

A Tribute to Leon Knopoff *May 5, 2011*

by Paul Davis, Professor of Geophysics, UCLA

Leon has been an academic father figure to me as he was to many of the others who have also had the privilege to know him. As a student I had heard of him, and knew he was ranked as one of the top geophysical theorists of the time. I first met him in Cambridge in 1976, when I gave my first seminar as a new post-doc in Geodesy and Geophysics. Both Dave Jackson and Leon were in the audience. They were on sabbatical, escaping the Palmdale bulge I assumed. During my talk he was taking notes and I thought: this looks like trouble. However his questions at the end were certainly challenging, but supportive, and his interest and caring enthusiasm for science made a huge first impression that set the trend that followed.

Leon fits the description as being one of the geophysical giants of the 20th century. Over the history of geophysics, similar such giants in our field, buoyed up by the rigor of physics and mathematics, have ended up with dramatically wrong geological conclusions. Kelvin used the diffusion equation to estimate the age of a cooling Earth to be 50 million years, too small by a factor of 100. Harold Jeffreys used the creep law equation to prove that plate tectonics could not work. I next met Leon on the train from Cambridge to London where he was invited to give the Harold Jeffreys Lecture, so named to honor Britain's leading geophysicist of the time. Graduate student David Young and I plucked up courage and broached the great man in the train, who invited us to join him, and gave us the first of many illuminating scientific conversations, as the Cambridge countryside sped by. His talk was on his group's discoveries of the structure of oceanic plates and continental keels, the basic structures of plate tectonics. He told us he was confident about his first talk on quantum mechanical calculation of the structure of iron in the Earth's core, but on his Jeffreys talk he wondered about describing plate tectonics to his non-believing host. In true form, after Leon had spoken, Harold Jeffreys got up and proved conclusively plate tectonics could not work. He ended his talk with the statement "And as for plate tectonics it is just not on." Not looking directly at Leon I might say.

Leon, I am glad to say, whose name ranks alongside the Kelvins and Jeffreys, broke this non-stellar record of physicists getting it wrong. The plate tectonic structures Leon and his students found, are alive and well, as are many of the other topics he touched. Let me mention just a few.

Leon's universe, both physical and intellectual, was all encompassing. He studied at the coldest place on Earth, with a seismic station at South Pole; the hottest place, the iron of the inner core; the lowest place with gravity readings at the Dead Sea; and when Dave Jackson, Yan Kagan and I visited him in hospital, shortly before he left us, we heard him again recall crossing the Himalayas and seeing Chomolongma, the highest place, for the first time. We were reminded both what a wonderful life he had, and the physical and intellectual range he spanned, a giant in our field, but a giant without arrogance, who was more interested in raising people to his height, rather than viewing them from above.

My mother had a statement "as every schoolboy knows. . . ." Every schoolboy studying physics knows Green's theorem. Knopoff extended to the elastodynamic problem Kirchhoff's retarded potential solution, thereby providing the elastic analog to Green's theorem. It would be fair to call it Knopoff's theorem – but, involving both P and S waves rather than just electric potential, it is quite more complicated; it remains a tough read for every schoolboy. It formed the basis of how we model earthquakes and established his status in 1956.

PREDICTION

One of his goals, and that of his long time colleague Vladimir Keilis-Borok, whom we affectionately call K-B, and is sitting here, was to predict earthquakes. Dave has already mentioned the paper with the shortest title. We instruct our students to make sure the most important conclusions are in the abstract. He also has the paper with the shortest abstract.

With John Gardner in 1974 he published a paper titled, "Is the sequence of earthquakes in Southern California, with aftershocks removed, Poissonian?" In case you are wondering what all that means, you will be relieved to know the paper has the shortest abstract, "Yes." That is they are random – and so not useful for prediction.

However, over time, the answer changed to "not quite". He modified this view for the very largest earthquakes, recognizing weak clustering and patterns over large regions before the largest earthquakes, as a possible forecasting tool, with publications with K-B in '80, '88. Along with Yan Kagan he modeled earthquake sequences as branching networks and using pattern recognition, information theory, sought to understand and exploit this non-randomness. The quest continues.

In the '60s when computers were a rarity, he pioneered computer music and, with John Gardner, wrote the leading computer music program in the country, Music V, for an IBM 360. He used this program to compose a piece of geophysical computer music.

After an earthquake the earth reverberates like a bell with the longest period 54 minutes. In 1960 after the great Chile earthquake the first measurements of these spheroidal modes were made by Louis Slichter on the UCLA gravimeter. In 1969 Leon combined his geophysics and musical talents and copyrighted his version of Mahler's "Das Lied von der Erde," Song of the Earth, in two (earth) movements. The first earth movement was Kern county 1952 earthquake and aftershocks, some might say a rhythmical piece, and the second movement called $M > 7$, involved digital recording of the normal modes of the Earth, somewhat more harmonic.

Other contributions are well-summarized in this letter from GIULIANO PANZA (University of Trieste) who asked that it be read out:

I had the extreme luck and pleasure of starting my career as his post-doc and subsequently to share with Leon some of the most exciting topics in seismology, co-authoring several papers that have been seminal worldwide. Leon has been a most effective teacher, both at the undergraduate and graduate levels, and I had the possibility to enjoy his very inspiring and enthralling lectures at many courses at the Abdus Salam International Centre for Theoretical Physics (ICTP). Among other things, at ICTP he shared his pioneering understanding about the non-linear dynamics that governs the scale invariance of earthquake sizes, a distribution that is observed in every earthquake zone in the world. His work on stochastic branching fault networks, fractality of earthquakes, placed him years ahead of groups that applied methods of condensed matter physics to understand earthquakes.

I simply would like to evidence my everlasting gratitude to Leon.

RUNNING

At one point in our careers we were both fit enough to go running at noon. However, in typical Leon fashion he would turn it into a lecture. The lecture ranged from music appreciation (the rule of 6 seconds where he would hum extracts from Eine Kleine Nachtmusik) and say did you notice the repeat time of 6 seconds, or discuss some moderately complex theory on dynamic cracks. As some of you may have experienced, his knowledge was so encyclopedic, sometimes the information he would impart left one at a loss for a suitable rejoinder. I found these were times to up the speed of the running, which could slow the conversation to my pace; quite useful to have an intellectual governor to allow the brain to catch up.

CONCLUSION

My staying at UCLA rather than returning to Australia was in large part due to him, among other colleagues, not just because of his intellectual powers but equally his being an exceptional person. He was very friendly to me and many were the tea bags we shared. Of an afternoon I would often hear the call "Cha?" Our doors were often open in our facing offices, and sometimes the noise was quite appreciable as on either side science was discussed, and on his side with an unmistakable vigor we all knew so well. The place is quiet now and will never be the same. But even so, his spirit lives on. A few of us gathered to remember Leon and printed out his CV. We looked at our publications with him and recalled memories they bought back. We mourn the loss, but at the same time rejoiced in the life, what it had given us, and how much of that will live on. Time will I am sure eventually heal the pain, which will be replaced by memories of a truly remarkable man, whose life touched many, and left an example we would be fortunate to emulate. There were personal things I would have liked to have said to him. They would have included, like Giuliano and many of us, a deep affection and gratitude for his mentoring, the example he set, and the friendship he extended.