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Teaching Mineralogy, Petrology, and Geochemistry

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David W. Mogk, Guest Editor

New Directions at the Intersection of Research about Earth and Research on Learning
David W. Mogk

Improving Instruction in Mineralogy, Petrology, and Geochemistry—Lessons from Research on Learning
Cathryn A. Manduca

What Should Our Students Learn?
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About the cover:
Students exploring columnar basalt at Hepburn Mesa, north of Yellowstone National Park, Montana, USA. Geologists use active-learning techniques every time they bring students in the field. Learning in the field occurs as students construct their own knowledge base through inquiry, discovery, application of scientific concepts and content, practice of technical skills, and use of the cognitive strategies employed by “master” geologists. These approaches to learning can be applied throughout the curriculum in mineralogy, petrology, and geochemistry. Photo courtesy Dexter Perkins
The Mineralogical Society of America is composed of individuals interested in mineralogy, crystallography, petrology, and geochemistry. Founded in 1919, the Society promotes, through education and research, the understanding and application of mineralogy by industry, universities, government, and the public. Membership benefits include special subscription rates for American Mineralogist as well as other journals, 25% discount on Reviews in Mineralogy & Geochemistry series and Monographs, Elements, reduced registration fees for MSA meetings and short courses, and participation in a society that supports the many facets of mineralogy. For additional information, contact the MSA business office.

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The Mineralogical Society of Great Britain and Ireland, also known as the M Soc, is the international society for all those working in the mineral sciences. The Society aims to advance the knowledge of the science of mineralogy and its application to other subjects, including crystallography, geochemistry, petrology, environmental science and economic geology. The Society furthers its objective through scientific meetings and the publication of scientific journals, books and monographs. The Society publishes three journals, Mineralogical Magazine (print and online), Clay Minerals (print and online) and the e-journal MINARS Online (launched in January 2004).

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The Clay Minerals Society (CMS) began as the Clay Minerals Committee of the US National Academy of Sciences – National Research Council in 1952. By 1962, the CMS was incorporated with many purposes including research and disseminating information relating to all aspects of clay science and technology. The CMS holds an annual meeting, workshop, and field trips, and publishes Clays and Clay Minerals and the CMS Workshop Lectures series. Membership benefits include reduced registration fees to the annual meeting, discounts on the CMS Workshop Lectures, and Elements.

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The Geochemical Society is an international non-profit organization for scientists involved in the practice, study, and teaching of geochemistry. Membership includes a subscription to Elements, access to the online quarterly newsletter Geochemical News, as well as an opportunity to subscribe to Geochemical and Cosmochimca Acta (24 issues per year). Members receive discounts on publications (IGS Special Publication in MSA, Elsevier and Wiley/Joosy-Bass), and on conference registrations, including the V.M. Goldschmidt Conference, the fall AGU meeting, and the annual GSA meeting.

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The Mineralogical Association of Canada was incorporated in 1955 to promote and advance the knowledge of mineralogy and the related disciplines of crystallography, petrology, geochemistry, and economic geology. Any person engaged or interested in the fields of mineralogy, crystallography, petrology, geochemistry and economic geology may become a member of the Association. Membership benefits include a subscription to Elements, reduced cost for subcribing to The Canadian Mineralogist, a 20% discount on short course volumes and special publications, and a discount on the registration fee to the annual meeting.

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The European Association for Geochemistry was founded in 1985 to promote geochemical research and study in Europe. It is now recognized as the premier geochemical organization in Europe encouraging interaction between geochemists and researchers in associated fields, and promoting research and teaching in the public and private sectors.

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The International Association of GeoChemist (IAGC) has been a prominent international geochemical organization for over 40 years. Its principal objectives are: cooperation in, and advancement of, applied geochemistry, by sponsoring specialist scientific symposia and the associated proceedings, and organizing by its working groups, and by supporting its journal Applied Geochemistry. The administration and activities of IAGC are conducted by its Council, comprising an Executive and ten ordinary members. Day-to-day administration is performed through the IAGC business office.

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The Société Française de Minéralogie et de Cristallographie, the French mineralogy and crystallography society, was founded on March 21, 1878.

The purpose of the society is to promote mineralogy and crystallography. Membership benefits include the “bulletin de liaison” (in French), the European Journal of Mineralogy and new Elements, and reduced registration fees for SFMC meetings.

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The International Association of GeoAnalysts is a worldwide organization supporting the professional interests of those involved in the analysis of geological and environmental materials. Major activities include the management of proficiency testing programmes forbulk rock and microanalytical methods, the production and certification of reference materials and the publication of the Association’s official journal GeoStandards and Geoanalytical Research.

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The Mineralogical Society of Poland, founded in 1969, draws together professionals and amateurs interested in mineralogy, crystallography, petrology, geochemistry, and economic geology. The Society promotes links between mineralogical science and education and technology through annual conferences, field trips, invited lectures, and publishing. There are two active groups: the Clay Minerals Group, which is affiliated with the European Clay Groups Association, and the Petrology Group. Membership benefits include subscriptions to Mineralogia Polonica and Elements.

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The Società Italiana di Mineralogia e Petrologia (Italian Society of Mineralogy and Petrology) was established in 1940, is the national body representing all researchers dealing with mineralogy, petrology, and related disciplines. Membership benefits include receiving the European Journal of Mineralogical methods, the production and a reduced registration fee at the annual meeting.

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Teaching, Explained

Years ago, I had a rude awakening after I had finished teaching an undergraduate mineralogy course. The petrology professor who taught the next course in the sequence told me that he had given a simple, short test (one that would not count towards the students’ grades) on the first day of class, not to check on my teaching, but to gauge the knowledge base of the students for more effective instruction—clearly a sound, educationally responsible idea. To his amazement, half of the students did not know the chemical formula of quartz. Many who thought they knew the formula wrote down “SiO4.” I was shocked. Only a month had passed between final examinations and my colleague’s test.

I had been very happy with that mineralogy course and those students. I was young, full of energy and enthusiasm. I tried to keep memorization to a minimum, and tried to make everything taught in the course directly relevant to the geosciences and/or to society. We went on several eye-opening trips, and not just to the field, but to the Smithsonian Institution and to a Corning plant where automotive catalytic converter substrates were manufactured out of synthetic cordierite. Clearly, however, something was missing. But what? I wondered. From what I know now about teaching, it turns out a great deal was missing.

