JOHN ALOYSIUS O'KEEFE

13 October, 1916 - 8 September, 2000

John O'Keefe, who achieved prominence in geodesy, astronomy, geochemistry, and planetary physics, died on 8 September, 2000, at the age of 83. His lengthy scientific career chronologically splits roughly into two segments: as a geodesist up until about 1960, and as a planetary physicist thereafter. Readers of this article who can recall the great forward strides made in geodesy during the fifteen years following World War II will surely remember the pioneering role played by O'Keefe in modernizing geodetic techniques and globalizing geodetic knowledge. Subsequently, his research into the origin of the Earth-Moon system and, in particular, his belief that tektites were ejecta from the Moon absorbed him, and he concentrated almost exclusively on these topics. But his geodetic accomplishments during the first part of his career left a deep and lasting influence on the subject.

Educationally, O'Keefe was trained as an astronomer, receiving a Bachelor's degree from Harvard University in 1937, and a Doctorate of Philosophy from the University of Chicago in 1941. Unable to serve in the military during World War II because of a physical disability, he entered civilian U. S. government service in 1942 as a mathematician for the Army Corps of Engineers. The Corps was responsible for producing topographic maps and the geodetic data required for military intelligence and artillery firing. One of O'Keefe's assignments entailed traveling to China after the end of the war in order to acquire maps and geodetic records while they were still available. The successful outcome of his effort was recognized by the presentation of the Army Meritorious Civilian Service Award.

In 1945 the Army Map Service (AMS) was formed as the component of the Corps of Engineers designated to carry out its mapping and geodetic missions. Floyd Hough, Chief of the Geodesy Division of AMS, appointed O'Keefe to head the Research and Analysis Branch with the responsibility for geodetic research and development. During the 13 years O'Keefe held this post, he not only made significant individual contributions to geodesy, but mentored and inspired members of his staff, thus creating an establishment whose productive output during this period equalled that of any other geodetic group in the U. S. Initially the most important geodetic task facing AMS was the conversion of geodetic coordinates on diverse datums to a single system, entailing transformations of coordinate systems, reference ellipsoids, and datum origins. In particular, Hough had acquired a massive set of such material covering the area of central Europe. O'Keefe was the dominant figure in the fulfillment of this assignment. The chief elements involved were the choices of transverse Mercator coordinates, the International ellipsoid, and a unified European datum, and means for converting from given data to these. O'Keefe realized the advantages of a transverse Mercator (Gauss-Krieger) coordinate system. First, its conformality preserved directions for artillery firing; second, adjustments could be simplified by employing complex variables; and third, the globe could be covered by identically produced zones. Army Map Service Technical Manual 19 (1948), due in large part to O'Keefe, records this thoroughly. Two publications in the Transactions of the American Geophysical Union (TAGU) cover his research into datum adjustments (August 1947) and ellipsoidal transformations (December 1953). But it must be emphasized that O'Keefe did not work solely as an individual researcher; he led a team, and had an operational mission to execute. He sought out experts as needed, for example, bringing Helmut Wolf to AMS for an extended period in the late 1940's to instruct Branch members in the Anfelderung method. He played an instrumental role in justifying the need by AMS for one of the first commercially available electronic computers—the UNIVAC.

O'Keefe was the first American geodesist to appreciate the original work of Antonio Marussi in developing 3-dimensional geodesy by utilizing tensor analysis. In a paper in the April 1951 TAGU, O'Keefe pointed out how the machinery of tensor analysis could be applied to many geodetic problems, presaging the magisterial work of Martin Hotine some years later. In 1951 Marussi visited AMS at O'Keefe's invitation, and they exchanged fruitful ideas on conformal representations and tensor applications.

One of the most important geodetic accomplishments of the late 1940's was the discovery published (TAGU, August 1949) by Carl Aslakson from Shoran surveys that the then-accepted value for the velocity of light was too small by 16km/sec. O'Keefe participated in the experiments involved, providing valuabletechnical contributions. Another important geodetic concern for AMS, and indeed, the most important geodetic problems for geodesy overall were the determinations of global positioning and of global gravity. The state of knowledge in these areas around 1950 was much closer to that of 1750 than to 2000. It was natural for O'Keefe by his inclination and training to attack the problem of global positioning from the perspective of an astronomer. In the pre-satellite era, this meant utilizing solar eclipses and lunar occultations. Deficiencies in observational opportunities and in observing equipment hindered the acquisition of useful results, but by the occultation technique he was able to extract relative positions of some widely separated Pacific islands with respect to each other to within 100 meters (a vast improvement). A byproduct of these experiments was a revised value of the lunar parallax (Bulletin Géodesique, 29, 1953). O'Keefe realized in the early 1950's that close Earth artificial satellites would serve geodetic needs much better, and lobbied for their launch to the highest authorities in the U. S. Department of Defense. He set forth his ideas in a short note appearing in the February 1955 issue of Jet Propulsion, "The Geodetic Significance of an Artificial Satellite", which is truly a landmark paper in the history of geodesy. In it he pointed out the efficacy of such a celestial object for the determinations of relative positions between continents, a reference value for terrestrial gravity, and the size of the Earth's semimajor axis. Well before the launch of Sputnik in 1957, he demonstrated (Astronomical Journal, August 1957) that the ellipticity of the Earth's equator (J22) could be obtained from satellite observations.

Of course, the launches of the Sputnik, Explorer, and Vanguard satellites in late 1957 and early 1958 revolutionized the geodetic world. Since O'Keefe had long anticipated this, he was among the first to obtain results, both dynamic and geodetic. He collaborated with the Naval Research Laboratory in designing the Minitrack tracking network, and helped adapt a simplified version (Mark II) as a replacement for the occultation stations in the Pacific. He reported in June 1958 (Harvard College Observatory Announcement Card 1408) a value of 1/298.38 for Earth's flattening, the first such obtained from Vanguard I, confirming results from Sputnik I on the considerable deviation from the 1/297 value of the International Ellipsoid.

