BOOK REVIEWS

Kruhl, J. H. *Fractals and Dynamic Systems in Geoscience.* Berlin (Springer-Verlag)1994. Price DM 148.00 vi + 421 pp. ISBN 3-540-57848-X.

The general subject area of fractals and dynamical systems has recently found a wide variety of practical applications in the Earth Sciences, following the publication of Benoit Mandelbrot's books on the fractal geometry of Nature in the late seventies and early eighties. Initially the general Geoscience audience was sceptical about its importance – after all Lyell had anticipated Mandelbrot's conclusions about the scale-invariance of geological systems by almost two hundred years, and ever since geologists have routinely put scale bars on photographs, thin sections and maps. So what is new? Moreover what had fractals got to do with classical problems such as plate tectonics or equilibrium thermodynamics in igneous and metamorphic petrology? In summary, what have fractals to tell us that is new about important geological processes involved in rock deformation and mineral physics?

First, Mandelbrot introduced a *quantifiable* measure of geometric scale-invariance in terms of a set of 'fractal dimensions' which describe the roughness, branching, clustering and space-filling properties of a wide variety of model and natural systems. Second, fractals found rapid application in the modelling of the *phase space* of non-linear, self-organising, dynamical systems. In these systems order could be spontaneously created by non-equilibrium processes, in apparent contravention of the second law of thermodynamics. For example in simple models of atmospheric circulation or mantle flow, ordered convection cells develop in order to maximise heat transfer at an intermediate Reynolds number. Here the behaviour is quasi-periodic, somewhat predictable and spatially ordered. In contrast, as the Reynolds number is turned up, the regular cells give way to a more disordered state in the transition to turbulence, unpredictability and chaos. In particular, fractal dimensions are used to quantify thc 'strangeness of strange attractors', and to discover the boundaries in phase space between separate attractors, in simple non-equilibrium systems with a few degrees of freedom. Thus it is important to recognise that fractal geometry is used in two senses – one referring to the geometry of the natural world (in 3D), and one referring to the n-dimensional 'phase' space provided by an orthogonal set of axes corresponding to the independent variables used to describe the dynamics.

The stated aim of this volume, based on papers submitted after a meeting on the subject at the Goethe Institute, Mainz, Germany, in the spring of 1993, is "to provide an overview of the applications of fractal geometry and the theory of dynamical systems in the geosciences". This has been achieved by collecting together a set of papers, presented at the meeting and by subsequent invitation, on the themes of: I - Deformation and Tectonic Structures; II - Physical Features and Behaviour of the Earth; III - Formation, Structure and Distribution of Minerals and Matter; and IV— Methods. Sections I–III are each introduced by a review, often the most generally useful contribution for a wider audience, followed by a set of more specialist individual papers. Although the editors have tried to maintain balance, it is inevitable that the shotgun approach of conference proceedings has left some significant holes and undefined jargon, so this is not a textbook in the conventional sense. Of course it is impossible to cover all of the 31 papers in detail, but a brief summary follows.

Contributions in Part I cover subject areas including Fracturing, Comminution, Veining, Faulting and Nonlinear Rheology. Some papers present new data, some review older material, and the latter papers on nonlinear rheology make a significant contribution to the logical next step, i.e. explaining the physics behind the organised features we see in deformation textures. In Part II, contributions are dominated by earthquake seismology, ranging from Earthquake Prediction Research in the West and in China, the Physics of Stick-Slip Phenomena, to Earth Tides and Fractal Topography. This diversity is not surprising since fractal geometry was applied early to seismology, and has also had a significant impact on the field. The section on Methods (Part IV) is important because there are many misconceptions in the literature regarding the resolution, utility and meaning of individual fractal dimensions. Here two methods are examined for the quantification of self-affine scaling, and the interpretation of the $\delta^{18}O$ record. Clarifying the utility and applicabilty of such techniques will remain a useful pursuit for the near future at least.

