

## Teaching on the Edge of Chaos

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Geology, as with all the natural sciences, has undergone a rapid transformation over the last half-century. Transitioning from an interval of largely descriptive science to the establishment of a unifying paradigm has resulted in an extremely rapid advance in our understanding of the Earth and its processes. For several decades plate tectonics has provided the foundation for all geological interpretation. While tectonics continues to be expanded and refined, a new method of observing and simulating nature has recently been developed. Currently, geology, like all other sciences is struggling to absorb the lessons of a new and growing field - complexity study. Mark Buchanan, in his new book *Ubiquity*, describes how densely interconnected networks of relatively simple mathematical expressions can simulate nature's complexity. While the physical sciences have embraced self-organization in its various forms, the historical sciences of evolutionary biology and geology are just beginning to explore the wide range of applications provided by this field of inquiry.

As science educators, we are faced with two challenges when considering the growing field of complexity science. First, we need to study the theoretical advances and evaluate

how we must modify our individual understanding of geology. In most cases the primary literature is accessible to non-specialists. As such, it is essential to understand how this new field is impacting our science. Beyond staying abreast of the growth of this new field, it is important for us to translate to our students the excitement of intellectual inquiry presented by the study of nature's complexity. Students are naturally drawn to the most complex aspects of the geosciences; earthquakes, mass extinctions, and climate change are all examples of highly dynamic processes that are well suited to study with complexity models. Translating student interest to meaningful instruction is, as always, a difficult proposition for geoscience educators.

Bringing complexity to the classroom presents some unique pedagogical problems for the geoscience educator. First, in order to be more than an exercise in show-and-tell, students must become actively engaged in the simulation of natural systems. Given that so many students have problems with unit conversions and elementary computation, suggesting that a time-rate-of-change relationship be expressed in mathematical form could prove overwhelming to many introductory stu-

dents. It is essential, however, that we demand numerical ability in our students. As such, simple exercises in complex systems provide a good process by which to introduce functional relationships and differential expressions. Given the iterative nature of most numerical models of complex systems, it is also necessary to introduce students to either spreadsheet calculation or simple programming formats. Likewise, the outcomes of experiments in complexity produce vast amounts of computational data and it is therefore necessary to introduce students to the basics of data presentation. Understanding graphical relationships is often a difficult skill for students to master, and complex systems provide an interesting way to have students construct and interpret visual data.

Beyond these somewhat traditional learning outcomes associated with building complexity experiments

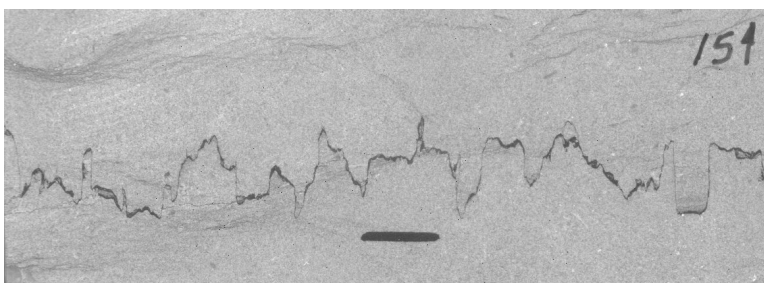
into the geoscience curriculum, the most powerful pedagogical benefit to be gained is in the introduction of students to the concepts of model design, testing, and modification. In order for students to learn to think scientifically, they must be encouraged to become engaged in scientific discovery.

Numerical simulation

of complex systems provides both an exciting and low-cost technique for delivering the pleasures and problems of scientific research.

Given the steadily declining numbers of students majoring in the sciences, the geosciences particularly, it is clear the future health of our profession demands that we do all we can to attract more and better students to our classrooms. I am convinced that today's students require, in fact demand, a rich and challenging learning environment. While it certainly remains necessary, it is no longer sufficient to pull out a tray of silicate minerals for student observation or drone on about the virtues of the township and range system in our introductory labs. Rather, we must embrace the pedagogical opportunities presented by the scientific discoveries of self-organization and complexity science. As such, I strongly encourage educators to prepare and submit manuscripts describing how they are using problems associated with modeling complexity in their classrooms. This field of study is too exciting, too important, and too beautiful to not explore with our students.

Carl N. Drummond, Editor



**Self-organized complexity demonstrated by a stylolite from the Mississippian Salem Limestone of southern Indiana, horizontal bar is 1 cm.**