visible ink, radio transmitters, secret meetings, stashes in safe houses, dead-letter drops, and an attractive woman. Stiller reports having delivered over 20,000 pages of secret documents to the West to be analyzed. Since the wall fell, he has admitted in several public appearances that the account in the book of the way in which contact was made with the BND is not quite true; despite further questioning, Stiller remains reticent on this question and loyal to the BND. Reportedly the BND reviewed the manuscript before publication.

After his spectacular defection in 1979, about 20 East German agents were arrested in the West, including many of Stiller's own agents. For example, Stiller's first agent active in the West, Rolf Dobbertin (cover name "Sperber"), a physicist from Rostock sent to Paris in 1956 to study at the expense of the Stasi (and placed in a French science institute by Rompe), was sentenced to 12 years in prison for his espionage activities. He sat in a French jail for five years before he was released in 1991. Although Dobbertin denies spying, calling his activity "scientific developmental aid for his GDR colleagues," Stiller describes the hundreds of documents Sperber collected from his contacts with French physicists and even Americans from Princeton, Berkeley, and the Lawrence Livermore Laboratory; these documents were passed to Stiller by way of West Berlin train-station lockers. During his first five-hour meeting with Sperber in an East Berlin safe house, Sperber received 4350 marks of "operational money." In addition, after the wall fell, more East German agents were unearthed at West Germany's major Nuclear Research Center in Karlsruhe, which was one of Stiller's main objects of study.

One revelation that should play a role in the current restructuring of the German science landscape is the number of Stasi agents placed in the Central Institute of Electron Physics of the East German Academy of Sciences: the institute was, according to Stiller, "interlaced" with Stasi agents and became an outpost for the Stasi. In contradiction to this view, however, a former physicist at the institute, Hans-Jürgen Fischbeck, in an interview in a recent compilation by Guntolf Herzberg and Klaus Meier (*Karrieremuster: Wissenschaftlerporträts*, Aufbau-Taschenbuch Verlag, Berlin, 1992), minimizes the influence of the Stasi and claims that the institute was not instrumentalized by them. Stiller's assertion may at least serve to confirm what we have begun to learn: that most academic institutes, to varying degrees, were interlaced with informants.

Because the HVA files were systematically (and legally) destroyed after the wall fell, Stiller's book will continue to be a major source on the HVA and its Sector for Science and Technology. It shows that, contrary to popular wisdom and the view reflected by the current de-Stasification of East German academics and scientists, the Stasi's grip embraced the scientific community perhaps more firmly and in a more far-reaching way than it did the humanities and social sciences. Whatever purposes the book may have initially served as a political instrument for the BND, it is of value for enlightening the reader about the realities of scientific espionage. The secrets Stiller reveals about the extent, scope, and inner workings of the Stasi's activities uncover a whole new world behind the crumbling and drab East German facade most Westerners encountered on crossing the wall.

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## Order in Disorder

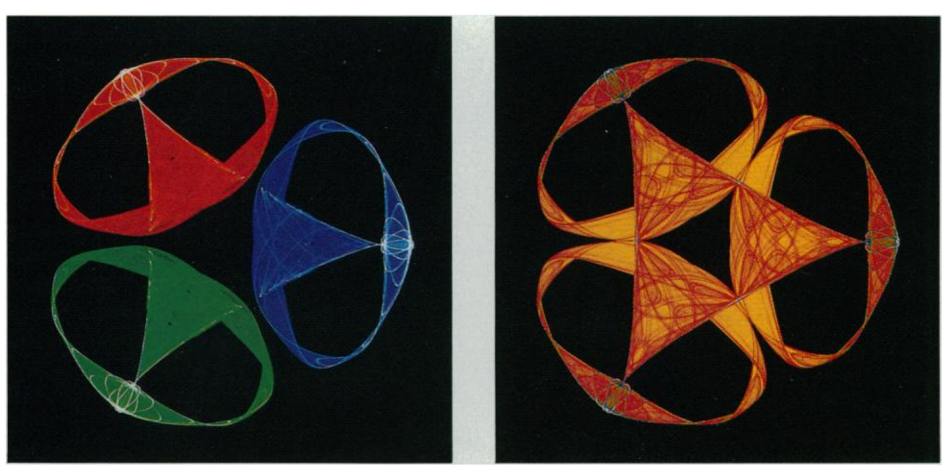
**Symmetry in Chaos**. A Search for Pattern in Mathematics, Art and Nature. MICHAEL FIELD and MARTIN GOLUBITSKY. Oxford University Press, New York, 1992. xii, 218 pp., illus. $35 or £19.95.

