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BOOK REVIEWS

Fractals for earth scientists

Turcotte, D. L. 1992. *Fractals and Chaos in Geology and Geophysics*. Cambridge University Press, Cambridge, U.K. Price £29.95, $54.95 (hardback).

Not so very long ago, to confess to an interest in fractals or (worse) chaos was to invite instant denunciation as a 'trendy'. It is a mark of the change that has taken place in the Earth Sciences over the last few years that these concepts have found their way into the classroom, and this evolution is celebrated by the appearance of a text-book designed for advanced-level undergraduates and beginning postgraduates which provides an introduction to these important concepts. This book is written by Don Turcotte, who has been one of the leading proponents of the application of these ideas to the study of the Earth.

There is a danger that, having agreed to review a book, it may sit unread on the bookshelf, staring reproachfully down as you prevaricate. No such problem is encountered with the present volume. Indeed, one warms immediately to an author who, in a radical departure from established practice, begins by handsomely acknowledging the graduate students who introduced him to fractals and contributed to his thinking on the subject.

The first two chapters are an introduction to the elements of fractal geometry using examples familiar from other similar introductions, such as the calculation of the length of a coastline.

Chapters 3, 4 and 5 extend the discussion of fractal geometry to include an analysis of the fragmentation of a body into a number of parts with a power-law distribution of sizes, and show the relevance of this simple example to the study of seismicity, specifically to the description of size distributions of earthquakes; and to the calculation of ore grades and tonnages.

Chapters 6 and 7 introduce further theoretical considerations of clustering. Chapter 7 is a discussion of self-affinity, particularly as it applies to the analysis of topography. Another aspect of geomorphology—the role of erosion and river patterns—is discussed in Chapter 8.

Chapter 9 introduces some of the basic concepts of the study of dynamical systems. The logistic map, a classical example of a non-linear system with well-defined chaotic behaviour is discussed in detail in Chapter 10.

On this basis, the following four chapters discuss specific non-linear models which describe systems of geophysical interest. The first of these is the slider-block model of seismicity, a simple low-dimensional paradigm for fault behaviour which is shown to lead to a chaotic regime, implying that earthquake prediction is not possible in a deterministic state. The simple model described in the chapter includes only two connected sliding blocks and is a useful example which allows a detailed analysis, but most current slider-block models appearing in the literature at the moment include a large number of inter-connected blocks. These models do not permit such a clear exposition of the characteristics of chaotic dynamics, but they do appear to lead to self-similar geometries. Larger models are discussed briefly in the context of self-organized criticality and cellular automata in Chapter 16, but the connection between the larger models and the two block model is not discussed. This is a pity, because such a discussion could have highlighted some of the difficulties in analysing more complex models in terms of, for example, the Lyapunov exponent. In addition, this would have been an excellent place to emphasize that what one is modelling is, after all, seismogenesis, and the question of the physical realism of the various sliding block models is not always evident, particularly where the models are small and dominated by boundary effects.

Although the word 'geophysics' occurs in the title of this book, it might more properly be described as a book about *solid earth* geophysics, since examples from oceanography and meteorology are conspicuously absent. This omission seems slightly unfair in Chapter 12, which continues the discussion of dynamical systems, by means of an exposition of the Lorenz equations. These equations describe thermal convection and were developed by Edward Lorenz, a meteorologist studying weather forecasting. Chapter 13 is devoted to the question of chaotic convection such as may occur in the mantle, and finally Chapter 14 describes the Rikitake dynamo, a chaotic model of the geomagnetic field which leads to a random pattern of reversals of the geomagnetic field.

The renormalization group method is the subject of Chapter 15. This is a technique which relies upon the concepts of scale invariance and has been used by physicists in the study of phase transitions, particularly those involving magnetism. It has been applied to simple cases of fault systems and rock fracture. Chapter 16, as has already been mentioned, is devoted to self-organized criticality, an approach to the study of seismicity which is the object of considerable interest at present.

The subject of this book is evolving rapidly: every month sees the appearance of a large number of articles which extend our insight into the role of fractal geometry and chaos in geophysics. It is therefore inevitable that any book will appear narrow. This is perhaps accentuated by the limited range of topics the book attempts to cover. Apart from basic matter which can be found in most elementary text-books on fractals and chaotic dynamics, the subject matter corresponds closely to the areas addressed by the author and his co-workers. This is in part a tribute to the immense, pioneering contribution of Professor Turcotte, but there are nevertheless a few surprising omissions. One might have expected to read rather more about percolation theory, which has a natural affinity with fractal geometry and has been employed quite extensively in seismology. Also, though most dynamical models of seismicity are based upon frictional phenomena, a number of authors have concentrated upon the fracture-mechanical aspects, and this might have been, at least, mentioned in passing.

