NATIONAL ACADEMY OF SCIENCES

VICTOR HUGO BENIOFF

1899—1968

A Biographical Memoir by

FRANK PRESS

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September 14, 1899–February 29, 1968

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VICTOR HUGO BENIOFF was born on September 14, 1899, in Los Angeles, California. His parents were both immigrants —his father from Russia and his mother from Sweden. Benioff's California roots and his origins from immigrant stock were reflected in later years in his love of nature and his sensitivity to people, particularly his sympathy for the underdog.

Benioff was drawn to science at an early age, expressing a career interest in astronomy as a boy of fourteen. He attended public schools in Los Angeles and Long Beach and took his undergraduate studies at Pomona College, where he was elected to Phi Beta Kappa in 1920 and received the A.B. degree in 1921. During his undergraduate years he served as a summer assistant working on solar astronomy at the Mount Wilson Observatory, returning to Mount Wilson each summer until his graduation from Pomona. His interest in astronomy continued following graduation and he took a position at the Lick Observatory for the year 1923-1924, observing stellar radial velocities. Were it not for his inability to tolerate the night hours and the cold, as required of an observer, Benioff would undoubtedly have become an eminent astronomer.

In 1924 he began work in Pasadena as an assistant physicist with the seismological program of the Carnegie Institution, then directed by H. O. Wood. His first assignment was to develop a drive system for the recording drums. Even at this early date Benioff's taste for sophisticated instrumental design was evidenced. By developing a new type of impulse motor driven from a fork-controlled 10 Hertz quarter-phase pulse generator, he solved the problem. This novel system was highly successful and made possible the determination of seismic-wave arrival times to the unprecedented accuracy of 0.1 second.

At about this time Benioff installed most of the original instrumentation and set up a number of the original auxiliary stations which subsequently evolved into the famous seismic network of the California Institute of Technology.

Circa 1929 he commenced design of the now world-famous variable reluctance seismograph and the linear strain seismograph. The former instrument was placed in service in 1931 and evolved to its final form in 1934. For a number of reasons, the variable reluctance seismograph was an immediate success; capable of extremely high magnification at a frequency of about 1 Hertz, it was useful for the study of near and distant earthquakes. Simplicity, reliability, sensitivity, and a judicious selection of response characteristics based upon the noise and signal spectrums are responsible for the adoption of this remarkable instrument by observatories all over the world. It made possible the precise determination of travel time, the discovery of new seismic phases, the extension of the magnitude scale to teleseismic events, and the world-wide availability of first-motion data to recover source mechanism. With minor modification this instrument was later selected for use in the World-Wide Standard Seismograph Network and formed the basis of the detection system recommended by the Geneva Conference of Experts for the monitoring of nuclear tests.

The original strain seismograph was built with water pipe and lacked the desired stability. Gradually it evolved over the years with fused quartz tubing used as the standard of length, velocity transducers with galvanometric recording, and finally variable capacitance transducers and recording oscillographs. This instrument achieved notable successes; in 1953 Benioff provided linear strain records to Frank Press and Maurice Ewing and thereby made possible the discovery of the mantle surface waves. The linear strain seismograph is now a primary source of data for the eigen-frequency spectrum of the earth.

Beginning about 1934, Benioff supervised the development of instruments for structural vibration studies in a program sponsored by the U.S. Coast and Geodetic Survey. This was followed in 1936 by a number of instrumental advances designed to improve the quality of the (Pasadena) Southern California seismograph stations, making them the most advanced network in the world. A number of resulting devices were manufactured commercially and placed in world-wide use. During this period Benioff also developed instruments for seismic prospecting—a field of rapid technological advances, keen competition, and overnight obsolescence. In these and subsequent instrumental developments Benioff led an enthusiastic staff of engineers and technicians, many of whom became well known in seismological circles: Francis Lehner, Ralph Gilman, J. L. Blayney, and William Giles.

