In Memoriam

Jack H. Healy (1929–2012)

John (Jack) H. Healy, a visionary geophysicist whose career was spent at the U.S. Geological Survey (USGS), died in the company of his family on 6 March 2012. His memory is cherished by all who had the privilege of knowing him. His scientific legacy survives him at the USGS Earthquake Science Center in Menlo Park, California, where research projects he founded continue to flourish.

Jack was born in Chicago, Illinois, on 7 August 1929 and grew up in Wausau, Wisconsin, a small, midwestern city noted for its lumber mills and a large, national insurance company. Initially an indifferent student, Jack, an only child, became more academically focused following the death of his father. After his mother died when he was 16, he lived alone in his parents’ home until he graduated from high school. His midwestern social environment and the loss of his parents undoubtedly had a life-long impact on Jack’s close relations with others. Jack was personally very warm and concerned about those around him, both new acquaintances and those he had known for decades. For this reason, and because he was a deep, independent thinker, many people consider Jack to be the person who had the most profound influence on their lives, both scientifically and personally.

Jack entered the Massachusetts Institute of Technology (MIT) in 1947 and completed a senior thesis in 1951 based on geological field work conducted in the summer of 1949 in Nova Scotia. The work was carried out under the direction of Walter L. Whitehead and Robert R. Shrock, two professors who founded the MIT-Nova Scotia summer field program. His thesis, co-authored with two other MIT seniors, argued for an extrusive origin for a suite of rocks that had previously been identified as intrusive. Jack’s firm grounding in geology was an excellent preparation for a career that would focus on deep geophysical studies of continental crust. The travel to Nova Scotia had a second, very significant benefit to Jack—it was there that he met Mary MacDonald, becoming his life-partner of 60 years. He and Mary were married in 1951, thereby forging a Scottish-Canadian/Irish-American union. They eventually had five children: Anne (b. 1952), Joan (b. 1955), Paul (b. 1956), Brian (b. 1958), and the youngest, Margaret (b. 1962).

While at MIT Jack joined the Reserve Officers Training Corps (ROTC) and graduated as a second lieutenant. He worked as a member of the military at the U.S. Air Force Cambridge Research Center in Boston from July 1951 through 1953 and was, thus, not assigned to combat duty in Korea. In Cambridge, he was assigned the task of evaluating the effect of heavy rain and fog on the effectiveness of an explosive blast. The work involved suspending large spherical explosive charges from wooden tripods and making pressure measurements at a distance. The air blast from one of his charges blew out the windows of a powerful U.S. congressman’s Chesapeake Bay summer home, resulting in the relocation of the project to a remote corner of northern California. Jack would continue to detonate seismic explosives throughout his career, occasionally inadvertently blowing out the odd window of a government field vehicle.

The Korean Armistice was signed in July 1953 and the U.S. military began downsizing, eventually allowing Jack to leave the Air Force and try his hand at field geophysics. He worked for three years in the oil exploration industry as a seismic doodle-bugger (field hand) in Louisiana. The migratory life of seismic exploration work, however, was ill-suited to raising a growing family, and the U.S. government’s G.I. bill offered the option of financial support as a graduate student. Jack was accepted for graduate study at Caltech in 1956. With the G.I. bill deadline for enrollment as a full-time student just a week away, Jack and family raced to the (old) Seismo-Lab at Caltech in Pasadena and asked Professor Frank Press to advance his matriculation date to June 1956, in order to meet the government’s deadline. His request was granted by the ever-gracious Professor Press.

Four very happy and productive years of graduate study at Caltech ensued, culminating in a Ph.D. thesis in 1961. Classmates receiving a Ph.D. in the same year were Bob Phinney, Stewart Smith, and Ari Ben-Menahem, and those graduating shortly thereafter included Don L. Anderson, Bob Kovach, M. Nafi Toksoz, David G. Harkrider, Shelton Alexander, and personally.

