

Foreword

Danie Krige

The initiative for this volume came from the Southern African Institute of Mining and Metallurgy with the aim of commemorating Professor Danie Krige's work, his contribution to geostatistics, and the creation of new knowledge that he has stimulated. At the outset I would like to sincerely thank the authors for their contributions and for the swift and diligent responses to the call for papers. Since most of the work fell to the authors of the papers, compiling this volume has been a pleasure. The first invitation to contribute to the volume went out on 10 May 2013 and as the volume stands, it will contain 37 papers from 67 authors from around the globe, all completed in a period of nine months. The readiness and willingness of geostatisticians to contribute their research to this volume signals their appreciation for the work and person of Danie Krige. Something worth noting is that most authors found the writing of articles in this volume an enjoyable experience. In fact one author commented that he hoped I would enjoy reading the paper as much as he enjoyed writing it.

I thought that a summary of the early development of geostatistics might be in order. Early publications by Danie Krige were translated into French and Russian and the effects of his new insights into mineral resource evaluation spread to mining centres around the world. From this interest the APCOM meetings arose, and as the need for a forum to discuss such issues in the South African and Australian mining industries became evident, the Geostatistical Association of South Africa and the Geostatistical Association of Australia were formed. Early development of the subject material (before the term *geostatistics* was coined) in the literature of the 1945 to 1965 period was couched in phrases such as 'statistical approach' or 'statistical analysis' and 'mine valuation'. At that stage geostatistics was unknown as a subject, but terms such as lognormal, correlation, regression, trend surface, moving average, and interpolation procedures began to appear in this literature.

It is interesting to use the number of publications in the field of geostatistics as a proxy for the way the discipline of geostatistics has evolved over the years since its first developments in the early 1950s. In 1988 Patricia Sheahan produced a bibliography of geostatistics for the Economic Geology Research Unit at the University of the Witwatersrand, in which she lists 315 publications on geostatistics in the period 1951 to 1988. Her definition for geostatistics from the *Glossary of Geology*, published in 1987 by the American Geological Institute: '(a) statistics as applied to geology; the application of statistical methods or the application of statistical data for use in geology; (b) statistical techniques developed for mine valuation by the French

school of Matheron', guided her choice of what to include, noting that her bibliography refers to practical aspects of geostatistics with an emphasis on literature since the mid-1970s, and that it is by no means comprehensive. However it is the best record that we have for that period of geostatistical development, so the data for the number of publications related to the subject for each year between 1951 and 1988 (Figure 1) is source from Sheahan (1988).

The period between 1950 and 1987, when the number of publications on geostatistics reached 133, is of particular interest. Figure 1 shows a moderate growth in the number of publications after 1964, but an exponential rise in 1976. Publications output in the 1978 to 1981 period was relatively subdued, but from 1982 growth in interest and output was rapid. I have found no bibliography of works relating to geostatistics after 1988 that meaningfully captures publications output. Webster's *Timeline History 1962-2007 of Geostatistics* (Parker, 2009) fails to capture many publications that were produced after 1987, and probably before that time as well. For interest, the numbers of publications by Danie Krige and Georges Matheron are also shown on the diagram.

It is probably dangerous to go down this road for risk of offending people by either getting the numbers wrong or by missing someone, but anyone with more than five publications in Sheahan's bibliography for this period is listed below. Some who have made huge contributions to the advancement of geostatistics, for example Ed Isaacs and Mohan Srivastava, besides many others (M. David, Ch. J. Huijbregts, P. Delfiner, and J.P. Chiles), do not feature in the list. So it should be said that the number of publications does not necessarily reflect the importance of the contributions to

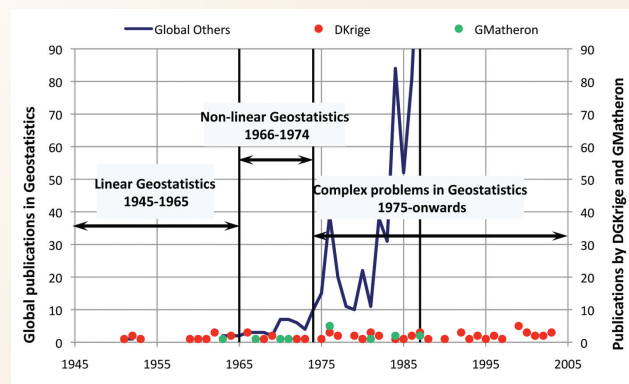


Figure 1 – The number of publications produced in each year from 1945 to 1987; publications by D.G. Krige until 2002 are shown, as are publications by G. Matheron (data sourced from: Sheahan, P. 1988. A bibliography of geostatistics. Economic Geology Research Unit, Information Circular No. 202. University of the Witwatersrand. 41 pp.)