Benioff received the Ph.D. degree from the California Institute of Technology in 1935. The Seismological Laboratory was transferred from the Carnegie Institution to Caltech in 1937 and Benioff was appointed assistant professor of seismology. In 1950 he was promoted to a full professorship at Caltech.

Although he would have made an excellent instructor, Benioff preferred research to teaching and had little contact with students either in the classroom or as thesis adviser. On the other hand, his influence via informal discussion with doctoral candidates, postdoctoral fellows, and visiting scholars was very great and more than justified the title "professor." By the mid-thirties the Seismological Laboratory of Pasadena became a world center for geophysical research owing to the originality and productivity of Benioff and his close colleagues, Beno Gutenberg and Charles Richter.

With the increasing concern for national defense connected with the outbreak of World War II in Europe, Benioff and his group undertook the development and improvement of radar and underwater listening and ranging devices mostly for the Submarine Signal Company of Boston. This work continued through the war years and terminated in 1946.

Following the war Benioff returned to geophysical research. He built an array of seismometers on Mount Palomar to study microseisms. He experimented with new types of seismograph systems involving novel concepts such as mixing strain seismograph outputs to obtain mode filtering, vectorial recording devices, mercury tube tiltmeters, tape recording and playback analysis of earthquakes. About 1957, Benioff became interested in magnetic micropulsations. He constructed an array of magnetovariographs and published one of the first papers—and still perhaps the most comprehensive—on the spectrum of geomagnetic fluctuations in the range 0.3 to 120 seconds.

Still widely used is Benioff's early definition of seismic destructiveness in which the acceleration spectrum is the important parameter in anti-seismic design. This was one manifestation of a special responsibility Benioff felt to the inhabitants of earthquake prone regions.

Benioff's curiosity was unbounded. In addition to geophysical instrumentation, he took an active interest in the fabrication of a super-lightweight bicycle and construction of exotic kites; he studied camera lenses in great detail and even delved into the workings of jet engines. The use of ultrasonic devices for cancer treatment also attracted his attention. He became intensely interested in the physics of musical instruments and worked toward the development of an electronic violin, cello, and piano. The last instrument reached fruition under sponsorship of the Baldwin Piano Company and was used in public concerts by famous artists. His motivation always was to heighten the pleasure of the listener and to lighten the task of the performer while preserving the fidelity of the instrument.

Benioff's instruments and the data which they produced were sufficient ingredients for a distinguished scientific career, However, his interests broadened, and beginning about 1950 he began working on the general problem of earthquake mechanisms and global tectonics—some fifteen years prior to the current great interest in this field. In a classic series of papers between 1951 and 1958 he introduced several of the concepts which today form the basic elements of the "new global tectonics." In attacking these problems he made good use of his broad knowledge of the engineering properties of materials. By nature he was inclined toward elegantly simple hypotheses and quantitative procedures. His approach was that of a mature scientist entering a dormant field; he was skeptical, bold, and unfettered by preexisting hypotheses.

During this period Benioff introduced the concept of instrumentally determined strain rebound. He was able to show that great earthquakes reveal a global pattern of strain accumulation and release. He outlined the relation between aftershock sequences and stress relaxation and showed that the strain rebound characteristics could be used to separate the crust and upper mantle into zones having different mechanical properties.

Benioff demonstrated that the geographic distribution of aftershocks was related to the dimension of the primary fault. He proposed that the distribution of epicenters could be used as evidence for the fault origin of ocean deeps. He cited both continental drift and continental growth as the possible causes of tectonic activity of continental margins and deep sea trenches, although he preferred the latter mechanism.

Benioff continually sought to elucidate the earthquake mechanism. He deduced source dimensions using strain energy considerations. He tried to explain the source of aftershock energy using laboratory results on creep strain. He showed how the direction of fault progression could be recovered from the asymmetric radiation pattern of seismic waves. While accepting the elastic rebound theory for shallow focus earthquakes, he proposed that certain deep focus events involved volume collapse. It is a tribute to Benioff's farsightedness that each of these contributions now represents a major field of research involving large numbers of workers.

