late fluid percolation through porous media, or the growth of dendrites and skeletal crystals by "diffusion-limited aggregation." Those who still doubt the scientific potential of fractal studies should read the articles on these two subjects by Feder and Jössang, and by Meakin and Fowler, in the second volume: if these articles do not convince them, then they have probably already aquired a severe case of fractal blindness. Fractal objects ("strange attractors") also appear in the state space of low-dimensional chaotic dynamic systems, but according to Bak and Chen (first volume, p. 233) "The belief that there may be a connection between low-dimensional chaos and fractals is without mathematical foundation." Instead, Bak (see next review) believes strongly that the most common cause of natural fractal objects, including sand avalaches, earthquakes, and many other geological phenomena, is a multidimensional dynamic state poised on the edge of chaos (or catastrophy), which he calls "self-organized criticality."

How Nature Works: The Science of Self-organized Criticality

Per Bak
Copernicus (Springer-Verlag)
New York, 1996, 212 p., US$27.00

Reviewed by Gerard V. Middleton
Department of Geology
McMaster University
Hamilton ON L8S 4M1

Per Bak is a physicist at Brookhaven, with a sceptical view of scientific institutions, and a low opinion of many of his fellow scientists, apparently especially of geophysicists:

> ... (who) often show little interest in the underlying principles of their science. Perhaps they take it for granted that no general principles apply, and that no general theory...can exist. (p.81)

This book is about a general theory to explain the existence of power laws, like the Gutenberg-Richter law relating the number of earthquakes $N(m)$ with a magitude great than some value m

$$N(m) = am^{-b}$$

A log-log plot of N against m is a straight line with a slope of $-b$. Alternatively, one might plot the magnitude of earthquakes against time: taking a power spectrum of this time series would reveal that the variance in earthquake magnitude was proportional to the frequence (f) raised to some negative power β. Time series with this type of spectrum are said to show "$1/f$" noise, and have been commonly observed in many fields. $1/f$ noise can be simulated by random walks, and the extended phenomenon was called "fractional Brownian motion" by Mandelbrot and Wallis. One of their pioneer papers about this has been reprinted in the first of the two volumes edited by Barton and LaPointe, and reviewed above. Power laws and $1/f$ noise are now generally thought to be characteristic of fractal objects.

Bak has developed a general theory to explain power laws and $1/f$ noise (and more generally, the complexity of nature): he calls this theory "self-organized criticality" (SOC). Bak argues that complex systems, with many degrees of freedom, that are driven far from equilibrium by the application of some extrinsic but possibly steady force tend

> ...to evolve into a poised "critical" state, way out of balance, where minor disturbances may lead to events...of all sizes... The state is established solely because of the dynamic interactions among individual elements of the system: the critical state is *self-organized*. (p.1-2).

Bak's model for such a system is a sand pile, continually fed by sand added grain by grain (but randomly) close to the apex.

Cellular automata (computer) models of such a system show that it builds up to a critical state, after which avalaching takes place. The timing and size of the avalanches, however, are quite unpredictable, and do not show any natural periodicity; instead, the power spectrum of the time series shows 1/f noise, and the number and size of the avalanches are related by a power law (real sand piles are not as satisfactory, in this respect, as computer ones: see Anita Mehta, ed., Granular Matter, published by Spinger-Verlag, 1994). In Bak's book, he extends the sand-pile model to: earthquakes, cotton prices, extinctions, landscape geometry and evolution, coupled pendulums, turbidite deposition, volcanic eruptions, pulsars, solar flares, evolution (including punctuated equilibria), the brain, and traffic jams. Perhaps you think this ambitious? I can only say that I know of several other published applications that he has omitted.

Most of the topics considered at length in this book are part of the earth sciences; earthquakes, landscape, sedimentation, evolution, and extinction are the major topics. The style is for the most part autobiographical, alternately entertaining and irritating, and at the *Scientific American* level. Bak argues for an approach to complex systems that is necessarily abstract and statistical. He claims that

> ... we must learn to free ourselves from seeing things the way they are!... If... we concentrate on an accurate description of the details, we lose perspective. A theory of life is likely to be a theory of a process, not a detailed account of utterly accidental details of that process... (p.10)

For most geologists, this approach may be one that they have never seriously considered.