Section III will be of most use to mineral physicists and chemists. Here we are introduced to the application of fractal geometry and non-linear dynamics to Mining; Gold Exploration; Self-Organising Fabrics and Geochemical Zoning applied to Agates, Geodes, Concretions and Orbicules; Manganese Dendrites; Nucleation and Growth during Crystallization; Weathering, Bioactive Marine Sediments; and Oxygen Isotope Records. No attempt is made consciously to separate 'geometric' fractals from 'phase space' fractals, although both figure prominently in this section. Again some of the material presented is more mature science than in other parts – for example Peter Ortoleva's classic work on geochemical self-organization has now appeared in textbook form in its own right. However, the general impression is that the physics of pattern formation in mineral physics is currently a hot topic, not least because many mineral-forming processes are now known to be the result of non-equilibrium, non-linear processes. This kind of physical insight stands out of the general crowd of empirical observation and method present in much, but not all, of the rest of the text.

So in the end we have a set of scholarly individual contributions of varying types, subject matter, writing style, perceptiveness and quality. Unfortunate, from the point of view of cohesion normally associated with a book, is the lack of cross-referencing in the text. Most contributions stand alone or can be read in parallel, and not a few of the key results in the ostensibly 'new' material presented have appeared in similar form elsewhere. Also there is comparatively little on the more recent advances in the physics of dynamic complexity (the ordered behaviour of non-equilibrium systems with many degrees of freedom). This is unfortunate because studies such as these are beginning to explain the emergence of fractal geometry in real space in many natural geological, biological and ecological systems.

As the editor states in his introduction: 31 contributions cannot possibly cover all of the possibilities of application within the broad field of the Geosciences. Certainly the prominence given to state-of-the-art material in Mineral Physics and Deformation Processes indicates the early and practical success with the techniques in these fields. Whether or not this insight will emerge in later work on fields as diverse as Global Climate Change, Earth Tides and Earthquake Prediction (?) remains to be seen. In any case the book highlights the idea that establishing fractal behaviour is only the first step in understanding the origin of the spatial order and pattern in the form of scale-invariant geometry in Geoscience, or any other field for that matter.

I. MAIN

Spear, F. S. *Metamorphic Phase Equilibria and Pressure–Temperature–Time Paths* Mineralogical Society of America. 1993 (2nd printing with corrections 1995) xxii + 799 pp., Price $45.00 (+$5.00 shipping). ISBN 0-939950-34-0.

In the last two decades, Professor Frank Spear has had an important influence on many facets of metamorphic petrology, and this most impressive monograph bears witness to just how much of a polymath he is. In his preface, he points out that tomorrow's metamorphic petrologists must be versatile scientists with a detailed working knowledge and understanding of many branches of earth science, from geophysics through mineralogy, isotope systematics and geochemistry to traditional petrology. The aim of this book is to teach the methods, within these disciplines, by which practising research workers can solve questions on the evolution of orogenic belts. To that end, Professor Spear's approach is to apply theoretical rigour to petrological analysis, and he makes no apology for the high density of mathematical equations, phase diagrams, chemical reactions and petrogenetic grids. Thus, the book is primarily a 'how to' manual, rather than a survey of the current state of petrological knowledge. Having said that, it contains (alongside the careful explanations and derivations) a huge amount of up-to-date petrological information, and in many places the review element is further provided for by pointers to extensive lists of references.

Much of the material in the book is at a very advanced level and would therefore be unsuited to form the basis of any but the highest-level undergraduate courses. Here and there are pockets of more basic material that serve to place the advanced stuff in context. The people most likely to benefit from the book are post-graduate students embarking upon their own petrological research projects (I wish I had had access to such a book as a PhD student!) or taking graduate petrology courses, lecturers setting up such courses, and senior researchers who are endeavouring to teach themselves new tricks.

The book is organised in five main sections and comprises 21 chapters in all. The first part is an overview of metamorphic petrology and incorporates historical perspectives as well as explanations of basic concepts and fundamental controls. The second part is an exposition of phase equilibria, both homogeneous and heterogeneous, insofar as they apply to the interpretation of metamorphic rocks. The third part is a discussion of the metamorphism of