A further criticism might be levelled at the publisher. The production is handsome, notwithstanding a number of trivial typographical errors, but a price of nearly £30 for such a slim volume must be regarded as excessive for a book aimed at students. In the current economic climate, even departmental libraries will think twice before ordering a copy.

And this is unfortunate, because this book will be particularly valued by students. The classic reference on fractals by Benoît Mandelbrot is a hugely impressive work, but it does suffer sometimes from being rather obscure. In contrast, Professor Turcotte's book is a model of clarity, with important concepts illuminated by carefully chosen examples. This comment is no less applicable to the parts which deal with chaotic dynamics. When the paperback edition is produced, which one hopes is soon, it should form a well-thumbed addition to the bookshelves of its target market.

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Iran's salt diapirs

Jackson, M. P. A., Cornelius, R. R., Craig, C. H., Gansser, A., Stöcklin, J. and Talbot, C. J. 1990. *Salt Diapirs of the Great Kavir, Central Iran*. Geological Society of America, Memoir 177. 139 pp. + 13 plates. Price $36.25 (hardback).

Memoir 177 of the Geological Society of America is entirely devoted to salt diapirism in the Great Kavir Basin of Central Iran. The Great Kavir dessert is one of few regions on earth were salt diapirs are relatively well-exposed at the surface but nowhere on earth are the two-dimensional internal structure of diapirs so well visible on aerial photographs and satellite images as here. The book consists of four parts: (1) *Geology*; (2) *Centrifuge modelling*; (3) *Analytical modelling of diapirism*; and (4) *Summary and conclusions*.

Part 1, *Geology* (pp. 3–96) forms the biggest part of the book and contains numerous aerial and field photographs. The source rocks of the diapirs consist of a lower layer of relatively pure salt and upper layer with numerous anhydrite (not gypsum as it is unstable below a depth of 800 m) and shale-bearing layers. The interface between the lower and upper layer clearly shows up on photographs and serves as an important marker horizon. The detailed internal structure is well visible in diapiric rocks from the upper layer but, unfortunately, relatively poorly visible in those from the relatively pure salt lower layer. Bedding in the surrounding sedimentary host rocks clearly outlines the regional structural geology (regional folds and faults). High strain zones and locally even syn-sedimentary rim synclines are visible around many of the diapirs as well as a gypsum rim, cap rock formed by dissolution of salt. By combining different erosion levels, the authors were able to do a three-dimensional structural interpretation of the diapirs and adjacent host rocks. Using an internal and external mushroom model, each with a subdivision in simple (less than one convection revolution) and vortex (more than one convection revolution) diapirs (Fig. 1.64), the authors group the various diapirs and explain the kinematics and dynamics.

Part 2, *Centrifuge modelling* (pp. 97–111) and Part 3, *Analytical modelling of diapirism* (pp. 112–129) investigate the plausibility of kinematic and dynamic models developed in Part 1; simple and vortex mushroom-type diapirs mainly formed by buoyancy. This is a very important part of the analysis but also the most difficult due to the scaling problem of physical and analytical models. For example, a question would be why the authors choose to use not only the same viscosity for overburden for the lower and upper source rocks but even for the overburden. Conservative estimates for the true viscosity contrast (unusually low in the Great Kavir Basin) would be in the range of 1:2–1:4 between the lower and upper source layer and around 1:10 for the lower source layer and overburden (due to numerous shale, anhydrite (not gypsum, see above) and sandstone layers). Using these values would influence the results of the centrifuge and analytical models. Nevertheless, the results of the centrifuge and analytical models presented seem to explain the evolution of the Great Kavir diapirs in general and in particular those of the canopy region with the large cluster of mushroom type diapirs.

Part 4, *Summary and conclusions*, gives a pointwise overview of the highlights of the book and also contains remarks, doubts and afterthoughts.

To summarize, the authors succeeded in giving a very complete description of the physiography of the Great Kavir dessert, stratigraphy of the Great Kavir Basin, regional structural geology and tectonic setting, the internal and external structure of the salt diapirs, and a structural interpretation (three-dimensional reconstruction and mechanism of emplacement), as well as comparisons between field, centrifuge and analytical models. The Memoir is not only suitable for specialist readers but also for non-specialists who want to understand more about the style and mechanism of diapiric intrusion. The book deserves a large audience as the text is clearly written and well organized, and it contains numerous, excellent (and unique) photographs and figures. I can recommend it for any geoscience library and given the relatively low price, not only specialists but also non-specialists should think of purchasing a copy.

