

## THE MARRIAGE OF STATISTICS AND SEISMOLOGY

DAVID VERE-JONES,<sup>1</sup> *Victoria University of Wellington and  
Statistics Research Associates Ltd*

*To create a little flower is the labour of ages*

William Blake  
A ‘Proverb from Hell’, from  
*The Marriage of Heaven and Hell*

Daryl Daley has kindly invited me to write some prefatory words, autobiographical in character, to the collection of articles which follows. I am very happy to do this, but first let me express my appreciation of the efforts which Daryl, Peter Thomson, and the contributors have put into the making of this volume. It is a wonderful tribute, which I greatly appreciate. May I also take the opportunity to acknowledge the help of all of those colleagues, whether or not they have contributed directly to this volume, whose support, professional advice, knowledge, competence and companionship have made my years as statistician and tyro seismologist extremely rewarding. To all such, a big thank you.

Too much autobiography would be redundant here; I shall be very happy if readers gain their views from Brian Phillips’s generous and perceptive article later in this volume; nor have I any wish to go over ground already traversed in earlier writing (Vere-Jones, 1964, 1978, 1986).

But I would like to comment briefly on one aspect of my life and activities that has really developed only in the last 10 years, and moreover helps to explain the make-up both of this collection of articles, and of the meetings for which they provided the core. This is the slow and still uncertain evolution of a scientific sub-discipline: statistical seismology. As far as I am aware, the name was first coined (in English) by the translator of an early Japanese article by the well-known seismologist Keiiti Aki (Aki, 1956). It contained, like a huge number of his later papers, ideas that were controversial, provocative, and new. Although written by a seismologist, it was concerned with the development of statistical models for use in explaining the occurrence of earthquakes, and it could well have been written by a statistician. Indeed, Aki’s grasp of statistical (and also stochastic) modelling principles, allied to his profound seismological knowledge, have remained a distinguishing feature of his work over several decades (see for example references in Aki and Richards, 1980).

But let me back-track, rather far, to my first experience of real science. This came during the summer vacation after my first year at university. My father, who worked

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<sup>1</sup> Postal address: School of Mathematical and Computing Sciences, Victoria University of Wellington, New Zealand. Email: [dvj@mcs.vuw.ac.nz](mailto:dvj@mcs.vuw.ac.nz)

at that time with the Chemical Engineering Division of the New Zealand Department of Scientific and Industrial Research (DSIR), helped to set up a holiday job with Athol Rafter's group, who at that time were pioneering, in New Zealand, and with the scantiest of equipment, the development of radiocarbon-dating methods. My tasks involved putting samples behind geiger-counters, connecting the geiger-counters themselves (which I hated, as they operated at high voltages and sparked at—and what is worse, sometimes shocked—those without careful and methodical ways of handling them), and collecting cans of sea water from distant points to test their ages. I didn't like it, but it gave me some understanding of the more practical side of scientific research, and of the circumstances of staff in a government research laboratory, both of which stood me in good stead in later years.

After post-graduate study at Oxford followed by a year in Moscow, I returned to New Zealand to work for the DSIR in 1962, in the Applied Mathematics Division (or Laboratory as it was then), which I had nominally joined before leaving for Oxford. My very first task, believe it or not, was to pick up work which had been ably started and largely carried through by an earlier employee, Steven Turnovsky, on the geographical distribution and other statistical characteristics of New Zealand earthquakes. This immediately involved me in discussions with the local seismologists, Frank Evison, George Eiby, and Robin Adams, as colourful, enthusiastic and able a group as a tyro could hope to encounter on his first scientific mission. Frank, in particular, was extremely encouraging, had worked earlier with Peter Whittle, and no doubt hoped (in vain, I fear) that I would show the same physical insight which has been such an outstanding characteristic of Peter's work.

This was the beginning of a life-long professional interest. In one of those early seismological articles (Vere-Jones and Davies, 1966), Robert Davies and I wrote

Any statistical analysis relies ultimately on a probability model of the process under consideration, and in the course of the paper we shall develop some simple models for earthquake occurrence. Like the chemical processes used by the Curies, these methods can be used to extract a small amount of active information from a large body of inert data. We hope that in the present context they may prove useful to the seismologist. In particular, it is possible that the study of suitable stochastic models may ultimately throw some further light on earthquake mechanism.

These comments seemed self-evident to me then, and they still embody much of what I feel about the role of statistics in seismology, or indeed of statistical seismology itself. I hoped that by articulating them we could make them self-evident to the seismologists who read them. How many seismologists did read them I do not know; but I certainly did not anticipate that it would take a further 40 years before the seismological community, slowly and reluctantly, began to reach similar conclusions. Keiiti Aki comes in here because he was one of a handful of seismologists at the time who offered me encouragement (even though, in his case, he had located an algebraic error: but then how often do your articles get read sufficiently carefully for someone to locate an algebraic slip?)