I have heard it all before… you don’t have to teach a teacher how to teach. Great teachers are born that way. For the rest of us, good or average teaching is a challenging task that requires much more than I was capable of through many years of my career. But this was simply because I didn’t know any better. As I started to learn about cognitive psychology and how the human brain learns and organizes knowledge, I was amazed, and was left wishing that I had known about this much sooner.

This issue offers all of us relatively straightforward ways to improve our teaching. Better teaching translates into students and citizens that are better educated and, perhaps more importantly, turned on and truly appreciative of our science. One can argue that this is as important as our research, or more so. The insight, methods, and Internet aids available from this issue could make a big difference the next time you step into a university classroom, address upper management, prepare a talk for a conference, or converse with a funding manager. In fact, you will find in these pages what I was missing years ago in my mineralogy class. In a nutshell, what I was missing were the techniques of turning passive learners into active learners. I am no longer a talking head. I constantly demand classroom interaction, even when teaching large classes. Learning and retention are up, and my teacher ratings are nearly off the charts.

Educational research is offering a remarkable gift to science. This is low-hanging fruit that we cannot afford to miss. Helping to prepare the next generation of scientists and society, in the very best way possible, is simply too important. On the other hand, if we choose to ignore modern educational research through our arrogance, we do so at our own—and our students’ and society’s—peril.

Michael F. Hochella Jr.
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FAREWELL TO MIKE HOCHELLA

Unlike many scientific journals, whose editors have been known to linger in harness for several decades, *Elements* has the wise policy of refreshing its team of principal editors every three years. Mike Hochella is the second of the principal editors to go, after two years as editor following our first issue at the end of 2004. When Rod Ewing first approached Mike to become one of the founding editors of *Elements*, he politely declined. A few days later, Rod phoned him again and persuaded him to join the editorial team. We are certainly glad he did so. The founding editors first met as a group, along with managing editor Pierrette Tremblay, three short years ago, in April 2004, at Rod Ewing’s base in Ann Arbor, Michigan. At the time, we had Rod’s strong, well-formed vision of the aims and general form that the magazine would have, but an enormous amount of detail had to be filled in, from hard-to-articulate but crucial factors, such as the level at which thematic contributions should be pitched, to nuts-and-bolts issues, like the style of artwork and the punctuation of references. Mike made a tremendous contribution to this phase—he was always wise, well tempered, and clear about objectives, a joy to work with. The level and look-and-feel of *Elements*, and themes covered to date, owe a great deal to Mike. He boldly volunteered his colleague Bob Bodnar to be guest editor of the inaugural issue, a task guaranteed to be more stressful than for any subsequent issue. Look behind the cover of the inaugural issue, with that iconic picture of the half-Earth above the lunar horizon, and you will find five supporting societies listed. Now there are thirteen, a success story in which Mike has played a pivotal role.

I’ve known Mike by reputation for many years, and in 2002, when we ran the 18th IMA General Meeting in Edinburgh, he was our choice for the first of our plenary lectures. His talk on the role of mineralogy in environmental science was brilliant, a perfect combination of cutting-edge mineralogy and geochemistry. I remember him saying, at the beginning of his talk, that he really considered himself, first and foremost, a mineralogist. At the time, he had just finished his term as president of the Geochemical Society! Despite a certain amount of historical baggage suggesting the contrary, geochemistry, mineralogy and petrology really do occupy the same scientific space. *Elements* has a number of objectives, one of which is ensuring that we act as a single, harmonious community, confident in its societal role and able to promote its scientific achievements and potential. Mike has done as much as anybody to achieve this, while at the same time being one of the most kindly, warm-hearted, and genuinely nice people you are ever likely to meet. Thanks from all of us, Mike!

Ian Parsons

On behalf of Bruce Watson, Susan Stipp, and founding editor Rod Ewing

THANKS TO ADVISORY BOARD MEMBERS 2005–2006

Since its inception, *Elements* has benefited from the wisdom of its advisory board. As outlined in the letter of agreement signed by all participating societies, “the advisory board members have the principal responsibility of identifying thematic topics and assisting editors for *Elements*. They will be consulted by the principal editors as need arises, particularly as part of an ongoing review of the content and quality of *Elements*.”

When the advisory board of *Elements* was initially formed, members were randomly given two- and three-year terms. The following members had two-year terms that ended at the end of 2006: Peter Burns, Monica Grady, Alain Manceau, Bice Fubini, Neil Sturchio, and John Valley. We gratefully acknowledge their contributions during the first two years of *Elements*.

Peter C. Burns received a BSc (honours) in geology from the University of New Brunswick in 1988, an MSc in geology from the University of Western Ontario in 1990, and a PhD in geology from the University of Manitoba in 1994. He joined the faculty of the University of Notre Dame in 1997, and is currently professor and chair of the Department of Civil Engineering and Geological Sciences. Burns has authored or co-authored more than 200 journal papers concerning mineralogy and solid state chemistry. He has received several awards. He is the vice president of the Mineralogical Association of Canada.

Bice Fubini was educated at the University of Torino, Italy, where she is now a full professor of chemistry in the Faculty of Pharmacy and head of the G. Scansetti Interdepartmental Center for Studies on Asbestos and other Toxic Particulates. She introduced a new quantitative, physical chemistry approach to understanding the toxicity of the mineral particles and fibers, based on their physicochemical properties, especially their surface reactivity, surface free radicals, and surface hydrophilicity. She has authored over 180 scientific papers and 20 review articles and book chapters, and has been invited to workshops organized by several international, European, and American agencies as an expert on the assessment of fiber and particle toxicity.

Monica Grady is a professor of planetary and space science at the Open University. She was formerly based at the Natural History Museum, where she curated the UK’s national collection of meteorites. She graduated from the University of Durham in 1979, then went on to complete a PhD on carbon in stony meteorites at Cambridge University in 1982. Since then, she has built up an international reputation in meteoritics, publishing many papers on the carbon and nitrogen isotope geochemistry of primitive meteorites, on Martian meteorites, and on interstellar components of meteorites.