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the development of geostatistics. Number of publications is not the only metric by which we should measure the development of a scientific discipline, but it really is interesting to see who was publishing geostatistical papers during the period (listed in the Table below).

The number and timeline of publications indicate two important features of Danie Krige as an outstanding researcher and academic – firstly the consistency, and secondly the number of publications produced during his lifetime.

Matheron and Kleingeld (1987), in their consideration of the evolution of geostatistics (APCOM 87, *Geostatistics*, vol. 3, pp. 9-12), note that the term ‘random function’ was not in use when Danie Krige and Herbert Sichel introduced statistics into ore evaluation. The term ‘*random variable*’ has been used fairly extensively in the past. For example, Paul Lévy (Ecole Polytechnique) wrote an article entitled ‘*Wiener’s random function, and other Laplacian random functions*’ (pp. 171-187 in *Proceedings, Berkeley Symposium on Mathematical Statistics and Probability*, University of California Press, 1951), and in 1962 A.M. Yaglom wrote the book ‘*An Introduction to the Theory of Stationary Random Functions*’ (published by Prentice-Hall). This term was first introduced by B. Matérn in his original 1948 publication on forestry in Sweden and was also used in the 1960 translation (with updates) from the Swedish version. The term ‘géostatistique’ was introduced by Matheron in 1962, as was the term ‘kriging’, although the latter appeared as a French word in a footnote. Matérn and Matheron also note that the concern around the adoption and acceptance of geostatistics was not related primarily to the mathematical complexities, but rather to the poor communication about the ‘... *conceptual and psychological interpretation of the given phenomena ...*’ between methodical mathematicians, practical mining engineers, and intuitive geologists.

They also identified three periods in the development of geostatistics, the earliest being 1945–1965 when linear geostatistics was developed. Application of the lognormal distribution to gold mining by Herbert Sichel was followed

by Danie Krige’s application of regression analysis between sampling and mining blocks for resource estimation. These works allowed Georges Matheron to fully develop the linear geostatistics of his doctoral thesis in 1965.

The second period, between 1966 and 1974, saw the development of nonlinear geostatistics on location at Centre de Geostatistique in Fontainebleau. M. David and G. Matheron made important contributions, but A.G. Journel, Ch. J. Huijbregts, P. Delfiner, P. Chauvet, and J.P. Chiles are said to have developed nonlinear geostatistics during this period. It is interesting to note how the number of publications escalated after the end of this period (Figure 1), but I leave the reader to interpret this observation. The third period between, 1974 and 1987, dealt with complex problems including ore/waste selection, change of support, transfer functions, parameterization of reserves, disjunctive kriging, and indicator kriging (Matheron and Kleingeld, 1987). Since that time, the interest and growth in geostatistics has shaped the extraction of minerals and metals from ore deposits around the world.

This volume is about geostatistics, its development, growth, and applications in the earth and natural sciences, but its importance lies in both the quality of the papers and the number and stature of the contributors in the geostatistical fraternity. This will indeed be a memorable volume. Of particular importance is the fact that the research presented here is at the forefront of the thrust in geostatistical research, and the collection of papers taken together indicates the forward direction for the frontiers of geostatistical research. I asked an eminent geostatistician where he thought the new frontiers of geostatistical research lay, and I believe that, collectively, the papers in this volume answer that question.

It is hoped that you will enjoy reading this volume as it commemorates the work of Professor Danie Krige and reflects the latest in global thinking about geostatistics.

R.C.A. Minnitt

Name	Number of publications	Name	Number of publications
Agterberg, F.P.	11	Krige, D.G.	23 (Sheahan, 1988) 92 (SAIMM, 2005)
Armstrong, M.	6	Marechal, A.	7
Clark, I.	9	Matheron, G.	14
Dagbert, M.	8	Philip, G.M.	6
David, M.	11	Rendu, J.M.M.	16
Dowd, P.A.	8	Royle, A.G.	13
Froidevaux, R.	6	Sinclair, A.J.	8
Journel, A.	19	Switzer, P.	6
Kia, Y.C.	10		