E. Bruce Watson

Geoscience Curricula for the 21st Century

Because of the rapidly changing nature of our field, many geoscience departments struggle with questions concerning the appropriate course content of today's bachelor's degree in geology. Those of us who completed our undergraduate education prior to 1980 probably have in common ~90% of our undergraduate geoscience courses, which would likely have included a "core" of physical and historical geology, mineralogy (2 terms), structural geology, sedimentation and stratigraphy, regional geology, paleontology, igneous and metamorphic petrology, sedimentary petrology, geomorphology, and a 6–8 week summer field course. Our predecessors designed this more-or-less standardized curriculum to provide essential knowledge in what were then largely disparate subfields of geology. All of these subjects were considered vital background for employment—mainly in the mineral and energy industries—and for advanced study in specialized graduate programs.

At many colleges and universities today, course requirements for the geoscience BS degree diverge substantially from the traditional curriculum described above. I work in a small department where solid-Earth geochemistry and petrology are vigorous research areas but, remarkably, our undergraduates are not actually required to take petrology. Our mineralogy requirement is limited to just one course (Earth Materials) that lacks an in-depth optical component. It could be argued that a great deal has been lost at Rensselaer as the traditional curriculum evolved to the present one. But perhaps a better way to look at the changes is to embrace what has been gained rather than bemoan what has been lost. Our students spend a limited amount of time under our influence; our job is to prepare them as best we can for careers in the modern geosciences.

What exactly has forced the widespread restructuring of geoscience curricula? At the risk of stating the obvious, I think there are two factors: (1) the Earth sciences have collectively migrated to more systems-oriented thinking and (2) entirely new subfields have emerged. The "geosystems" approach has arisen from the realization that treatment of individual Earth systems in isolation rarely provides a complete picture: at the very least, for example, the solid Earth interacts with the hydrosphere and the biosphere, and the latter two interact with each other and also with the atmosphere (see *Elements* volume 3, number 5). Many of these interactions were unknown when the traditional undergraduate geology curriculum was conceived, and they have spawned—or expanded the scope of—what must now be acknowledged as fundamental subdisciplines in their own right, e.g. organic geochemistry, geomicrobiology, chemical hydrology, biogeochemistry, and geobiology (perhaps even medical mineralogy, the theme of this issue). Moreover, the increasing coincidence of frontiers in geoscience research with fundamental issues of the environment (global climate, contaminant fate and transport, water resources) blurs the distinction between Earth science and environmental science. Many of our graduates find employment not in the mineral or fossil-energy field (though jobs still exist in these sectors), but with environmental consulting firms or government agencies having environmental oversight or regulation responsibility.

Given all this, I think it's worth asking what is the "right" geoscience curriculum for the 21st century. My personal view is that the "classical" fields of mineralogy, petrology, and inorganic geochemistry (MPG) remain vitally important because they provide essential background about Earth's dominant materials and the geological processes that produce and affect them. No matter how much our curricula are modernized, it is important to ensure that our students are exposed to the "foundation" methodologies and paradigms of these crucial disciplines—but somehow we must also create space for the newest ideas and applications of our science. Perhaps we can benefit by recalling how plate tectonics was accommodated in the classical undergraduate geology curriculum. Plate tectonics impacted so many subfields of geology in the 1960s and 1970s that it was essentially infused into existing courses with few if any changes in degree requirements: regional geology, petrology, structural geology, and other courses were simply "modernized" by setting them in the new context. I think we can use a similar mechanism to introduce students to recent developments in MPG science. In Earth materials courses, for example, time can be devoted to discussion of the role of microorganisms in the synthesis and alteration of minerals. In introductory geochemistry courses we can address the role of microbes in element cycling. If existing courses are thus enhanced with new material in concert with the development of new subdisciplines, perhaps we can view the need to sacrifice traditional content in a more favorable light.

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This brings me to what may be the biggest curriculum dilemma in modern geoscience: should we require two or more courses in biology *in addition to* the six to eight courses we generally require in physics, chemistry, and mathematics? We may be at a point where it is necessary to provide the

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THIS ISSUE

This Medical Mineralogy issue provides illuminating perspectives on the diverse roles of minerals, both natural and unnatural, in the human body. In addition we gain insight into the properties of minerals as they affect biomolecules in soils. Fascinating science!