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and Charles B. Archambeau. All of these people remained Jack’s life-long friends. Their colorful interactions as graduate students were extensive and were a source of countless amusing anecdotes that commonly began along the lines of, “We were all sitting in a dimly lit cowboy bar in Lone Pine, California, when in walked two local ranchers, clearly annoyed that their favorite bar stools were occupied by squatters…”

Jack’s thesis presented interpretations of shallow seismic refraction and gravity data from several basins on the eastern flank of the Sierra Nevada. Scientific guidance was provided by Professors Clarence Allen and Charles Richter as well as Frank Press. Jack’s life-long interest in the Earth’s crust, tectonic processes, and earthquakes were presaged in a characteristically philosophical concluding paragraph to his thesis, which states: “The area appears to provide an excellent opportunity for the study of tectonic processes… in particular, a detailed study of the nature and location of earthquakes with respect to these (crustal) structures, and detailed knowledge of… the crust in the region would provide important information about the tectonic process.” In the years to follow, Jack pursued his quest to understand the linkage between physical processes in the crust and the occurrence, and even prediction, of earthquakes.

In June 1961, Jack was hired by Louis C. Pakiser to work for the USGS Branch of Crustal Studies in Denver, Colorado. Lou, a close friend of Frank Press, was an excellent judge of scientific merit in young scientists. Pakiser himself had carried out numerous seismic refraction measurements and gravity surveys, so he and Jack shared many common scientific interests. At that time the Branch of Crustal Studies had no direct funding from the USGS and was entirely dependent on funds from the Department of Defense (DOD), which provided support for studies of seismic wave propagation in the western United States. These studies were related to the monitoring of nuclear tests. A limited nuclear test ban treaty, signed by President John F. Kennedy on 7 October 1963, prohibited the testing of nuclear weapons in the atmosphere, in outer space, and under water. However, underground nuclear tests were permitted, and seismic monitoring was the primary means of identifying such tests.

Effective monitoring of nuclear tests required a detailed knowledge of seismic wave propagation in the crust and uppermost mantle. Hence, the DOD provided support for a network of 64 seismic-refraction profiles in the western United States that were acquired by the USGS, between 1961 and 1963. These active-source profiles calibrated passive seismic monitoring systems by measuring seismic travel-times and amplitudes for controlled, explosive sources, as well as determining the regional P-wave seismic velocities of the crust and uppermost mantle. Jack and Lou provided the overall project leadership with critical support from numerous colleagues, including Jerry P. Eaton, Sam W. Stewart, Wayne Jackson, John C. Roller, and David J. Stuart. Field hands included Roger Borcherd, David P. Hill, and Mitch Pitt. The results were presented in numerous publications, including the comprehensive USGS Professional Paper 1034 authored by Claus Prodehl (1979). As a scientific discipline, seismic crustal imaging, begun in the early 1960’s by Jack Healy and Lou Pakiser, has continued up to the present day at the USGS, thereby surpassing 50 years of active research.

The 1964 the Good Friday earthquake in Alaska provided the stimulus for an additional line of research for the USGS Branch of Crustal Studies. In 1965, in response to the event, a panel of the National Academy of Sciences recommended a 10-year program of research on earthquake prediction. In what may now be recognized as a prescient decision, the USGS decided to move the Branch of Crustal Studies from Denver to Menlo Park to form the nucleus of a National Center for Earthquake Research. Leadership was provided by Jack, Lou Pakiser, Jerry Eaton, Robert E. Wallace, and Barry Raleigh. Although short-term earthquake prediction has proven to be a more elusive goal than originally envisioned, the earthquake research center initiated in Menlo Park in 1965 was the foundation for the present USGS Earthquake Science Center, with offices in Pasadena, Menlo Park, and Seattle.

Jack always remained at the center of earthquake research at the USGS. A seminal study was the 1968 Science paper, “The Denver Earthquakes,” written with William W. Rubey, David T. Griggs, and C. Barry Raleigh (Healy et al., 1968, Science, Vol. 161, pp. 1301–1310). That paper examines the hypothesis that a series of earthquakes felt in Denver from 1962 to 1967 was induced by the injection of chemical-waste fluids at a deep disposal well at the U.S. Army’s Rocky Mountain Arsenal. This much-cited paper presents statistical evidence for a close correlation between the fluid injection and the Denver earthquakes, as well as proposing a physical model of the mechanism for inducing these earthquakes based on increased pore-fluid pressures. Jack’s initial foray into understanding the factors controlling earthquake occurrence was...
followed by a life-long pursuit of the physics and statistics of earthquakes.

