Paul G. Silver (1948–2009)

Max Planck once observed that a pioneering scientist “must have a vivid and intuitive imagination, for new ideas are not generated by deduction, but by an artistically creative imagination.” Intuitive, artistic, creative—these terms aptly describe the life and mind of Paul Silver, who was killed with his 22-year-old daughter, Celine, in a tragic automobile accident on 7 August 2009.

Paul Gordon Silver was born and raised in Los Angeles, earning his first bachelor’s degree from UCLA in psychology during a time when music was in the air. On graduating in 1970, he began a short but lively musical career, playing in rock and jazz bands from San Francisco to Israel. He returned to the University of California system in 1975 to pursue a second calling, geoscience, picking up a B.A. in geology from Berkeley in 1976 and a Ph.D. in geophysics from the Scripps Institution of Oceanography in 1982. Paul’s application to Scripps did not indicate a strong background in math and physics, but his aptitude was obvious, and he learned very quickly. After a couple of years of rigorous course work and several research projects in low-frequency seismology that ranged from the study of aspherical Earth structure to quantifying large earthquake sources, he submitted a dissertation that won the Carl Eckart Prize for “the most original and most stimulating” thesis of the year. Paul then accepted a staff position at the Carnegie Institution’s Department of Terrestrial Magnetism (DTM), where he remained for the rest of his professional career.

Paul pioneered the use of seismic anisotropy to infer the flow field of the mantle. With Winston Chan and later Martha Savage, Cecily Wolfe, Georg Rumpker, and others, he developed the methodology to measure shear-wave splitting from broadband SKS waves and to relate that anisotropy to the mantle’s mineralogic fabric oriented by bulk flow. He first applied these procedures to records from one of the first modern portable broadband seismic experiments, which he co-led, on the North American craton. He quickly extended those first observations to other continental regions. By showing that the dominant signal in the anisotropy beneath most continental interiors is the result of alignment of olivine grains by past and present internal deformation of the subcontinental mantle, Paul provided a means to image the continental assembly process at depth.

Measurements of shear-wave splitting from another portable broadband seismic experiment that Paul led in western South America indicated that the direction of fast shear-wave propagation in the mantle beneath the subducting Nazca plate is parallel to the trench, rather than perpendicular as might be expected from two-dimensional models of subduction-driven flow. He and Ray Russo argued that such an anisotropy pattern is the consequence of westward movement of the subducting slab relative to South America and decoupling of the slab from the underlying mantle. Last year, with Maureen Long, Paul generalized that result to 13 subduction zones and demonstrated that the shear-wave splitting delay beneath subducted slabs scales with the magnitude of the migration velocity of the slab relative to the overriding plate. Maureen and Paul further showed that the splitting delay in the mantle overlying the slab varies systematically with the ratio of slab migration speed to convergence velocity.

Paul extended his study of the relation between shear-wave anisotropy and mantle dynamics, first to actively deforming continental areas and then globally. With Bill Holt, Lucy Flesch, and others, Paul combined shear-wave splitting measurements with geodetic and geological observations to address the relative motion of the crust and upper mantle in western North America and in central Asia. With Mark Behn and Clint Conrad, Paul showed that the pattern of anisotropy manifested by shear-wave splitting observations in oceanic regions is well-matched if the anisotropy is primarily a signature of modern mantle flow driven by a combination of plate motions and mantle density heterogeneity. In a provocative paper last year, Paul and Mark argued that the history of plate tectonics might be better described by intermittent rather than quasi-steady plate motions, on the grounds that a large reduction of subduction flux may follow closure of a major ocean basin.

By good fortune, Paul’s portable broadband seismic experiment in South America captured, at close range, the largest known deep earthquake (1994 Bolivia). From local records of that event Paul showed that the source dimen-
sions were too large to agree with the prevailing explanation for deep earthquakes, that they are the result of phase changes within a wedge of mantle material dominated by metastable olivine within cold subducted lithosphere. Paul championed the alternative idea that intermediate and deep earthquakes occur on fault structures inherited from near-surface lithospheric deformation that are reactivated at depth by slab dehydration, and with Wenjie Jiao, Linda Warren, and others he sought seismic and laboratory observations to test that hypothesis.