THREE YEARS OLD ALREADY

With this issue, we close our third year of publication. We are pleased with the recognition *Elements* has received in this short span of time, and we are committed to further improvements. As we reach this milestone, we thank all the guest editors and authors who have contributed their time and energy (see list on this page) since volume 1, number 1. Without them, *Elements* would not be here.

When Ian Parsons steps down at the end of 2007, the original team of principal editors will have been entirely replaced. A special thanks to Rod Ewing, Michael Hochella, and Ian Parsons who took the concept of a multi-society thematic magazine and made it into reality.

Our advertising revenue increased markedly in 2007, with the August issue bringing in the most advertising revenue so far. This has allowed us to increase the number of pages per issue from 64 to 72 in 2007.

ONLINE ACCESS

One thing we had not planned for is that you, the readers, would clamor for electronic access to *Elements*. Since the magazine's launch, we have posted a single pdf file of every issue with a delay. Initially the delay was one issue. Last year, the Executive Committee asked that the delay be extended to two issues. However, we kept getting requests from libraries stating, very rightly so, that because they subscribe to *Elements*, there should be no delay for them to access the content. This spurred the development of a new webpage with gate access. Subscribers to *American Mineralogist* already have access to this improved web access (http://www.elements-magazine.org/archives/index.html). We thank Seth Davies of the Geochemical Society for making a pdf file of each article available for posting. We are working on ways to give all our members access to this site within the next few months.

GEOSCIENCEWORLD

As mentioned in the previous issue, *Elements* became the 35th journal to join GeoScienceWorld on December 6. Take the opportunity to check it out during the two-month free viewing period, which will last until the beginning of February 2008. GSW will provide searchable html and pdf files, cross-reference linking, etc. for the thematic articles and pdf files for all non-thematic content.

COLOR OR COLOUR?

This is a reminder that both American and British English and style are used in *Elements*. We just try to be consistent within a given contribution. It is a bit of an editorial challenge because no bell rings when the word colour, for example, appears in an American-style text.

UNSUNG HEROES

Lots of people read *Elements*, but some read it more than others. Take our talented copy editor, Thomas Clark, for example; he spends 60 to 70 hours per issue poring over every article and proof. We are grateful for his immense volunteer contribution. We also thank Dolores Durant, our volunteer proofreader: she typically finds things everyone else has overlooked. Their work contributes to a high-quality product.

EDITORIAL *(cont'd from page 371)*

option of taking a "bio" specialization as an alternative to a largely physical science–based foundation. Through our deliberations, we need to listen to the students, too. Our current undergraduates at RPI have made it clear that they consider Geographical Information Systems (GIS) to be the most important course in their entire undergraduate program, because this course above all others makes them employable at the BS level. Is GIS fundamental in the traditional sense? probably not; is it important? definitely!

Today there is probably no standard answer to the question of what constitutes an ideal undergraduate geology curriculum. Geoscience departments—especially small ones—should develop curricula that they can deliver effectively given the expertise of the faculty. Emphasis should be placed on critical thinking, acquisition of basic skills, honing those skills on modern applications, and appreciation of the breadth and depth of modern geoscience.

The *Elements* editors try to highlight frontier areas and interfaces of MPG science, including developments in pedagogy (see volume 3, number 2). At the same time, however, we appreciate the need for our science to remain firmly based in the fundamentals of our fields. Sometimes this is a difficult fence to walk. I personally regret the loss from our education programs of skills that I still find valuable (e.g. optical mineralogy), but I think it is crucial to embrace what we have gained in recent decades so we can convey the essence of our fields to our students in the most effective way possible—even if curricula are not standardized across all geoscience departments.

E. Bruce Watson[1]
watsoe@rpi.edu

[1] Bruce Watson was the principal editor in charge of this issue.

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Guest editors

Robert J. Bodnar
Susan L. Brantley
Georges Calas
Jon P. Davidson
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