To further evaluate the role of fluid pressure in earthquake generation, Barry Raleigh, John Bredehoeft, and Jack investigated earthquakes occurring within a large oil field in Rangely, Colorado. It appeared that the Rangely earthquakes were being triggered by fluid injection at two locations where faults crossed the field. Raleigh and others presented a landmark study with the audacious title "An Experiment in Earthquake Control at Rangely, Colorado," (Raleigh et al., 1976, Science, Vol. 191, pp. 1230–1237) which showed that these earthquakes could be turned on and off by raising and lowering fluid pressure. The key discovery was that "variations in seismicity were produced by controlled variations in the fluid pressure in a seismically active zone." This work laid the scientific foundation for much of the ensuing effort to understand injection- and reservoir-induced seismicity, which has received renewed attention in recent years with the advent of large-scale hydraulic reservoir stimulation in geothermal energy projects and the deep-well disposal of fluids produced from oil and gas, and other operations. Jack and his colleagues came to the realization that surface observations were insufficient to study earthquakes; it would be necessary to drill deep into fault zones to monitor, and even control, fault-zone fluid pressures. This insight led to a new chapter in Jack's scientific life: deep scientific drilling as a means to understand the physics of earthquakes.

Deep drilling is not for the faint of heart. Technically it is difficult, scientifically it is rewarding, but time consuming and financially it is demanding. Jack was not easily dissuaded by such challenges and he found a like-minded scientific partner in Mark D. Zoback, a newly minted Stanford Ph.D. hired by the USGS in 1975. Together, they realized that deep drilling provided the best opportunity to measure fluid pressure as well as the state of stress along active fault systems. Over the next 10 years, Mark, Jack, and their colleagues John Roller, Stephen Hickman, Joann Stock, and Hiroaki Tsukahara would revolutionize deep scientific drilling by making in situ stress measurements at such places as Yucca Mountain, Nevada, and along the San Andreas fault, including in central California and in the Cajon Pass, located east of Los Angeles. This work was summarized in the seminal paper entitled "New Evidence on the State of Stress of the San Andreas Fault System," (Zoback et al., 1987, Science, Vol. 238, pp. 1105–1111), one of the most frequently cited papers in all of geophysics. In addition to Jack, co-authors included Mary Lou Zoback, Van S. Mount, John Suppe, Jerry Eaton, David Oppenheimer, Paul Reasenberg, Lucile Jones, Barry Raleigh, Ivan Wong, Oona Scotti, and Carl Wentworth. The results formed the basis for the development of a fault-zone deep drilling project at Parkfield, California, known as the San Andreas Fault Observatory at Depth (SAFOD), initiated by Mark Zoback, Stephen Hickman, and Bill Ellsworth as part of the EarthScope project, and cooperatively funded by the National Science Foundation, the USGS, and the International Continental Scientific Drilling program.

Jack always placed a high priority on international science. The Cold War was at its height in the late 1960s, resulting in very limited scientific exchanges between U.S. scientists and those in what was then the U.S.S.R. In August 1968, the Institute of the Physics of the Earth of the Russian Academy of Sciences, Moscow, had organized an international conference on seismic studies of the Earth's crust. However, international participation at this meeting was suddenly thrown into doubt when Russian tanks rolled into Prague on the night of 21 August 1968 to quash the "Prague Spring" in Czechoslovakia. Already in Germany en route to Moscow, Jack faced the difficult decision of choosing between personal loyalty to his Russian scientific counterparts and a political boycott of the meeting. It came as no surprise to Jack's friends that he chose personal loyalty, thereby helping solidify Russian-American scientific cooperation during the decades that followed.

The volatile Middle East did not escape Jack's scientific attention either. In the early 1970s USGS colleague Gordon E. Andreasen alerted Jack to an opportunity to build a seismic monitoring network in Jordan. Jack was determined to seize...
this opportunity to promote "peace through science" and successfully negotiated a plan for seismic data-sharing with Israel. The project was not without challenges, and some tragedy as well. Andreasen suffered serious burns in an accident in the field, and unanticipated policy or fiscal changes often required major adjustments to technical plans. Despite these setbacks, the project continued and the Jordanian seismic network is fully operational today.