The opportunity to read a paper on statistical models for earthquake occurrence to the Royal Statistical Society at the end of 1969 was a major confidence booster. By that time the group with whom I had written contacts had expanded to include Cinna Lomnitz from Mexico, Tokuji Utsu from Japan, and V. N. Gaisky from the Soviet Union. From very different standpoints, they shared the view that statistical issues in seismology had to be grappled firmly if the subject was to realize its full potential. Yan

Kagan swam into my horizons at about the same time. I met him first on one of my return trips to Moscow, while he still worked at the Institute of Mines, but this was after a prolonged stay in hospital during which, as a result of excess time for reading, he had been converted to the dominant theme of his own working life—the realization of earthquake processes as the solid state equivalent of turbulence in fluids and gases. I was astounded to find in him someone who knew more about probability generating functionals and point processes than I did. I had come to them from examining the thesis of Peter Brockwell, who had them from Moyal who was his supervisor at ANU, and I was proud of my achievement, while Yan had them from the Russian theorists Bogoliubov, Yaglom, and later Bol'shakov, although he knew the Western papers of Bartlett, Moyal and Kendall as well. He was clearly exceptional, and within a year or so I found myself enthusiastically supporting his appointment to a research position at UCLA with his principal backer, Leon Knopoff.

Then came my first visit to Japan, in 1976. This has to be laid at the feet of Joe Gani, whose generosity in supporting visitors from all quarters found me, a year or so earlier, briefly sharing an office with Ryoichi Shimizu, from the Institute of Statistical Mathematics in Tokyo. Brief though our joint habitation was, it was long enough to strike up a warm friendship, and to raise the possibility of visiting their Institute at some time in the future. It turned out that my interests, point processes and earthquakes, fitted well with Akaike's plans to extend the applied work of the Institute, and break across some of the 'vertical strata' which tended to divide Japanese society. Our subsequent visit to Japan is described in more detail in Vere-Jones (1978). Suffice it to say here that the links with the Japanese seismologists and probabilists in general, and with the extremely talented group of students that Hiro Akaike had gathered round him in particular, gave me a new picture of the potential links between statistical modelling and seismology. Yosi Ogata and Tohru Ozaki were delegated to work with me specifically, and how could I have been luckier than that? Both have remained staunch friends, and through that have given me the wonderful opportunity of watching two scientific and personal lives evolving and maturing in a country very different to my own.

At home, I was equally lucky to have the opportunity of supervising first David Harte, and then Mark Bebbington, in directions which have led them to develop related interests of their own, and then to come back and share in our recent joint projects.

Such were the seeds of statistical seismology in my own life. Now let me come back to the last 10 years. The feature that has made these years such a memorable period for me centres around the Chinese link. Having a Chinese wife makes it inevitable that, sooner or later, Chinese links will start to play a special role. For me, this did not happen quickly. For many years China was inaccessible. Mary herself was very uncertain, having been brought up in Hong Kong during the war, and having relatives who were, by and large, part of the diaspora of Christians from South China triggered by the war and the subsequent Communist takeover. But in the late 1970s and early 1980s, as a result of such distinguished New Zealand personalities as Rewi Alley and James Bertram (whose support, incidentally, I am convinced played a key role in somehow having me elected to a Rhodes Scholarship), New Zealand enjoyed a favoured role with the Communist Chinese Government at the time, and received some of the first invitations for groups to visit China after the cultural revolution. I was lucky enough to have my name included in one such group of New Zealand doctors and academics, but I had other commitments which prevented me from taking it up. So

Mary went in my place, alongside Jock Hoe, our much beloved and respected Chinese statistician scholar. The trip played an important part in Jock's subsequent career, I suspect, for he ended up in a Chinese hospital, experiencing an effective combination of Western and Chinese treatments which may well have disposed him subsequently to join the English Language Institute in Shanghai—not a common career move but he is now widely respected in both hemispheres as an expert on early Chinese mathematical texts.

The trip also had its influence on Mary, and although she remained very circumspect about political matters, she accompanied me with increasing enthusiasm on our trips to China. Initially, Frank Evison, and then I, made solo visits to the Geophysics Institute of the State Seismological Bureau, now the China Seismological Bureau (CSB). Later on, we met Deng Yonglu in Canberra, enjoyed his subsequent stay in Wellington, and ultimately visited him to lecture, again on point processes and earthquakes at Zhongshan University in Guangzhou (Canton) where he still works. A year or so later, through David Brillinger's good offices, I received an invitation to lecture at a summer school for advanced students at Jilin University in Chanchung. This was the first occasion on which Mary and I travelled extensively together in China. We both enjoyed it considerably, despite a foul-up with the payment of our fare, which we were given in non-convertible currency, so that we ended up being among the first foreigners to deposit a significant amount of money in a Chinese Post Office Savings Bank Account, which from memory earned the princely return of  $\frac{1}{2}\%$  per annum. On the same visit we met Zheng Xiaogu, from Beijing Normal University, who later came to work with us as a post-doctoral fellow, wrote several key papers on the stress-release model, and has since established a unique reputation as a powerful theoretical statistician within the New Zealand Meteorological Service (NIWA).

