SCIENTIFIC FRONTIERS AND RISKY VERSUS SAFE SCIENCE

E. Bruce Watson

The thematic content of *Elements* is devoted to describing the forefronts of mineralogy, petrology, and geochemistry ("MPG science") as perceived by our scientific community and by the editorial and advisory boards. Each issue contains articles written at a level that we hope will make the science accessible to a broad readership. From *Elements*' inception, however, the intent has been not so much to provide a well-digested review of the state of affairs in a given subdiscipline, but rather to convey—somewhat "anecdotally"—the essence and excitement of research occurring on the frontiers of our science. Naturally this means that the editorial board must struggle with the question of what constitutes a frontier in MPG science. In some scientific fields the question "Where is the frontier?" might elicit a consistent answer from the majority of practitioners. In theoretical physics, for example, the nature of dark matter and dark energy might predominate; in biochemistry the majority might concur on protein folding and/or molecular self-assembly.

Intertwined with the question of what constitutes a scientific frontier is the not-unrelated value judgment of whether "risky" science or "safe" science is inherently better.

In MPG science and the geosciences in general, it would be naïve to expect uniformity in our answers to the "frontiers" question. The breadth and diversity of our field and its multi- and interdisciplinary character impart a very wide range of perspectives. Some geochemists look at our field in a manner that is literally "global"—if the science doesn't affect our entire planet, then it's relatively uninteresting. At the other end of the spectrum are those who view the fundamental aspects of MPG science as occurring at the atomic level—a view that is also difficult to contest. Key to maintaining harmony amongst us might be to acknowledge that there are different *kinds* of frontiers in MPG science, and that a range of criteria can and should be applied in assessing value and importance. At some level we are all certainly aware that reviewers of our papers and proposals bring wide-ranging perspectives.

Intertwined with the question of what constitutes a scientific frontier is the not-unrelated value judgment of whether "risky science" or "safe science" is inherently better. To get the discussion going I'll suggest some end-member definitions: "risky science" is research that is difficult and/or costly to perform and stands a relatively small chance of producing a definitive conclusion, but (implicitly) has the potential to dramatically affect our thinking. "Safe science" is research that is clearly doable if the effort is made (so the chances of success are very good), but probably won't change our perceptions or further our understanding dramatically, at least in the short term. Scientists serving in numerous capacities—researchers, laboratory and department heads, deans, directors of funding programs, etc.—face the philosophical question of which kind of science is better: Which furthers the interests of the field more effectively? Which provides better value for the funding dollar? Which is more easily justified to policy makers and budgetary decision-makers? It is in the very nature of many scientists and lab directors to aspire to "high-impact" research, so there is an understandable tendency among us to embrace risky science: nothing ventured, nothing gained. But risky science costs money, and we have to ask how many "failures" we can afford.

Leaving aside huge endeavors like missions to other solar-system bodies, examples of risky MPG science might range from drilling a deep hole in the crust to developing new mass-spectrometric protocols (or even new instruments) for measuring abundances or isotope ratios of rare isotopes. Whether or not the risks inherent in this kind of work are worth the potential payoffs must be evaluated by individual scientists who devote their time and effort to the research and by those making decisions about monetary support. My personal view is that we can't afford *not* to support this type of research, both philosophically and monetarily. Discoveries resulting from risky science have resulted in entire new frontiers and paradigms throughout the history of science.

Examples of "safe" MPG science might include experimental determinations of phase equilibria and thermodynamic quantities of Earth materials using time-proven techniques and well-established instrumentation. There exists a tendency to think "all the important stuff has been done," but we sometimes rely on rather old measurements made with technologies that were only emerging at the time, and in some cases there is good reason to question the accuracy of the data. The cumulative

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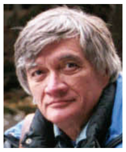
INTRODUCING THE 2008 EXECUTIVE COMMITTEE

Elements is overseen by an executive committee composed of a representative of each of the 14 participating societies. We would like to thank Jeremy B. Fein, Norman M. Halden, Russell S. Harmon, Cliff Johnston, Daniel J. Kontak, Kathryn L. Nagy, and Eric H. Oelkers, who recently completed terms on the Executive Committee. Current members of the committee are introduced below.

ROBERT BOWELL is Principal Geochemist for SRK Consulting in Cardiff, Wales. He holds a PhD in geochemistry. His main field of expertise is in the application of geochemistry in mineral processing and mining. He is also an active micromounter and enjoys mineralogy as a pastime. He is the past president of the Association of Applied Geochemists.

GIUSEPPE CRUCIANI is an associate professor of mineralogy in the Department of Earth Sciences of the University of Ferrara (Italy). His major research interests are in the crystallography and crystal chemistry of zeolite-like minerals and their synthetic analogues, rock-forming minerals (e.g. micas and melilites), and oxide systems. He is the SIMP representative.