Alain Manceau received his PhD in 1984 from the University of Paris 7. The same year he joined the CNRS as a researcher. In 1992 he established the Environmental Geochemistry team in Grenoble, a component of the Observatory of Earth and Planetary Sciences. His research interests focus on the environmental mineralogy and biogeochemistry of trace elements using X-ray techniques. Since the mid-1990s, he has pioneered the application of synchrotron radiation to determine the speciation of metal contaminants in natural systems. He is also co-lead principal investigator of the French absorption spectroscopy beamline in material and environmental sciences (FAME) at the European Synchrotron Radiation Facility (ESRF) in Grenoble.

Neil C. Sturchio is a professor of geochemistry at the University of Illinois at Chicago. He received his PhD in Earth and planetary sciences from Washington University in St. Louis (1983) and was a staff scientist at Argonne National Laboratory from 1985 to 2000. His research interests are mainly in the areas of mineral-fluid interactions and the application of stable and radioactive isotopes as tracers of geochemical processes. He does both experimental and field-based research. Dr. Sturchio was editor of *The Geochemical News* from 1997 to 2001. He currently serves on the editorial boards of *Chemical Geology* and *Environmental Forensics*. He has authored or co-authored over 130 journal articles and book chapters.

John W. Valley, the Charles R. Van Hise Professor of Geology at the University of Wisconsin–Madison, received his AB from Dartmouth College and PhD from the University of Michigan. He has pursued new applications and techniques in stable isotope geochemistry, and in 2005 installed a multicollector ion microprobe for in situ analysis of ultrasmall samples. His interests in the early Earth and the thermal and fluid history of mountain belts span 30 years. His more recent research interests range from diamonds to cancer cells. He was president of the Mineralogical Society of America in 2006.

In the next issue, we will introduce the current advisory board, including the new members for the 2007–2009 term: Tim Drever, Janusz Janecek, Hans Keppler, David Lentz, Maggi Loubser, Eric Oeklers, and Olivier Vidal.
FROM THE MANAGING EDITOR

More about Mike

I met Mike Hochella for the first time at the founding editorial meeting in April 2004. I was touched by his extraordinary kindness and his genuine interest in everyone. Mike is one of the most positive and happy persons I have ever met. He always sees the diamond hidden in the rough stone, the good rather than the bad. I even secretly wondered if he could refuse a manuscript, so it was a relief when he cut a whole paragraph of a text I had written for the From the Editors section and kindly suggested the rest had to be rewritten (he landed the rewrite job). I also discovered that Mike is a gifted writer. To me, his article on nanoparticles is still the best we have published. He nailed the level of writing right on. I remember the excitement I felt when, after a quick read of his article, I understood what was so exciting about nanoparticles and was able to explain it to others. I will miss Mike’s cheerful contributions but hope to rope him into being guest editor for a thematic issue very soon.

Mike and Teaching

It is fitting that we publish this homage to Mike in the “teaching issue,” a theme very close to Mike’s heart. When he first introduced the idea of a thematic issue devoted to teaching, he had to be persuasive. How will people react to a whole issue on teaching? (It is vitally important for our disciplines.) What about readers who do not teach? (We are all teachers in one way or another.) And the list of questions went on and on. Mike kept his course, and we are now very proud to bring you this special thematic issue. As I worked on it, I discovered that there is an extraordinary wealth of resources on the Web to help you make the changes—small or big—toward cooperative learning. This community is amazingly generous in sharing the resources it develops. Use them.

Yes, Teaching Matters

I am a geologist today because of a teacher. He taught my geology 101 course—a mandatory class at my school. He was young and passionate about geology; I was dissatisfied with physics. Within weeks, I had switched to a major in geology. I never regretted it.

On Outreach and Public Education

I spent the 1990s working on outreach projects, and I would probably be happily doing it still if funding had not dried up. I would like to relate an anecdote that really brought home to me how the way we present information can make a difference. In one of our projects, we visited over 100 classrooms, from kindergarten to grade 6. Once I had prepared the outline of my presentation, I showed it to a teaching specialist at Laval University. She listened to me attentively and then told me, “You can choose to share a lot of content or you can give the content to the kids.” With her help, I totally revised my approach and provided a hands-on workshop.

In the kindergarten to grade 3 classrooms, I started the workshop by a short presentation in which I explained the work of the geologist. To do this, I chose a child to be the geologist of the day and dressed him or her in a geologist’s vest. Initially I had thought I would wear my field clothes, but the teaching specialist suggested that I could empower the children by choosing one to be the geologist. Then we discussed the type of work a geologist might do through some of the tools he uses. Several children then got to pick a rock or a mineral from my packsack. This was an opportunity to introduce properties of minerals and the difference between a rock and mineral. At the end of the activity, each child was given a bag containing a few mineral chips and had to match the minerals with the clues provided (I am metallic gray; your fingers will feel greasy after you touch me. I am graphite). And they got to keep the chips.

Cont’d on page 86
LACK OF FUNDING LEADS TO DEAD MUSEUMS

I was touched by Peter Heaney's Triple Point article; I applaud the inroads he has made on his topic in the Earth sciences community. However, I must say, the article was a bit depressing. Particularly so in light of many similar articles in recent issues of Mineral News regarding the Philadelphia Academy of Sciences, which sold an historic and irreplaceable mineral collection to three dealers; the collection is now in the process of being dispersed worldwide and The Mineralogical Record (wherein articles and editorials have given an account of major museums and universities in England that have deaccessioned or removed systematic mineral holdings can’t be made accessible. Dead museums.

Minerals under Assault

Congratulations to Peter Heaney on a fine article; I applaud the inroads he has made with this topic in the Earth sciences community. However, I must say, the article was a bit depressing. Particularly so in light of many similar articles in recent issues of Mineral News regarding the Philadelphia Academy of Sciences, which sold an historic and irreplaceable mineral collection to three dealers; the collection is now in the process of being dispersed worldwide and The Mineralogical Record (wherein articles and editorials have given an account of major museums and universities in England that have deaccessioned or removed systematic mineral collections from public view). It appears that minerals are under assault everywhere—apparently if it’s not furry or Creteceous, it must not be worthy of curating.