Jack's vast experience in seismic crustal studies, his love for instrument development, and his tireless (some would say tenacious) devotion to field work found a perfect outlet in the late 1970s in an ambitious project to record a controlled-source seismic-refraction profile across the Arabian shield. This project was undertaken with Richard Blank and Mark Gettings, who were based at the USGS mission on the site of the Saudi Geological Survey in Jeddah, Saudi Arabia. Jack's team designed a field program that called for 10 deep borehole or marine shots and recording with 100 newly developed, portable seismographs. These seismographs, dubbed the USGS cassette recorders (for their FM cassette data tapes), revolutionized controlled-source seismology. Although they were first used in Saudi Arabia, these seismographs remained in use for 20 years in the United States. Key contributors to the development of the cassette recorders were John van Schaack, Gray Jensen, Bob McClearn, and Fred Fischer. In 1978 I was hired by the USGS to work with Jack and his colleagues on the interpretation of the Saudi Arabian seismic-refraction data. Our close relations lasted more than 30 years. Beginning in 1979, Jack, Bob Hamilton, Gary Fuis, and I organized numerous controlled-source experiments, with able field assistance from John van Schaack, Ed Criley, and Ron Kaderabek. These large-scale crustal imaging experiments continue to this day, including across the San Andreas Fault in central and southern California, under the skilled leadership of people such as Gary Fuis and Rufus Catchings, who continue Jack's legacy of linking the mechanics of faulting to plate-boundary processes and large-scale crustal structure.

In 1989, non-USGS investigators claimed to have predicted the deadly M 6.9 Loma Prieta, California, earthquake. As a result, Jack became fascinated with earthquake prediction algorithms that are based on the analysis of earthquake statistics. He focused, in particular, on the Russian algorithm known as M 8. Together with Vladimir (Volodya) G. Kossobokov and Jim W. Dewey, he designed future tests for this algorithm that would preclude cheating or self-deception. The goal was to eventually produce a definitive evaluation of the merits of this algorithm. Their methodology was published as a USGS Open-File Report (Healy et al., 1992).

Jack retired from the USGS in 1995, at age 66, after 34 years of service. As usual, his timing was excellent because he would enjoy 12 years of excellent health, enabling trips to visit family and friends, and time to read, relax, and indulge in perhaps his favorite activity—discussion and debate with friends. Soon after retiring, Jack and Mary drove the trans-Canadian highway, eventually making their way to Newfoundland and Nova Scotia. A road trip to Alaska followed, as well as visits to Ireland, the United Kingdom, Italy, France, and China. Jack suffered a serious stroke in December 2007, and his health gradually deteriorated over the next four years and three months.

Ever a loyal friend, Jack was visited by a steady stream of visitors at the Healy household in Palo Alto, where Mary, a subset of the five children, and an ever-present dog could also be found (they’d had a dozen dogs over the years). Topics for discussion invariably included economics (especially the stock market), international affairs, and national politics. Rising stocks were favored over falling ones, interesting countries over dull ones, and liberal policies over conservative ones. His personal religious convictions, while deeply held, were never displayed unless solicited, but guided his pursuit of truth and science applied to the public good.

Many scientists will remember Jack as the wisest, most supportive mentor in their scientific careers. He had the rare talent of being critical while also being supportive and caring. He was intolerant of sloppy thinking, but he found a way to encourage quality thinking without stifling creativity. He promoted independence and intellectual growth by giving great freedom to junior scientists. He managed to challenge their ideas at just the right time to encourage deeper thinking about scientific fundamentals. He was always entertaining, whether railing against a perceived wrong or quietly commenting on life’s ironies. He had a magnetic personality that drew people to him, and developed fierce loyalty in family, friends, and coworkers. Jack was that rare person that one feels very fortunate to have met during life’s long journey. He will not be forgotten and his scientific inspirations live on in the younger scientists whom he nurtured during his long, productive career.

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