In late 1958 O'Keefe decided to join the newly constituted NASA Goddard Space Flight Center (GSFC) as Assistant Chief of its Theoretical Division. His incentives were the opportunity to concentrate on research with less operational responsibilities and security restrictions, and the ability to engage in projects more attuned to his own desires which lay in the more purely astronomic domain. But his first work at GSFC was a direct continuation of his investigations at AMS on the data flowing in from the artificial satellites. In December 1958, just after O'Keefe's arrival at NASA, Harvard College Observatory Announcement Card 1420 reported that O'Keefe and his associate, Ann Eckels, had discovered a perturbation in the orbit of Vanguard I which could be attributed to the third zonal harmonic (J3) of the Earth's gravitational field, producing a geoid undulation of about 15 meters, positive in the Southern Hemisphere. This result became popularly known as yielding a "pear-shaped" Earth, and because of its propitious (albeit exaggerated) phrasing turned out to be O'Keefe's best known geodetic accomplishment. A more complete calculation of even and odd zonal harmonics was published in the Astronomical Journal, September 1959.

Even before leaving AMS, O'Keefe had become fascinated by the question of the origin of tektites and the relationship of this problem to the origin of the Earth-Moon system, and he wanted to focus on this field of research. But he did not completely abandon his geodetic interests. He was struck by the difference between the satellite-observed value of the flattening, 1/298.3, of the standard Earth model and that consistent with the hypothesis of hydrostatic equilibrium, 1/299.8, and the implications of this for global tectonic theory. He showed (Journal of Geophysical Research Dec 1959) that classical isostatic theory was inadequate to account for this difference, and argued in subsequent presentations that the hydrostatically flattened ellipsoid was the best reference figure for tectonic (as opposed to geodetic) analysis. Probably the last major publication by O'Keefe on a geodetic topic was a proposal for the replacement of the semimajor axis in the IAG Earth reference model by the equipotential value of the bounding surface (Bull Geod., 111, 1974). Currently this subject is an active topic of discussion within the IAG, providing another example of O'Keefe's remarkable foresight.

Of O'Keefe's substantial research outside the geodetic area, just one example is mentioned here to illustrate his versatility. In 1986 a Nobel Prize was awarded to two Swiss physicists for the development of a scanned-probe microscope, which can discern objects smaller in dimension than wavelengths of visible light. The principle by which this can be achieved was found by O'Keefe (independently of an earlier discovery by E. H. Synge) in 1956 (Scientific American, October 1989). Unfortunately, the requisite technology was not available until many years later. Left untouched in this account are discussions of O'Keefe's abundant output in many aspects of planetary science, which far exceed in volume his geodetic contributions. Despite becoming disabled by a severe case of Parkinson's disease over the last decade of his life, he remained scientifically inquisitive to the end. He retired from GSFC in 1995. When his physical problems caused him and his wife to move from the Washington DC area, their home for 50 years, to South Dakota in 1999, he remarked that he was looking forward to investigating certain types of rocks there which might be related to tektites.

O'Keefe was chosen in 1962 as one of the original Fellows of the American Geophysical Union. In 1985 Alfred University awarded him an honorary Doctorate of Science. GSFC bestowed on him the Award of Merit, its top honor, in 1992. In 1997 an asteroid was named after him in recognition of his many contributions to planetary science. His typical insistence that his subordinates take full credit for achievements in which he himself had played a significant role precluded him from receiving much of the geodetic acknowledgment he deserved. For example, the bulk of my own work at AMS on geodetic effects on guided missiles, on map projections, and on the figure of the Earth depended in great measure on O'Keefe's guidance and assistance.

For sheer creativeness, John O'Keefe surpassed any geodesist I have known. The wealth of imaginative ideas that poured out of his fertile mind reminded me of a mature oak tree shedding its innumerable acorns, many of which did not take root, but enough sprouted to raise a magnificent geodetic forest, examples of which have been mentioned above. Another distinctive trait was his enthusiasm, which often exceeded conventional bounds. His public presentations could be flamboyant, as the following anecdote illustrates: At the 1957 IAG General Assembly in Toronto, O'Keefe was giving a talk on the inadequate knowledge of Pacific island positions. He drew a line at chest level on the lower segment of the two- piece vertical blackboard, and stated "The average deflection of the vertical in the United States is about 4 seconds of arc." He continued by drawing a line on the same board as high as he could reach, saying "However, at some U. S. points the deflection could be over 10 seconds. But, at Pacific islands the deflection could reach ...", and then he tried to draw the corresponding line by pulling down the upper blackboard segment. By mischance it stuck, but O'Keefe was not deterred and flung the piece of chalk upward, proclaiming "...30 seconds of arc!". Charles Whitten, who was presiding on the lectern at the session, had his back turned, and was unaware of what had occurred until he noticed flecks of chalk descending onto the top of his head.

The main inference to draw from this story is that O'Keefe was never boring. His vehemence was limited to scientific opinions, and seldom carried over to personal relationships. As my supervisor at AMS he was the kindest and most considerate of persons. Above all, he always followed the dictates of his own conscience in determining his actions. He was devoted to his family: his wife, Martha, three sons and six daughters. He suffered the loss of one of these sons in military service in 1969, but heas blessed by 27 grandchildren. They can be proud of a grandfather who was an exceptional scientist, and a splendid human being.

Bernard Chovitz