the best way to characterize the size of an earthquake source and the strength of its long-period waves. Among many uses of seismic moment are integrative estimates of the earthquake-associated motion between two tectonic plates. When compared with total plate motion derived from geomagnetic, geological and geodetic methods, one learns the fraction of motion on a particular plate boundary that takes place suddenly in earthquakes — permitting estimates of the long-term seismic hazard.

In the 1960s, Aki showed that radiated seismic displacements have a 'corner frequency' below which the spectrum is flat and proportional to seismic moment, and above which it decays as $(\text{frequency})^{-2}$. He showed that seismic coda (the waves following signal onset) can be used to make stable measurements of source spectra.

The following decade, Aki interpreted seismic-wave arrival times at a network of stations to determine the three-dimensional inhomogeneities of Earth structure beneath the network. His 'inverse method' has been applied via instrument deployments on every continent to quantify inhomogeneities in the crust and upper mantle. He also began quantitative studies of fault models that examined the physical features controlling earthquake nucleation, spontaneous rupture, and the eventual stopping of the rupture process on a fault surface because of some barrier or asperity — or because the rupture has run out of a region of stress concentration.

As an observational science, seismology deals with vast ranges of scale. Wavelengths range over a factor of more than 10^8; the time windows over which data are analysed range over more than 10^9; ground displacements range over more than 10^{11}; and the size of seismic sources ranges over about 10^{25}. Consequently seismology is largely conducted as a collection of diverse specialities. Some seismologists interpret signals to map out the remaining commercial deposits in an oilfield; others quantify strong ground-shaking and measure how it decays with distance travelled. Different seismologists study the Earth's internal structure — from the inner core, up through the mantle, and on up to the shallowest structures in the crust. They identify targets for an archaeological dig, find buried pipelines, measure rates of continental deformation, monitor compliance with nuclear test ban treaties, and assess seismic hazard. Aki and his students worked in many of these specialities, and he himself retained a strong and optimistic interest in arguably the most important of them all, earthquake prediction.

In March 1975, he wrote me a letter beginning, "I wonder if you would be interested in coauthoring a text book on theoretical seismology with me...". It was a surprise, for even then he was a senior figure. I was so junior, and we were not then personally acquainted. I accepted, and will never forget our first meeting. As background to our conversation, he jotted down some apparently random descriptive phrases on a large sheet of paper that soon filled to become the working plan and table of contents for what emerged as *Quantitative Seismology*, now translated (with its more than 6,000 equations) into Russian, Chinese and Japanese. His goal was a unified survey that brought out underlying ideas relevant to many different types of seismologist.

In 1984, Aki moved to the University of Southern California, where he could experience earthquake phenomena more directly. He became the founding science director of the Southern California Earthquake Center, where earthquake geologists and the fault model of quantitative seismology were used to make probabilistic estimates of earthquake hazards. He was also fascinated with volcano seismology, which he continued to study in 'retirement', especially on Réunion with its local seismographic network. He studied volcanic tremor, estimated the location of magma chambers, monitored magma ascent and searched for physical causes.

Aki probed more deeply into the phenomena of shaking ground, and with greater insight, than any other individual. He advanced our understanding of how earthquakes nucleate, how they reach their eventual size, and how their signals spread throughout the Earth, carrying information on their origin and what they have traversed. He showed us how to tease out this scientific information about sources and Earth structure. And he successfully faced the challenges of taking information about strong ground motions into the earthquake engineering community, and to policy-makers needing guidance on managing earthquake hazard.

Kei Aki shared ideas with his more than 50 PhD students and numerous postdocs. He helped them to shine, and many are now leaders of their field. He himself was a gentle leader, informal and approachable, pleased with the many honours that came his way but never needing them, calm in adversity, and always eager to hear of new ideas that had some support from data. With his pioneering studies of seismic moment, his results on spectral scaling and coda stability, and his demonstration of successful methods to invert data to infer Earth structure in three dimensions, he provided methods that now guide the work of thousands of Earth scientists around the world.

Paul G. Richards

Paul G. Richards is at the Lamont-Doherty Earth Observatory, Columbia University, 61 Route 9W, Palisades, New York 10964, USA.
e-mail: richards@ldeo.columbia.edu