RODNEY C. EWING is the Donald R. Peacor Collegiate Professor in the Department of Geological Sciences at the University of Michigan. He is also a professor in the departments of Nuclear Engineering & Radiological Sciences and Materials Science & Engineering. Ewing's research is on radiation effects in minerals and the crystal chemistry of actinide minerals and compounds. He is the past president of the Mineralogical Society of America and the International Union of Materials Research Societies. He has received the Dana Medal of the Mineralogical Society of America and the Lomonosov Medal of the Russian Academy of Sciences. He is *Elements*' founding editor.

RAY E. FERRELL JR., past president of The Clay Minerals Society, is the Webster Parish Chapter Alumni Professor in the Department of Geology & Geophysics at Louisiana State University. He served as editor-in-chief for *Clays and Clay Minerals*. He has published on the origin of clay minerals and instrumental analysis techniques. Currently, Ray is exploring ways to increase student learning through the use of multimedia and enjoys grant support to increase minority participation in graduate geoscience programs.

DAVID A. FOWLE is an assistant professor in the Department of Geology at the University of Kansas. His research interests range from mineral–metal–bacteria interactions to trace-element cycling in lakes and soils. He currently serves as the secretary of the Mineralogical Association of Canada.

JOHN M. HUGHES received an undergraduate degree from Franklin and Marshall College and graduate degrees in Earth sciences from Dartmouth College, and then undertook a predoctoral fellowship at the Carnegie Institution of Washington. Professor Hughes joined the faculty of Miami University in 1981 in the Department of Geology. He served in various administrative positions at Miami and in July 2006, he moved to the University of Vermont, where he serves as provost and senior vice president, and professor of geology. His research is in the area of X-ray crystallography. John currently serves as the treasurer of the Mineralogical Society of America.

CATHERINE MÉVEL holds a CNRS research position at the Institut de Physique du Globe de Paris (IPGP). She is currently managing the European Consortium for Ocean Research Drilling (ECORD) on behalf of 17 countries. She graduated in petrology at the Université Pierre et Marie Curie (UPMC), Paris, in 1975. Her main research interest concerns the generation and evolution of the oceanic lithosphere. She recently focused on serpentinization processes at mid-ocean ridges and their impact on chemical fluxes. She is the past president of the Société Française de Minéralogie et Cristallographie.

MAREK MICHALIK is a lecturer at the Institute of Geological Sciences of the Jagiellonian University. He graduated in geology in 1974 from the Academy of Mining and Metallurgy in Kraków and obtained his PhD in 1985 and habilitation in 2002 at the Jagiellonian University in Kraków. He is the president of the Mineralogical Society of Poland, a member of the editorial board of *Mineralogia* (formerly *Mineralogia Polonica*) and a member of the Presidium of the Committee on Mineralogical Sciences of the Polish Academy of Sciences.

MANUEL PRIETO, president of the Spanish Mineralogical Society, received his PhD in geology at the University of Madrid, Spain, in 1982. Since 1991 he has been a professor of mineralogy at the University of Oviedo. His research interest is crystallization behavior in low-temperature geochemical systems, particularly nucleation in porous media and mineral–water interactions involving solid solutions. He has co-authored over 70 papers on these topics.

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value of certain kinds of safe science can be huge: Where would we be, for example, without thermodynamic databases? Where would we stand in the climate change discussion if C. D. Keeling had not begun to monitor atmospheric CO_2 at Mauna Loa 50 years ago? Like risky science, safe science can also create new frontiers, but the pathway is fundamentally different: safe science contributes to, among other things, the databases required to develop models that can both unify ideas and stimulate further questions.

It is probably fair to say that some scientists are motivated by living on the edge—doing risky science because of the potential benefit and attention it garners both immediately and in the longer term. Others are more comfortable contributing to a bigger picture that will be assembled at a later time, possibly by a different researcher. I think the history of MPG science encourages us to embrace both philosophies. Cast in purely monetary terms, the analogy of wise investment in the stock market may be appropriate here: we should develop a mixed portfolio; take some chances when the odds and potential gains look good, but stick with some consistent (if seemingly unexciting) performers for the long haul, too.

This "Deep Earth" issue of *Elements* describes science that has had its high-risk aspects (e.g. development of the multi-anvil apparatus in the 1980s and, more recently, the quest for post-perovskite and high-pressure "H-storing" phases). However, it also includes some safer strategies whose importance is undeniable (e.g. measurement of the physico- and thermochemical properties of deep-Earth phases). Interestingly, the science of the deep Earth has opened several frontiers simultaneously: the nature of our planet's deep interior; the fundamental physics of ultrahigh pressure; and the technology needed to sustain the relevant P–T conditions and characterize the samples produced. We hope the articles will make compelling reading, whatever your taste in great science.

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