In nonequilibrium systems the transition to states of lower spatial symmetry, often with more complicated dynamics, is a commonly observed behavior. Characteristically such transitions occur as one increases the applied stresses forcing the system out of equilibrium. In mathematical models, these transitions are described as symmetry-breaking bifurcations; the progression from symmetric states with simple dynamics to asymmetric states with complex dynamics is captured by a sequence of progressively less symmetric attractors in the space of states of the system (the phase space). In the best-understood examples, the emergence of complex dynamics corresponds to the appearance of a chaotic attractor in phase space.

Less widely recognized is the possibility of an inverse phenomenon if the applied stresses are increased further after an asymmetric chaotic state has been reached. Known as symmetry-increasing bifurcations, these latter transitions have been studied recently in mathematical models ranging from the cubic logistic map in one dimension to reaction-diffusion equations and the complex Ginzburg-Landau equation, both infinite-dimensional dynamical systems. Some evidence for such bifurcations in real systems has been noted in experiments on fluids, specifically in the flow between concentric rotating cylinders.

In a symmetric system, the attractor corresponding to an asymmetric chaotic state is a set in phase space whose elements correspond to the instantaneous physical states that lack (or "break") the symmetry of the system. The dynamics on the attractor takes the system along a chaotic trajectory from one asymmetric instantaneous state to another. Despite the lack of symmetry in the individual states, the attractor may nevertheless be invariant under the full symmetry of the system, or it may have only partial symmetry. The symmetry characteristics of the attractor cannot be detected by examining the instantaneous states; rather, they are revealed by computing time-averaged states over intervals long enough for the trajectory to effectively cover the attractor. Thus the symmetry of an attractor is observable only in the statistical features of the chaotic state that Field and Golubitsky dub "symmetric chaos." Chaotic states that have the full symmetry of the system only on average have recently been reported in experiments on chaotic surface waves in square geometry and in chaotic fluid convection in circular and hexagonal containers.

If the chaotic attractor does not have



*Left*: "Three conjugate attractors of a triangularly symmetric mapping." *Right*: "Attractor with full triangular symmetry." [From *Symmetry in Chaos*] the full symmetry of the system, there are symmetric images of the attractor elsewhere in the phase space. For example, in a reflection-symmetric system, if an attractor is not invariant under reflection, there must exist a second attractor that is the reflected image of the first. In a symmetry-increasing bifurcation, two or more such symmetry-related attractors collide, resulting in a new attracting set having greater symmetry than before. Such a bifurcation produces a transition to time-averaged states of greater symmetry.

The potential scientific importance of symmetric attractors and symmetry-increasing bifurcations motivates the research described by Field and Golubitsky. However, they have not written a research monograph, and applications to physically interesting systems are not considered in any detail. Rather, the authors provide an elementary and reasonably accessible introduction to the theoretical constructs by examining the behavior of various symmetric mappings in one and two dimensions. These dynamical systems offer the simplest setting in which symmetric attractors and symmetry-increasing bifurcations arise and the results are easily visualized; indeed, the attractors found here define stunning patterns, which have been beautifully rendered by color-coding the trajectories that cover the attractor. In more precise terms, the colors are assigned to reflect the local concentration of the trajectory on the attractor. The resulting catalogue of brilliant geometric patterns can be enjoyed even if no deeper understanding of the underlying mechanism is attempted.

That would be unfortunate, though, since Field and Golubitsky explain in detail how the illustrations were produced, starting with the equations needed to define the various maps and ending with a listing of the computer programs used to calculate the images of the attractors. In the process the reader is offered a brisk introduction to complex numbers and complex arithmetic, the precise definition of symmetry through the concept of a group of transformations, discrete dynamical systems including the logistic map and period-doubling cascades, and chaotic attractors. A final chapter explores the extension of these ideas to nondeterministic "iterated function systems." Here one considers a set of symmetric mappings (two or more) and constructs trajectories by iterating a randomly chosen map at each point of the trajectory. Basic theorems due to Barnsley regarding the existence of unique attractors for these stochastic systems are explained.