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Magmatism in extensional Africa

Kampunzu, A. B. and Lubala, R. T. (editors) 1991. *Magmatism in Extensional Structural Settings: The Phanerozoic African Plate.* Springer, Berlin, Germany. Price DM 328, approx. £115 (hardback).

British geology has enjoyed a long and profitable association with Africa; the 'Dark Continent' that set the scene for much of Holmes's work and other major geological advances in the first half of this century. These developments evolved largely as a consequence of our national role as a colonial power which provided the infrastructure necessary for field expeditions and regional geological surveys on a scale now rarely seen. The same has been true for two other countries, France and Belgium in west and central Africa, respectively, and the influence of the colonial heritage is clear in this volume: 26 of the 30 non-African contributors (out of a total of 43) come from these three European countries. Since the colonial era, many aspects of African geology (with some notable exceptions) have languished away from the mainstream of the Earth Sciences, a condition largely due to the efforts of the superpowers during the Cold War, to convert numerous African countries into their surrogate battlefields. Yet despite working in conditions that many in the developed world would find exhausting and exasperating, Kampunzu and Lubala have undertaken and completed a huge task for which they should be highly commended. Under the aegis of I.G.C.P. 227, they have assembled 15 chapters into an excellently produced 637-page volume that covers many aspects of extension-related magmatism in Africa. An enormous achievement when working in a country where the telephone and mail systems, so necessary in a task of this magnitude and which many of us take for granted, seldom function efficiently.

The title of this volume may lead the uninitiated to expect a series of case studies, integrating magmatism and extensional tectonics into a coherent geological whole. This is not the case. The book is unashamedly petrological, with variable amounts of geochemical data and a few geodynamic interpretations. While some may not agree with the more fanciful models presented, and this is true for any work, the subjects covered are broad in scope and provide a good basis from which future investigations will evolve. Sadly, few of the papers refer to structural studies and none provide petrological interpretations within a well defined structural framework. This book will therefore be a disappointment to most structural geologists (for whom, I presume I am writing). For the petrologist and geochemist, however, it does provide an excellent review of the state of progress in the areas covered up to the late 1980s and is a valuable source of information for anyone active in or contemplating research into extensional magmatism in Africa.

The book is divided into four parts, each with an introduction by one or other of the editors and co-authors. Part 1 concentrates on the East Africa Rift system, for which Paul Mohr provides an historical perspective. This is followed by two chapters on the potassic magmatism of the Western Rift by Lloyd *et al.* and Edgar, and a comprehensive fourth chapter by Kampunzu and Mohr which reviews the evolution, petrology and geochemistry of the whole rift system. Part 2 comprises four chapters on extensional magmatism in West Africa. These tackle the Mesozoic tholeiite province of NW Africa (Bertrand), Cretaceous and Cainozoic (largely oceanic) magmatism of the Senegal Basin (Bellion and Crevola), a review of the tectonic, magmatic and geodynamic framework of the Canary Islands by Araña and Ortiz (a curious inclusion in this book, but one of the only chapters with some structural information) and an article on magmatism and mantle xenoliths from the Hoggar, Algeria (Dautria and Girod). Ring complexes and related structures are the subject of Part 3 and five chapters cover a variety of topics including: the Cameroon line (Déruelle *et al.*), two chapters on the The Aïr Massif, Niger (by Moreau *et al.* and Damaiffe *et al.*), the Chilwa carbonatite complex, Malawi (Wooley) and a mammoth review (75 pages) of the magmatism and mineralisation associated with Phanerozoic anorogenic plutonic complexes of the African plate (Kinnaird and Bowden). The final part has two chapters on kimberlites, to my mind not immediately associable with extensional tectonics, but valuable contributions nonetheless. The first, by Gurney *et al.*, reviews the kimberlites of southern Africa, and Demaiffe *et al.* cover those of Central Africa. There then follow 60 pages of references, and an invaluable geographical index for those of us who do not know the location of such places as Esauria-Agadivi and Pretoria.

Clearly this is a very mixed bag with some sections concentrating on geographical associations, others on related igneous phenomena. Some chapters are of a review nature, others more specific and focused in their subject matter. As a result, any reader will find some chapters a pleasure to read while other chapters may frustrate and possibly infuriate. It is not a book that anyone is going to read from cover to cover and, given the price, it is unlikely to find its way on to many private bookshelves, but I wholeheartedly recommend it for geology departments and libraries.

As the publishers claim on the back cover, this volume is "the first complete and up-to-date review" of many aspects of extensional magmatism in Africa. It by no means offers a complete picture, as the editors themselves explain in their introduction. But it does highlight those areas of the vast continent that remain geologically underexplored and present challenges for modern Earth Sciences in what is increasingly a less exploitive and more co-operative era of international scientific exchange.

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