Dan Kile
Littleton, CO

FROM THE MANAGING EDITOR (cont’d from page 85)

In the grades 4 to 6 classrooms, I showed several large, eye-catching samples to introduce minerals, rocks, their properties and use. Questions were asked and answered. Then, the children worked in teams using a simple flow sheet to identify some minerals handed to them—the same approach mineralogists use. Classroom response varied a lot. In classrooms where teachers encouraged enquiries, we were deluged by questions from curious kids; in others, kids were silent and amorphous (guess how the teachers were.) But in short, we were amazed by the amount of information the children retained. No workshops were exactly the same, as they were led by the children. The main point I want to make is that, once I was encouraged to do so, it was relatively simple to change the way I presented the workshops; I did not need extensive training, just a willingness to experiment and try a new way to do things.

Pierrette Tremblay

HISTORY AND FATE OF THE RENSSELAER POLYTECHNIC INSTITUTE MINERAL COLLECTION

During the nineteenth and twentieth centuries, the Rensselaer mineralogical and geological collections thrived, attracting visitors and students. After close to 200 years of geological sampling and preservation of precious samples (1824–2000), the collections were discontinued and the material was dumped, stored in basements, or donated to other institutions (Friedmann 2007)...

Peter Heaney’s note (Elements 2007, volume 2, issue 6) on historic American mineral collections relates to three basic steps: “Step 1: Starve the beast, Step 2: Carve up the space, and Step 3: Box the minerals for ‘safekeeping.’” At Rensselaer Polytechnic Institute (RPI), one step included dumping minerals collected in the nineteenth and twentieth century on a university lawn. I spent years preparing the Accession Records of the 5960 items (as of the 1960s) in the mineral collection. The main collector was Henry B. Nason (1831–1895), the de facto curator of the vast mineral collections of Rensselaer. He acted as agent for Rensselaer in acquiring specimens, and with James Hall (1811–1878), arranged, and labeled them. Nason’s interest in mineralogy had a profound influence on the scientific advancement of mineralogy. Washington A. Roebling (1837–1926) took Nason’s course at Rensselaer. Inspired by Nason, he embarked on a study of systematic mineralogy. Later the Roebling collection was donated to the National Museum of the Smithsonian Institution, and his son, John A. Roebling (1885–1952), gave $150,000 for its care. Nason’s dedication to RPI was embodied in the donation of his private collection of 5000 minerals to RPI in 1883.

The alumni built a special building to house James Hall’s fossil collection of 2000 specimens, which were recorded by H.B. Nason (Friedman 2007, Fig. 13). In 1999, part of the collection was donated to the New York State Museum in Albany, New York, together with the mineral collection.

Gerald M. Friedman
Northeastern Science Foundation, Troy, NY

CAUGHT IN THE WEB OF VIRTUAL EDUCATION

There is a scene in the movie *Jurassic Park* that must send a shudder down the spine of every reader of this journal. No, not the moment when a lightning storm disables the electronic security system and frees the T rex to enjoy a murderous rampage. It occurs when John Hammond, the evil genius who cloned extinct animals to make an amusement park, first shows his creation to a select band of incredulous scientists. Ian Malcolm, the brilliant mathematician who specializes in chaos theory, reacts in horror as he envisions the tragic cascade that will inevitably follow this act of hubris.

“Don’t you see the danger, John, inherent in what you’re doing here? … You stood on the shoulders of giants to accomplish something as fast as you could, and before you knew what you had, you patented it, packaged it, slapped it on a plastic lunch box, and now you want you knew what you had, you patented it, packaged it, slapped it on a plastic lunch box, and now you want to sell it.”

An annoyed Hammond retorts, “You don’t give us our due credit. Our scientists have done things no one could ever do before.”

Malcolm scathingly replies, “Your scientists were so preoccupied with whether or not they could that they didn’t stop to think if they should.”

When I first watched *Jurassic Park* in a movie theater off Route 1 in central New Jersey, I was taken aback when the audience spontaneously burst into whistles and sustained applause when it heard this line. Of course, Michael Crichton’s career is wildly successful because he so skillfully taps into Americans’ love–hate relationship with scientific innovation. The public adores high-definition television sets, and ipods, and laptops, but it simultaneously rebels against the stream of new discoveries that require constant assimilation. Scientists are equally confronted with the need to absorb black-box technologies. But we are bred to be comfortable with uncertainty and to embrace the unknown, and so we tend to react to these changes with a higher ratio of excitement to fear.

Still, there are some advances that place me uncomfortably back within that audience in the New Jersey cinema. This issue of *Elements*, dedicated to education in mineralogy, petrology, and geochemistry, provides an opportunity to open a forum on an explosive pedagogy that might lead us to ask whether we should even though we can: teaching courses using only the worldwide web.

Any criticism of classes that employ the web as the sole means of exchanging ideas with students must begin with a large number of concessions. One must acknowledge that web-based instruction has become extremely versatile with respect to the delivery of course content. Instructional text can be reinforced using images, animations, audio files, digital video, and hyperlinks to other websites. Assessments of student understanding can be automated through online exams that provide instantaneous feedback, which itself promotes learning. Most obviously, the web is universally accessible, and web-based courses can reach a diversity of students that is infinitely larger than can be touched by traditional lecture courses.

But let’s be honest. At my university and many others, web-based courses are not merely offered but are tailored to students who are living on campus.

A professor risks being tagged a pedagogical Luddite if he or she suggests that we pause before proceeding with this revolution. Nevertheless, it strikes me that the community of Earth scientists is especially burdened with an obligation to resist this latest wave, because internet-based instruction is antithetical to almost every insight that experts in geoscience education have championed over the last decade. A digital image on a flickering computer screen cannot convey the essence of the actual object, and a knowledge of mineralogy and petrology can only be communicated when students are required to heft, touch, smell, see, in some cases even taste rocks and minerals using all of their senses. Similarly, electronic text cannot impart an understanding of processes like mineral growth and dissolution in the way that the hands-on doing of them can.

Web-based courses not only ignore the vital role of experiential learning, they also deny the central presumption on which universities were founded—that the personal give-and-take between teacher and student provides an educational bond that is unique and irreplaceable. Here is a telling comment from a laudatory review of one of our web-based courses from RateMyProf.com: “Never saw the guy, he’s like the Wizard of Oz.” Isn’t it an abdication of our responsibility as teachers when the students reduce us to black boxes along with their ipods?