But the real turning point in our Chinese links came in 1994, when Victoria University hosted the regular IASPEI (International Association for Seismology and Physics of the Earth's Interior) meeting. Before the meeting I had fielded a letter from a Dr Ma Li, a senior scientist working with the Centre for Analysis and Prediction (CAP) in CSB, but hitherto unknown to me. She was looking for an opportunity to spend a sabbatical period working in Wellington with Jim Ansell, whose tragic early death ended a career that was just starting to come into full flower, and myself. I had no objections, but was somewhat taken aback by the energy and force of personality which emanated from this diminutive, unconventional, and totally dedicated Chinese woman scientist. She worked here for much of the rest of the year, helping us with studies of the M8 and ETAS algorithms, and, with her colleague Shi Yaolin from the Chinese Academy Graduate University, forging a link which has persisted to the present day. The next year Mary and I were invited to Beijing to lecture on statistical methods in seismology, and before I knew it, a new incarnation of statistical seismology had emerged. It appeared in the title of the Chinese introduction and translation of my lecture notes. When we returned to New Zealand, I applied for a grant from the newly formed ASIA 2000 Foundation of New Zealand, with the aim of establishing a scientific cooperation project in statistical seismology between CAP in China, and the Institute of Geological and Nuclear Sciences (IGNS) and VUW in New Zealand. With Robin Falconer's backing from IGNS we were lucky enough to receive the grant for a double term. It was not large in financial terms, but it enabled some half-dozen young trainees from CSB to visit New Zealand, and gain some idea of our work in statistical seismology, and of seismology in New Zealand more generally. It also assisted return trips to

China, not only for Mary and myself, but also for David Harte and Ray Brownrigg, who formed key parts of the team in the Institute of Statistics and Operations Research developing the *Statistical Seismology Library*. Added to our subcontract with IGNS for work in earthquake forecasting, the ASIA 2000 grant helped us to attend the First International Workshop in Statistical Seismology in Hangzhou in 1997, to purchase additional software and computing equipment, and to host further small workshops in statistical models for rock fracture and earthquakes.

As with my Japanese students two decades earlier, I now have the pleasure of watching a new generation of talented individuals, to whose training I have made a small contribution, make their way through life in a distant, exciting, and potentially extremely productive environment. The sadness is that Mary, whose quiet but welcoming presence I think affected all our Chinese visitors, helping to give them confidence and cultural reassurance, is no longer here to share that enjoyment.

As often happens, success in one direction engenders success in others. With the Chinese links came new contacts with seismologists and other colleagues in the US, especially with Yehuda Ben-Zion and his colleagues at the University of Southern California, and links to further statisticians intrigued by the non-standard and undoubtedly challenging problems that the seismological setting provides.

So where does this leave the marriage of statistics and seismology? My personal view is that it has never been a more exciting field to work in. One of the underlying factors, as I have commented elsewhere (Vere-Jones, 2000), is the steady improvement in the quality and quantity of seismological data. Better quality data demand better quality statistical modelling and analysis. Even if the signals that the data carry are weak, I think they are strong enough to be detectable by statistical methods, although we have to be careful in selecting the methods we use, for the data do not conform to standard stationary time series or linear models. And we have to be careful also with purely empirical methods when they are not based on an underlying physical model.

The challenge now, as wide open as it was 40 years ago, but perhaps now closer to being cracked, is to find the right way of marrying the statistical and physical ideas. That should be the ultimate goal of statistical seismology. Forecasting and risk reduction measures should then fall out as corollaries.

It is significant to me that the events accompanying this volume cover the anniversary of Mary's death one year ago. For my part, I shall hold the volume as a tribute to her memory, to her support, and to the friendships with scientific colleagues that we forged together, and that neither of us could have achieved alone.

## References

- AKI, K. (1956). Some problems in statistical seismology. *Zisin* **8**, 205–228 (in Japanese). (English translation: A. S. Furimoto, Hawaii, 1963.)
- AKI, K. AND RICHARDS, P. G. (1980). *Quantitative Seismology: Theory and Methods*. Freeman, San Francisco.
- VERE-JONES, D. (1964). The mathematician's tale. *Survey* **52** (Report on Soviet Science), 52–60.
- VERE-JONES, D. (1978). Four months, three children and one wife in Japan. *Bull. Japanese Phys. Soc.* **32**, 543–549 (in Japanese). (English translation: *Scientific Bulletin*, Department of the Navy, Office of Naval Research, Tokyo, 37–42.)
- VERE-JONES, D. (1986). Probability, earthquakes and travel abroad. In *The Craft of Probability Modelling—A Collection of Personal Reminiscences*, ed. J. Gani, Springer, New York, 222–235.
- VERE-JONES, D. (2000). Seismology—a statistical vignette. *J. Amer. Statist. Assoc.* **95**, 975–978.
- VERE-JONES, D. AND DAVIES, R. B. (1966). A statistical survey of earthquakes in the main seismic area of New Zealand. Part II: Time series analyses. *N. Z. J. Geol. Geophys.* **9**, 251–284.