It is fitting that the last major contribution in an already distinguished career came with Benioff's participation on one of the teams which detected the free vibrations of the earth. As early as 1952 he thought he detected these elusive planetary oscillations. Although this claim was later shown to be in error, there is no question that his efforts stimulated other geophysicists to continue the theoretical and computational work which eventually was successful, opening the new field of terrestrial spectroscopy.

Benioff's contributions to geophysics did not go unnoticed and many honors came his way. He was elected to the National Academy of Sciences in 1953, received the Arthur L. Day Award of the Geological Society of America in 1957, was elected president of the Seismological Society of America in 1958, and received the William Bowie Medal of the American Geophysical Union in 1965 "for unselfish cooperation in research." He was a fellow of the American Academy of Arts and Sciences, the Geological Society of America, the Royal Astronomical

Society, the Acoustical Society of America, the American Geophysical Union, and the American Physical Society.

Benioff was sought after for consultation by industrial firms and governmental agencies. He advised the Office of Science and Technology, the Department of State, the Department of Defense, and the Department of Water Resources of the State of California.

He married twice; in 1928 he married Alice Silverman. They had one son, Paul, in 1931 and two daughters, Dagmar (1931) and Elena (1932). His first marriage ended in divorce and in 1953 he married Mildred Lent, with whom he had a daughter, Martha, who was born in 1956.

In his middle years Benioff stood at 5 feet 10½ inches and weighed about 175 pounds, had graying, sandy-colored hair, a prominent moustache, and penetrating gray-green eyes. Typically he was sportily attired, walked with a bounce, and radiated good humor, optimism, warmth, and good will. Although he suffered from often debilitating allergic reactions, this did not show in his demeanor.

He was inclined toward liberal views, which he freely expressed, and he championed the cause of repressed minorities. He showed a rare sensitivity and concern for people as individuals, and his relationships with students, colleagues, and friends reflected his intuitive understanding of the human personality. Benioff was a proud man and he did not suffer fools or fakes very easily. However, he was humble and self-effacing as a scientist. Upon receiving the Bowie Medal he said:

"I was fortunate in coming to the Seismological Laboratory at a time when the science of seismology was in its infancy. Many of the problems then were of a simple form in which an intuitive guess now and then was a sufficient solution. I am quite sure that were I reincarnated into the world of seismology as it now is with its complex problems resolvable only with very sophisticated means, my accomplishments would approach zero, and that I would not be standing here forty years later as a recipient of the Bowie Medal."

An important factor in Benioff's life was his love of nature. He was particularly attracted to the wilderness areas of California and Nevada and lived in them for such periods as his professional life permitted. For his personal enjoyment he often bought land that he considered scenically attractive and on occasion he was a part-time rancher. Benioff had an infallible instinct for judging land values and often reaped a handsome profit when the time came to dispose of a holding. However, his primary motivation always was to share the beauties of the back country with his family and friends.

In 1964 Benioff retired from Caltech and became Professor Emeritus of Seismology. For his retirement estate he chose the wild and beautiful coast of Cape Mendocino in northern California. He spent his retirement years advising government agencies and private industry, insisting that all consultations be held in his home. In his last years he received much pleasure from his young daughter and he enjoyed clearing his land, raising animals, and growing vegetables and fruit.

Hugo Benioff died on February 29, 1968, at the age of sixty-eight in Mendocino, California. His was a monumental, multidimensional career, spanning forty years and resulting in works that will survive for a long time to come.

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KEY TO ABBREVIATIONS

Bull. Geol. Soc. Am. = Bulletin of the Geological Society of America
Bull. Seismol. Soc. Am. = Bulletin of the Seismological Society of America
Eng. Sci. = Engineering and Science
J. Geophys. Res. = Journal of Geophysical Research
Trans. Am. Geophys. Union = Transactions of the American Geophysical Union

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