At a time when specialists in college education are exhorting professors to incorporate “active-learning” exercises in classes that are “student centered,” it is ironic that universities are urging their faculty to develop courses that terminally separate the student from the kinds of sensory and personally interactive experiences that we know are the most effective means of transferring knowledge. I have sampled a number of online courses at several universities, and I would argue that this innovative mode of instruction is not substantively different from that most ancient form of learning: reading a book.

What’s the latest by Michael Crichton?

Peter J. Heaney
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BROECKER AWARDED 2006 CRAFOORD PRIZE IN GEOSCIENCES

Wallace Broecker, a geochemist at Columbia University’s Lamont-Doherty Earth Observatory and the Newberry Professor of Earth and Environmental Sciences at Columbia, was awarded the Crafoord Prize in Geosciences by the Royal Swedish Academy of Sciences. The prize is widely regarded as the geoscience equivalent of the Nobel Prize. In its citation the Academy noted Broecker’s “innovative and pioneering research on the operation of the global carbon cycle within the ocean–atmosphere–biosphere system, and its interaction with climate.”

Born in Chicago, Broecker received his undergraduate degree in physics at Columbia College in 1953 and his PhD in geology from Columbia University in 1958. He joined the Columbia faculty in 1959 and has remained there to this day.

As a young graduate student at Lamont-Doherty, Broecker was inspired by the late Maurice W. Ewing, the founding director of the Observatory. He began his scientific career with a study of the geological and oceanographic applications of radioactive carbon-14. This was the beginning of a long path of research along which he has made many pioneering discoveries that have had a profound impact on our understanding of the ocean, and its role in global climate change. His research has been instrumental in developing the use of a wide range of geochemical tracers to describe the basic biological, chemical, and physical processes that govern the behavior of carbon dioxide in the oceans and its interactions with the atmosphere.

In the early 1970s, his chemical model of the ocean unleashed a tide of progress in oceanography. Next he was a core contributor to our knowledge of the global carbon cycle and the central role of the ocean in that cycle. When the polar ice cores were analyzed in the early 1980s, Broecker was a key figure in showing the links between carbon, climate, and ice ages. Starting in the mid-1980s, he warned about the possibility of rapid climate change due to shifts in the “conveyor belt” of ocean currents carrying heat around the globe.

Broecker has played an active role in the environmental policy debate. He has been a leading voice warning of the potential danger of increased greenhouse gases in Earth’s atmosphere. He has written articles for the popular press, testified before Congressional committees, and briefed officials at the highest levels of government in an effort to bring scientific insights to bear on policy issues.

A prolific researcher, teacher, and author, Broecker has published more than 400 scientific articles and is the author or coauthor of several textbooks. Among his many awards and citations, Broecker was elected to the National Academy of Sciences in 1979. He is also a member of the American Academy of Arts and Sciences and a Fellow of both the American and European Geophysical Unions. In 1996, he was presented with the National Medal of Science by President Bill Clinton.

For more information about the prize and Broecker’s pioneering research, visit www.crafoordprize.se

Adapted from press release at www.columbia.edu/cu/news/07/01/crafoord.html

2007 MSA DISTINGUISHED PUBLIC SERVICE MEDAL TO HUIZING

The 2007 MSA Distinguished Public Service Medalist is Marie Huizing, managing editor of Rocks & Minerals. The award was presented at the 2007 awards banquet of the Tucson Gem and Mineral Society in Tucson, AZ, in February 2007. MSA member John Rakovan read the citation and MSA president Barb Dutrow presented the award in front of an audience of over 300 people.

The MSA Council awards the Distinguished Public Service Medal to individuals who have made important contributions to furthering the vitality of the geological sciences, especially in the fields of mineralogy, geochemistry, petrology, and crystallography. Rocks & Minerals is published by Heldref Publications, but its content and much of the financial support for its production and marketing comes from the mineral-enthusiast community. Of all the individuals who contribute hard work and support, Marie Huizing stands out for extraordinary and tireless effort. Since joining Rocks & Minerals in 1979, Marie has made major changes and additions to the magazine, which have increased its scientific and educational quality and strengthened its mission of teaching and outreach. Her efforts extend beyond the journal. She travels to many national and international mineral shows each year to promote the magazine and a wide range of other mineral publications, events, and organizations. This is a wonderful honor for Marie, in recognition of her contribution to the effort that has made Rocks & Minerals what it is today.

NEW AGU FELLOWS

The number of new American Geophysical Union fellows elected in any year is limited to 0.1% of the total membership. From the nominations submitted to the Volcanology, Geochemistry and Petrology Division Fellows Committee by AGU, eight were approved by the Union Fellows Committee for 2007:

Susan Brantley, Pennsylvania State University
Rodney C. Ewing, University of Michigan, Ann Arbor
Tom H. Heaton, California Institute of Technology
Bernard Marty, CRPG Nancy, France
David D. Pollard, Stanford University
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Caledonides and in Saudi Arabia. More recently, he switched to grain-scale microstructural studies of regionally metamorphosed silicate and sulfide rocks, using electron backscatter diffraction as a key analytical tool to investigate mineral growth and deformation mechanisms. In parallel with this, he has been involved in pedagogical research through some key national UK-based projects for computer-based learning (UKECC) and assessment (TRIADS), and is currently investigating the affective domain.

Barbara L. Dutrow is the Adolphe G. Guemyard Professor in the Department of Geology and Geophysics at Louisiana State University. She received her PhD in 1985 from Southern Methodist University, where she worked on field, experimental, and theoretical studies of metapelitic rocks. Subsequently, she received an Alexander von Humboldt Fellowship. Her more recent research involves computational studies of heat and mass transport related to fluid–rock interactions in the crust. She also teaches courses that interweave Earth materials with societal issues. She is the current president of the Mineralogical Society of America.

David W. Mogk is a professor of geology at Montana State University. He received a BS degree from the University of Michigan and MS and PhD degrees from the University of Washington. Over the past 15 years, he has worked on many aspects of geoscience education, including advocacy for an Earth system science approach, development of instructional digital libraries, integration of research and education, and faculty professional development programs. He was a program director in the Division of Undergraduate Education of the National Science Foundation. In 2000, he was recipient of the American Geophysical Union Excellence in Geophysical Education Award. His research interests include the evolution of Archean continental crust, petrologic processes at mid-crustal levels, spectroscopy of mineral surfaces, and the search for life in extreme environments.