Paul also made important contributions to the mechanics of shallow fault zones. He loved a good argument, and he was naturally drawn to the controversial question of whether earthquakes might be predictable. With his wife and colleague, Nathalie Valette-Silver, Paul showed that geyser eruption intervals in hydrothermal areas demonstrated changes in advance of nearby large earthquakes. With Steve Gao, Alan Linde, and Selwyn Sacks, Paul discovered an annual periodicity in the seismicity of hydrothermal areas triggered by the 1992 Landers earthquake. Arguing that annual variations in atmospheric pressure were the cause, he and his colleagues deduced that very small changes in stress can affect earthquake occurrence. Together with Taka’aki Taira, Fenglin Niu, and Bob Nadeau, Paul recently documented temporal variations in the locations of seismic wave scatterers and the characteristics of repeating earthquakes—both proxies for changes in fault strength—allong California’s San Andreas fault that coincided with the passage of seismic waves from two large but distant earthquakes. Their findings imply that a large earthquake anywhere can affect the likelihood of earthquakes worldwide and, indeed, that the 2004 Sumatra-Andaman great earthquake may herald a higher than average rate of large earthquakes.

These highlights of Paul’s work serve to illustrate the extraordinary diversity of his interests, his consistent focus on large-scale issues, and the broad impact of his findings. A true pioneer, he tended to roam on the wild side of geodynamics and seismology, and he was more likely to write the first words on a subject than the last. He authored his share of lengthy treatises in Journal of Geophysical Research and the Bulletin of the Seismological Society of America, but his preferred medium for communicating research was the short paper in a high-profile journal such as Science (nine papers), Nature (nine papers), and Geophysical Research Letters (22 papers). More often than not, his ideas stimulated thinking along lines that diverged from conventional views, revising our notions about how the planet works.

Paul also invested generously of his time to advance the infrastructure of Earth science. He served as the president of the American Geophysical Union (AGU) Seismology Section and as chairman of the boards of both UNAVCO and the Incorporated Research Institutions for Seismology. Paul originated the concept of the Plate Boundary Observatory more than a decade ago and guided its development as part of the National Science Foundation’s EarthScope Project. His vision of dense geodetic and strainmeter arrays to monitor time-dependent deformation along the North American plate boundaries has become a national facility with a broad constituency.

Paul had an unmatched ability to intrigue, motivate, and guide the young scientists who regularly came to DTM for postdoctoral fellowships. His resume lists more than 30 individuals who began their collaborations with him in this manner. Many continued to work with Paul long after they moved on to positions at other institutions, their joint papers evidence of the impact that his mentorship had on their careers.

Paul enjoyed speculating on the larger issues of science (you may have heard him propound, for instance, on his theory of left-handed civilizations), and he was a great promoter of informal scientific discourse. While a graduate student at Scripps, he organized a remarkable series of conversational dinners on diverse topics such as “Why does mathematics work?” and “Seismology of the human brain,” to which he invited physicists, biologists, and mathematicians, as well as geoscientists. Those who attended remember well one hilarious exchange in which the biologist Francis Crick responded to the geophysicist George Backus with the retort, “You, sir, do not understand normal modes!” In further discussions expertly moderated by Paul, Crick learned otherwise.

For Paul, scientific and intellectual zeal were balanced by a love of physical activity—from basketball and volleyball to hiking and windsurfing—and by devotion to family. When Paul, the geophysicist, was introduced to Nathalie, the geochemist, at one of his first AGU meetings, his eyes literally lit up. The physical chemistry and deep affection that bonded them were an important source of Paul’s joie de vivre. Outgoing and persistently good-humored, Paul was adept at brokering disparate viewpoints, building consensus, and recruiting cohorts to a cause. Because of those skills, Paul was tapped to head both his neighborhood association and the PTA at his daughters’ school. Paul’s passion for music remained undiminished throughout his life, and his talents as a percussionist anchored a jazz trio that played regularly throughout greater Washington, DC.

Among his other honors, Paul was elected a Fellow of the American Academy of Arts and Sciences in 2007, and he was the Royal Astronomical Society Harold Jeffreys Lecturer in 2005. He was also an AGU Fellow, a Fellow of the Geological Society of America, and a member of Phi Beta Kappa.

Paul is survived by his wife, Nathalie, of North Bethesda, Maryland; his daughter, Karen Silver, of Baltimore; and his two sisters, Ellen Silver, of Santa Rosa, California, and Lauren Silver, of Indianola, Washington. He is deeply missed by his family, friends, and all of us who were touched and inspired by his creativity, his energy, and his exuberance.

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