



Carolyn and Gene at the telescope used for their survey of asteroids and comets (credit USGS)

Memorial – Carolyn S. Shoemaker (1929-2021)

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Among a stand of Ponderosa trees, on a ridge with a clear view of the San Francisco Peaks and star-filled skies overhead, an extraordinary woman raised a family and then became one of America's best-known astronomers. Carolyn Spellman Shoemaker, born in Gallup, New Mexico, and raised in Chico, California, passed away August 13, 2021 in Flagstaff, Arizona, a community that revered her as a northern Arizona pioneer. I had the good fortune of working with Carolyn on several projects, including the Planetary Geology Division's Eugene M. Shoemaker Impact Cratering Award. For that reason, I was asked to write a few words about her and the wonderful life she lived.

Carolyn began her academic career with a master's degree in history and political science, becoming a teacher, before learning science while working with her husband, Gene, of 46 years.

Soon after they were married in 1951 and moved to Grand Junction, Colorado, she went into the field with Gene when he was mapping. There she learned the stratigraphy and structural deformation of the Colorado Plateau. Gene soon became involved in Apollo, first at NASA Headquarters in Washington DC in 1962, and then to the new USGS Branch of Astrogeology in Flagstaff in 1963, where stratigraphic mapping, the development of field geological tools, and geologic training for the Moon began, and where Carolyn sank roots that would last the rest of her life.

Despite the demands of the Apollo program, Carolyn and Gene continued to explore the western landscape. In 1968, in the midst of final preparations for the Apollo 11 mission, the USGS sponsored a photographic survey of the route taken by John Wesley Powell's 1871-1872 run of the Green and Colorado Rivers. Carolyn joined Gene on the second and third legs of the expedition, from the Flaming Gorge Dam to the town of Green River, Utah.

After the Apollo 11 mission, Carolyn and Gene moved to Pasadena, California (while keeping their home in Flagstaff). There Carolyn had a scientific awakening during the Voyager mission. As she later wrote: "I shall never forget walking over to the Caltech campus, where, on a large screen in Beckman Auditorium, images of the Jupiter flyby were being displayed as they came in. Then and there, I fell in love with planetary science, the skies, our solar system, and the universe. I was excited and captivated. Exploration of the Moon during Apollo days had been vicariously, for me, a heady experience, but the idea that *I* could look at Jupiter and its moons in something like real time left me awestruck."

Carolyn began learning and eventually teaching astronomical techniques at Caltech. In 1982, she and Gene began the Palomar Asteroid and Comet Survey (PACS). She found her first near-Earth asteroid that same year (1982 RA) and soon thereafter found her first comet while scanning films in Flagstaff that had been captured at the Palomar Observatory. The find was designated Comet Shoemaker 1983p. Carolyn was captivated by the search and discovery process. By the time PACS ended in 1994, she had discovered a world record 32 comets. Within a dozen years, Carolyn had surpassed the accomplishments of many other investigators who spent an entire career scanning the skies.

Among the most famous of those discoveries was Comet Shoemaker-Levy 9, detected by both Shoemakers and David Levy in 1993, after the ice-rich denizen had split into 21 fragments during a close pass of Jupiter in 1992, and before the fragments hit Jupiter, one after the other, in dramatic fashion in 1994.

The scientific community recognized Carolyn's accomplishments in several prestigious ways, both before and after the discovery of Comet Shoemaker-Levy 9. In 1985, Hildian asteroid 4446 Carolyn was named in her honor. In 1988, she and Gene received the Rittenhouse Medal from the Rittenhouse Astronomical Society. In 1996, she received an honorary doctorate degree from Northern Arizona University and NASA's Exceptional Scientific Achievement Medal. In 1998, she and her husband were bestowed the James Craig Watson Medal by the U.S. National Academy of Sciences. That joint award was particularly important, because, as Carolyn later noted, "Together, we could do more than either of us alone."

As their work so eloquently illustrated, asteroids and comets continue to pummel planets and produce impact cratering phenomena. In an effort to study both the cause and effect of collisional processes, Carolyn and Gene augmented their astronomical survey of the heavens with a geological survey of Australian impact structures, studying 17 impact sites between 1984 and 1997. Sadly, that work was interrupted by a tragic accident that injured Carolyn and claimed the life of her husband.

In the aftermath of that event, Carolyn contacted Caltech geologist Lee Silver and me with an idea for an award in memory of Gene that we both quickly endorsed. Carolyn provided seed money for the award's endowment, which I helped her shepherd through the GSA Foundation. Officers and members of the Planetary Geology Division endorsed the initiative and provided sufficient funds for the endowment to begin supporting student research in 1999. The award has since sponsored the research of 22 students, including a few students who are now professors and researchers in our community. As the outline of the award describes, Carolyn "established the endowment so that students will have an opportunity to pursue studies of impact craters, which was the focus of her husband's graduate student studies and a large part of his professional career." The award has a broad scope: it is for undergraduate and graduate students of any nationality, working in any country, in the disciplines of geology, geophysics, geochemistry, astronomy, or biology. The award is to be applied to the study of impact craters, whether they be on Earth or any other solid body in the Solar System. The focus of proposed work can be on cratering process, the bodies (asteroidal or cometary) that make the impacts, or the geological, chemical, or biological results of impact cratering.

In addition to that endowment, Carolyn continued to inspire students and the general public with summaries of the work she and Gene had done together. She was an advocate of science education and an active member of the Lowell Observatory Advisory Board for many years.

In the midst of a pandemic that forces so much distance between people, I find Carolyn's last words in an autobiographical article to be particularly important: "Since the time of the accident in which I lost Gene, the awareness of our human need for others has dominated much of my thinking. Family and friends have been very important in my own recovery, and the concept of their importance, I discover, is as essential as the need for knowledge of our physical world. Without the human relationships we cherish, knowledge would count for naught; both are to be nourished. Henceforth, I'll continue my scientific exploration, knowing that I must not neglect the other side of living." She did not neglect either side of living and we are thankful for the opportunity to have known her.

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*Wolfe Crater in Australia (credit Wolfe Creek Crater National Park), which Carolyn and Gene mapped together with Frances McDonald (E. M. Shoemaker, F. A. Macdonald & C. S. Shoemaker (2005) *Geology of five small Australian impact craters*, *Australian Journal of Earth Sciences*, 52:4-5, 529-544).*