Karl R. Wirth, associate professor in the Geology Department at Macalester College, Minnesota, received his undergraduate training in geology at Beloit College and a PhD from Cornell University (1991). His research involves undergraduate students and utilizes geochemical and geochronologic tools to investigate magmatism associated with continental rifts, oceanic islands, and Precambrian terranes. Recently, his scholarship has broadened to include teaching, learning, and instructional methods.

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March 2007. 2nd ed. 493 S. 270 illus. Hardcover ISBN 978-3-540-71236-7 ▶ approx. $119.00

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New advances in cognitive psychology and learning science provide insights into how people construct knowledge, with important implications for how we learn from, and teach about, the Earth. Research on learning has demonstrated that effective instructional practices require students to construct their own knowledge bases (i.e., a shift in emphasis from teaching to learning), address diverse student learning styles, employ a variety of active-learning strategies, and encourage inquiry and discovery. These emerging principles provide a context for us to reflect collectively on what and how we teach in our mineralogy, petrology, and geochemistry courses. If we are to meet the challenges of the 21st century, our new instructional goal should be to develop students who are lifelong learners and who use the knowledge base, technical skills, and cognitive strategies that are used by “master” geoscientists. As a result, we will help sustain the long-term health and relevance of the mineralogy, petrology, and geochemistry community.

Mineralogy, petrology, and geochemistry (MPG) have never been more important than they are today—as an integral part of the geoscience curriculum and in service to society. To sustain the exciting research currently being done in the MPG disciplines, to secure the long-term health and vitality of these disciplines, and to extend their influence in the broad public discourse, we need to effectively recruit and train the next generation of mineralogists, petrologists, and geochemists. We simply cannot afford to miss the opportunity to provide excellence in education in the MPG disciplines for all students in the geosciences and related fields. The training of the next generation of scientists may arguably be as important to the scientific enterprise as the direct results of our research.

Consequently, this is a good time for the MPG community to reflect on its goals and expectations for geoscience education. What should our students know and be able to do as a result of the courses they take? In light of the changing requirements of the workplace (both academic and industrial), what additional “orthogonal” skills are needed—for example, the ability to communicate complex ideas, verbally, in writing, and in visualizations; to apply quantitative reasoning; to integrate ideas across many disciplines and disparate lines of evidence; and to work in teams (NRC 1996; NSF 1996)? What critical-thinking and problem-solving strategies are exemplified by master geoscientists, and how can we best instill these characteristics in novice learners? How can we measurably demonstrate that our learning goals have been achieved in the classroom, laboratory, and field?

As noted in Science for All Americans (AAAS 1989), “Learning is not necessarily an outcome of teaching,” so it is also fair to critically ask what teaching methods and strategies are most effective in promoting student learning. Fortunately, new advances in research on learning from the fields of cognitive psychology and learning science (Bransford et al. 1999) provide a solid foundation on which we can design courses, develop instructional activities, and assess learning of mineralogy, petrology, and geochemistry to optimize student learning. In the past decade, the landscape of science education has changed dramatically to address the increased emphasis placed on learning. Among science educators there is a broad consensus on “what works”:

- Instruction that is increasingly “student-centered” and less “content-centered,” and that takes into account the diversity among students with respect to their experiences, expectations, and learning styles
- Learning environments that encourage “active” rather than “passive” learning and where a variety of instructional strategies are used to encourage inquiry, discovery, collaborative and cooperative learning, and critical thinking

As instructors, the application of these principles requires a major shift in emphasis from “what” we teach to “how” we teach. To help facilitate this transition, Table 1 provides a compilation of online collections of teaching activities, strategies, and related instructional resources that have been developed through a series of community-based workshops with support from the National Science Foundation (USA).
In this collection of articles, we introduce many new advances in learning theory and give examples of how these can be applied to MPG courses. We do not presume to provide a detailed outline of topics and texts for MPG courses—Earth provides too many learning opportunities, and instructional settings are too diverse to attempt to prescribe a preferred curriculum. Rather, by exploring the intersection between our knowledge of Earth and research on learning, we hope to provide an intellectual framework that will help guide the development of future instructional practices. Implementation of better practices will allow us to recruit and train students who are happier in their studies and better prepared in their professional development and will help faculty teach in ways that are more effective, personally satisfying, and fun. The articles in this volume provide an introduction to different aspects of the scholarship of learning.

Cathy Manduca summarizes research on the impacts of our teaching methods on recruiting and retaining students, and shows how research on learning can be applied to the design and implementation of a full array of learning exercises. This article also identifies the need to engage into discipline-specific research on learning in mineralogy, petrology, and geochemistry.

Dexter Perkins asks us to carefully reflect on the essential content that we deliver in our classes and to place a higher emphasis on helping students develop the cognitive skills to help them become lifelong learners, including the ability to self-assess and reflect on their own learning.

Karl Wirth continues with the theme of lifelong learning and advocates a co-curriculum that allows students to take responsibility for their own learning. He provides examples of active-learning, collaborative-learning, and problem-based learning activities in mineralogy and petrology courses.

Alan Boyle provides a practical example of how we can achieve measurably better learning outcomes by aligning teaching and assessment methods with students’ learning-style preferences.

Barb Dutrow presents the latest research from cognitive psychology in the use of visualizations, and she demonstrates their effective use in both education and research presentations.

The articles in this issue focus on undergraduate education because a large segment of the MPG research community has teaching responsibilities at this level. But these principles are also applicable on a broader basis, including graduate and K–12 education and community outreach. And, although the curricular structure of teaching MPG will be different in detail from country to country and the demographics of students may also be different, the principles of how people learn are universal.