This book nicely complements two other popularly written books, *Does God Play Dice?* by Ian Stewart (Blackwell, 1990) and *Fearful Symmetry: Is God a Geometer?* by Golubitsky and Stewart (Blackwell, 1992), which focus on dynamical chaos and symmetry breaking, respectively. Whereas the popular scientific literature on these topics is fairly extensive, *Symmetry and Chaos* is the only presentation of symmetric chaos and symmetry-increasing bifurcations outside the technical literature. Although these ideas may not have the same impact on the physical sciences as chaos and symmetry breaking, there is growing interest in the symmetry of a time-averaged chaotic state as one tool for analyzing states of so-called spatiotemporal chaos. Field and Golubitsky have written a unique book that will appeal both to casual readers intrigued by the patterns of symmetric chaos and to scientists interested in testing the relevance of the underlying mathematics.

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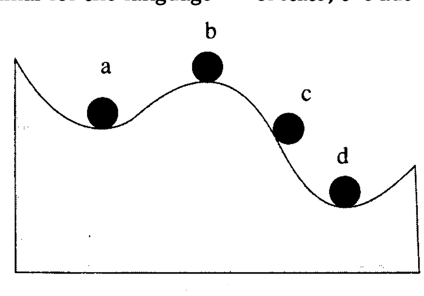
## Phase Equilibria

**Thermodynamics in Geochemistry.** The Equilibrium Model. GREG M. ANDERSON and DAVID A. CRERAR. Oxford University Press, New York, 1993. xx, 588 pp., illus. $75 or £65.

Thermodynamics, the science that relates chemical and physical changes of matter to heat flow and work, is useful in a large variety of practical problems and can help us understand some of the most fundamental questions in science. Indeed, because its laws governing the flow of energy apply to all physical systems, thermodynamics can be considered the grammar for the language of science. There are numerous good books introducing the laws of thermodynamics and developing their consequences. Thus, as Anderson and Crerar acknowledge in their preface, one may wonder, "why another book on thermodynamics?" The answer will become clear to the reader of this book, which provides an innovative, careful, and complete development of the subtleties of thermodynamics that anyone seeking an understanding of phase equilibria in a wide variety of earth processes needs to grasp. As geochemists, Anderson and Crerar have drawn on their extensive experience in both research on and teaching of the problems of phase equilibria to develop a cohesive treatise with well-explained examples. I imagine it will become the standard text for teaching the basics of thermodynamics as well as introducing more advanced models of solution theory, not only in the earth sciences but also in many branches of engineering. It will also likely become a classic reference for working scientists.




"Four positions of a ball on a surface, to illustrate the concept of equilibrium. Position *a*—metastable equilibrium. Position *b*—unstable. Position *c*—unstable. Position *d*—stable equilibrium." [From *Thermodynamics in Geochemistry: The Equilibrium Model*]

The book begins by drawing a clear distinction between reality and the thermodynamic model. Like any model, thermodynamics is governed by simple mathematical relations. The authors review this mathematics, showing the relationship between variables, functions, differentials, and a number of transforms. Energy minimization and metastable equilibrium constraints are then elucidated in the context of this mathematical framework. A separate chapter is devoted to thermodynamic terms and concepts, including metastability, degrees of freedom, stable and metastable equilibrium, partial and local equilibrium, reversible and irreversible processes, and single-valued and continuous properties. The zeroth, first, and second laws of thermodynamics are then introduced, with the second law developed through a discussion of the thermodynamic temperature scale and the equality of temperature ratios to the negative of heat ratios between states rather than the typical discussion of Carnot cycles. This approach seems to be more intuitive to students and therefore more effective in conveying the fundamentals of entropy. The subsequent discussion of the statistical interpretation of entropy using configurational probability theory and the partition function avoids the appearance of being grafted onto a classical approach, as is the case in many textbooks.

Having developed all the useful functions of state, the authors go on to consider simple mineral systems. The constructs of activity, ideal and dilute solution, standard states, and the equilibrium constant are evolved. An up-to-date explanation of the thermodynamics of solutions includes discussions of the models of Margules for solids, Redlich and Kwong for gases, and Pitzer as well as Helgeson, Kirkham, and Flowers for aqueous electrolytes. Separate chapters describe approaches to solving redox problems, with a variety of real-life examples, and methods of undertaking distribution-of-species calculations, with discussion of the theory behind reaction path modeling.

This book strikes a good balance between developing the fundamental concepts and presenting techniques to solve practical