My recommendation: read this book, and decide for yourself how valid the approach is. At the very least, it is entertaining to read a book by a physicist who does not believe that meteorite impacts cause extinctions!

The Geology of South Australia: Volume 1. The Precambrian

Edited by J.F. Drexel and A.J. Parker
South Australia Geological Survey
Bulletin 54
1993, hardbound, 242 p., A$75.00, + A$20.00 overseas surface postage and packaging

Reviewed by G.M. Ross
Geological Survey of Canada
3303 33rd Street N.W.
Calgary, Alberta T2L 2A7

This attractive volume provides an up-to-date overview of the Precambrian geology of South Australia (an Australian state roughly comparable in size to British Columbia). Volume 2 will cover the Phanerozoic geology. As mentioned in the introduction, the book is designed to provide the reader with a comprehensive regional account of the products of sedimentation, deformation, metamorphism, and magmatic activity in South Australia, with some insights into associated crustal processes. In many ways, Australia is comparable to Canada from a geopolitical perspective: a sparsely populated country with a resource-based economy heavily rooted in Precambrian geology, a long history of geologic mapping, and, especially in recent years, a very thorough and precise geochronologic control. In addition, much of the country, and South Australia in particular, is covered by relatively high-resolution aeromagnetic anomaly data, an attempt to counter the effects of generally poor exposure. This volume attempts to tie together each of these data sets, and successfully presents a very thorough overview of the geology of South Australia with abundant maps, geochemical data, and outcrop photographs. An attempt is made to integrate all these observations with the potential field data. In many ways, one could see such a volume as a model for comparable work in Canada.

The authors should be complemented on a very thorough job, as this book is well written, logically organized, and thorough. It begins with the typical introductory material and includes some discussion of the concepts of geochronology and sequence stratigraphy as they are used in South Australia. Subsequent chapters cover the regional geologic framework and then systematically cover the Archean, Paleoproterozoic, Mesoproterozoic, and Neoproterozoic. The book is lavishly illustrated with virtually all figures in color and includes a new compilation map of South Australia at a scale of 1:2,000,000. The production must have cost a fortune, but at the time of writing of the volume, the state of South Australia had just begun a $16M aeromagnetic program, a staggering ante by Canadian standards!

The book was published in 1993 and most of the references are up-to-date. Some of the real values of the book are the extensive tabulation and reference to the abundant modern U-Pb age determinations as well as graphic display of the rock units, ages, and deformation events, which is an immense aid in sorting through the bewildering (at times) nomenclature.

What are the drawbacks of this book? I found myself trying to compare this publication to Canadian analogues (the DNAG series for example). The main difference I find is the nearly complete lack of structural and tectonic perspectives in the Australian work. Although mylonite zones are described and pictured, there is not a single kinematic discussion of them, even though some of them, such as the Woodroffe Thrust in the southern Musgrave Block, are classic localities that have been well studied. Discussion of orogenic events presents the magmatic, metamorphic, and geochronologic constraints but never places them in a dynamic scenario. Along these lines, there are very few cross-sections, perhaps reflecting the lack of outcrop control; however, such sections, even if only schematic, are an effective way to communicate structural and geologic relationships. A final complaint: when you first open this book you will be taken by the profusion of color, especially the abundant and attractive potential field maps, chiefly aeromagnetic anomaly data. Virtually every chapter makes use of such maps to illustrate the position of a particular fault or domain boundary. What one discovers on closer scrutiny, however, is that there is a real dearth of annotation of such figures and virtually no discussion of the origin of the potential field fabrics (magnetite-bearing gneisses, for example). Additionally, the figures are poorly integrated into the geologic text. In other words, they are simply pretty pictures.

In summary, this book is a superb inventory of the geology of South Australia but fails in the integration of the geology and potential field data into geologic history. However, I think that Canadian geologists will find this a very readable and useful publication and one that might well find its way onto required reading lists, especially given recent suggestions that Australia may be the conjugate margin to the Canadian Cordillera.