In the MPG disciplines, we have always had great content to work with, using Earth as the best-possible natural laboratory. We now have the opportunity to redirect our instructional efforts to train the next generation of scientists more effectively, bringing to bear the new advances in research on learning from cognitive psychology and the learning sciences. In the following articles, we hope you will find new and interesting insights into learning that will help make teaching and learning about Earth more rewarding for you and your students. For further exploration, we have compiled a comprehensive bibliography and collection of online resources, which can be accessed at http://serc.carleton.edu/NAGTWorkshops/petrology/elements.html/

REFERENCES
NSF (National Science Foundation) (1996) Shaping the Future New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology. NSF 96-139, 76 pp

TABLE 1

| Teach the Earth: http://serc.carleton.edu |
| Collections of teaching activities and web-based supporting resources |
| Teaching mineralogy: http://serc.carleton.edu/NAGTWorkshops/mineralogy/index.html |
| Teaching petrology: http://serc.carleton.edu/NAGTWorkshops/petrology/index.html |
| Teaching geochemistry: http://serc.carleton.edu/NAGTWorkshops/geochemistry/index.html |
| Finding analytical instruments to support teaching and learning |
| Analytical instrument registry: http://serc.carleton.edu/NAGTWorkshops/petrology/instruments.html |
| Collections of teaching strategies with examples, instructions, and references |
| The Starting Point collection: http://serc.carleton.edu/introgeo/index.html |
| Observing and assessing student learning |
| Teaching geoscience with visualizations |
| Using images, animations, and models effectively: http://serc.carleton.edu/NAGTWorkshops/visualization/index.html |
| Using data in the classroom |
| Collections of Earth data, tools, activities, examples, and pedagogic resources: http://serc.carleton.edu/usingdata/index.html |
| Teaching quantitative skills in the geosciences |
| Techniques, activities, and resources: http://serc.carleton.edu/quantskills/index.html |
| An Earth system approach |
| Designing an Earth system course, learning resources: http://serc.carleton.edu/introgeo/earthsystem/index.html |
| Integrating research and education |
| Examples include use of EarthChem and the MSA Crystal Structure Database: http://serc.carleton.edu/research_education/index.html |
| Course design |
| Tutorial for designing effective and innovative courses: http://serc.carleton.edu/NAGTWorkshops/coursedesign/index.html |
Improving Instruction in Mineralogy, Petrology, and Geochemistry—Lessons from Research on Learning

Cathryn A. Manduca*

Effective instruction can enhance our ability to retain students in the geoscience major and to raise their level of expertise in mineralogy, petrology, and geochemistry (MPG). Research on learning and education provides a framework for designing learning experiences in our classes. As a community we are well positioned to consider the goals of MPG instruction and to evaluate the materials and methods we currently use in our teaching. This will enhance the ability of faculty members to design and implement courses that meet the needs of their department and capitalize on their strengths as teachers.

Keywords: teaching methods, instructional design, education, pedagogy

INTRODUCTION

While geoscience programs vary from department to department around the world, they have all been designed with care to develop the geoscience workforce needed for our future. Preparing geoscience professionals—those who go on to advanced degrees in any of the geosciences, as well as those who work in business, government, and education—lies at the heart of our work with undergraduate geoscience majors. Mineralogy, petrology, and geochemistry (MPG) are an essential part of this preparation. As a discipline we face a challenge in recruiting and retaining a diverse cadre of students. As instructors, we are challenged in developing the expertise needed by future geoscientists. In this paper, we consider what we might learn from research on teaching and learning that could help us be more successful in our efforts to recruit and train the next generation of geoscientists.

OUR TEACHING MATTERS

Many factors influence a student’s decision to study geoscience and his or her success in developing expertise in mineralogy, petrology, and geochemistry. Many of these factors are beyond our immediate control as faculty members: the perception of science and geoscience in modern culture, the absence of geoscience from most high school curricula, and the attitudes and knowledge that students bring into our classes. However, we do have control over our teaching. Are we doing all that we can in this important arena? What do we know about the impact of our teaching on students’ decisions to study science and on their mastery of mineralogy, petrology, and geochemistry?

Seymour and Hewitt (1997), in their book Talking About Leaving: Why Undergraduates Leave the Sciences, present one of the most compelling lines of evidence that the quality of our teaching is critical. In this landmark study, they used an ethnographic approach to demystify many claims about the science pipeline and to understand in detail why undergraduate students in the United States switch majors from science, mathematics, and engineering (SME) to other fields. They found that more students switch out of SME majors than out of majors in other areas. In a national sample of more than 800,000 students beginning college in 1987, 44% of students who had initially declared an intent to major in SME declared or intended a major outside of SME in 1991. In contrast, only 30% of students who intended a major in social science or the humanities switched to a major outside this area.

However, in contrast to common wisdom, Seymour and Hewitt conclude that this is not a result of real or perceived inadequacy in the face of challenging material. Rather, they found, through a robust analysis of interview and focus group data involving 460 students at thirteen institutions, that the four most commonly cited concerns leading to a switch from an SME major to a major in another field are:

- “Lack or loss of interest in science
- Belief that a non-SME major holds more interest or offers a better education
- Poor teaching by SME faculty
- Feeling overwhelmed by the pace and load of curriculum demands”

In the words of Seymour and Hewitt (1997), “Complaints about poor teaching were almost universal among switchers and were the most commonly-cited type of complaint among students who remained in SME majors.” They note that SME faculty are often represented as “unapproachable”; students perceive the curve grading systems widely employed by SME faculty as reflecting disdain for the worth or potential of most underclassmen; harsh grading systems discourage collaborative learning strategies, which many students view as critical to a good understanding of the material; conceptual difficulty at particular points in a particular class commonly sets in motion a downward spiral of falling confidence, grades, and despair; and teaching assistants (TAs) bear a disproportionate responsibility for teaching fundamental material.
These findings are similar across the full range of institutions in their study, which included private and public institutions, large and small institutions, liberal arts colleges, comprehensive universities, and research universities drawn from across the United States. Seymour and Hewitt note that at six of the seven institutions in the primary sample, “switchers cited the same factor as the strongest contributor to their switching decisions—namely being drawn to a non-SME major that held more interest or offered a better educational experience. This was closely followed by being ‘turned off to science’ by their experiences in SME classes.” At the seventh institution, “poor teaching by SME faculty was ranked as their most serious concern.”

While the study did not differentiate results from students in the geosciences, it is hard to leave this book without a sense that, at least in the United States, our teaching may be causing problems. In the US, geoscience now has the distinction of having the lowest ethnic and racial diversity within its student population of any science (Hill 2002). This is a complex problem with many causes (Tinto 1987, 1993; Seymour and Hewitt 1997; Melton et al. 2005). However, it seems inappropriate not to at least consider that aspects of US teaching at the undergraduate level might be contributing to the continued absence of minorities in our profession.

If the quality of teaching is critical to students’ decision to study geoscience, what do we know about teaching specifically in the geosciences? Geoscience faculty members in the United States were surveyed in 2004 to investigate what teaching methods were in use (Macdonald et al. 2005). The data indicated that lecture dominates our teaching. Most faculty members appear to be trying a range of teaching methods, but these are still used relatively rarely (Fig. 1). While lecture can be an important component of teaching, allowing groups of motivated students to obtain information quickly, the dominance of lecture suggests that we have not yet found the right balance of activities in our teaching. The study also notes that teaching strategies placing learning in societal contexts (role playing, debate, problem solving related to national or global issues) are less commonly used in courses for majors than they are in introductory courses. This result seems important in view of the Seymour and Hewitt (1997) finding that students lose interest in pursuing science majors. This study, specifically addressing teaching methods in geoscience, suggests that we may not be using all the tools at our disposal to engage students in learning geoscience effectively. It would be valuable to have similar data from the UK where students appear to be more satisfied with their instruction (Higher Education Funding Council for England 2006), though anecdotal evidence suggests the lecture is similarly prevalent.

The data on methods may also speak to faculty frustration with the quality of learning taking place in our courses (see for example Perkins 2007 this volume). Are our students learning as much as they can from us? While learning is a function of both the teacher and the student, instruction plays a very important role. A case in point is faculty concern regarding the quantitative preparation of geoscience students. While geoscience students have substantial training in mathematics, they are often unable to use this information to solve quantitative geoscience problems (SERC 2006a). Using the language of cognitive science, this is a problem of “transfer” (NRC 2000). The students have the requisite knowledge but lack the ability to transfer this knowledge to a new situation. Students’ ability to transfer knowledge can be improved if their learning experiences are designed with that goal in mind (see for example Halpern and Hakel 2003). Teaching can have a significant impact on the students’ ability to solve quantitative problems in our courses and beyond.
GUIDANCE FROM RESEARCH ON LEARNING

Lessons learned from research on learning and education can help us refine our teaching in ways that will address issues of recruitment and retention and at the same time help us bring students to a higher level of expertise.

Educational practice has always rested on theories of how people learn (see summary in Bok 2006). Up until the mid-1800s the predominant theory in the United States was that students needed to develop mental discipline by thinking hard about difficult problems. Classics, mathematics, logic, English, and philosophy formed the heart of the educational program. It was generally held that once students had developed mental discipline in these areas and participated in a rigorously disciplined campus culture, they were prepared to be leading citizens. Following the Civil War, the college curriculum in the United States underwent a major revision emphasizing practical knowledge, including instruction in the sciences. The underlying learning theory held that the key to learning was access to relevant information.

The most important shift in learning theory in recent times has resulted from a much better understanding of the role of the learner in developing knowledge (NRC 2000). Comparisons of experts and novices have revealed that experts in a particular field not only know a great deal of information relevant to that field, but they have organized their knowledge into structures that facilitate its retrieval and use in both familiar and unfamiliar situations. Developing these knowledge structures is as important a part of learning as memorizing the information itself.

We are all familiar with this concept. Consider the information needed to identify minerals. The information itself, the properties of minerals and their occurrence, can be and often is laid out in a table. However, when we use this information to identify an unknown mineral, we use a complex thought process that involves considering what minerals are likely and what minerals are not possible, and deploying a rapidly branching stream of logic that narrows our choices. Often this is done so quickly that it is hard for us to perceive. Consider the question, which of the major properties of minerals should one consider first in trying to identify a mineral? This question makes no sense to most students. It is a problem that experts can readily answer but novices have great difficulty answering. The information on minerals is not organized this way in our minds. The key thing that must happen in a mineral identification laboratory, and the reason that this laboratory is embedded in a mineralogy class, is that students must move from knowing the characteristics of specific minerals to understanding them in a way that enables mineral identification. In this process, they are developing a knowledge structure that supports an aspect of geoscience expertise: mineral identification.

What do we know about how people (including students) form knowledge structures? The most important lesson is that they must do it for themselves (see for example Edelson 2001). The very best lecture will be ineffective if the students are not engaged in processing and organizing the information. This means that if we want our students to learn, we need to be thinking about much more than the quality of information in our lecture. Key questions include:

1. What is motivating the student to engage with this information?
2. What are the key relationships that are critical to understanding the use of this information? How will the student make these connections?
3. What skills are associated with using this information (here I refer to both thinking skills and technical skills)? How will the student practice these skills and acquire proficiency in using the information and skills together?
4. What is the range of situations in which a geoscientist regularly uses this information (or these skills)? How will the student be prepared to transfer this knowledge and associated skills from the context of a class to a broader range of situations?

Another fundamental principle of learning follows naturally from this type of thinking: any new learning builds on the knowledge structures already in place (NRC 2000). We are most familiar with this idea in the realm of misconceptions—wrong ideas that students bring into class (e.g. the mantle is made of magma; volcanic islands float on the ocean). These misconceptions are part of students’ existing knowledge structure and they interfere with new learning. What we often overlook is that these misconceptions can be deeply rooted in a knowledge structure that is at odds with the concepts we are trying to teach. Understanding the origin of the misconceptions and providing learning experiences that lead to deep revision of a knowledge structure can be time consuming and difficult work. However, expecting students to easily abandon the knowledge structure constructed through previous experiences or to make sense of new material in a way that is at odds with their knowledge of the world is unrealistic. Knowledge structure plays an equally important role in facilitating learning. An understanding of mass balance as it is used in physics can facilitate students’ ability to understand the idea of mass balance in a geochemical system. Clearly, understanding the knowledge students bring to the classroom underpins our ability to work with them effectively.

A final major lesson from research on learning is that people develop skills in learning. This set of skills, called metacognition, is the ability to monitor one’s level of mastery or understanding and decide when it is not adequate (NRC 2000). Skill in metacognition is fundamental to students’ ability to take control of their own learning. The most familiar example is undoubtedly the ability to determine if they understand a concept. Students who are surprised when they fail an exam are lacking in metacognitive skills. Students with good metacognitive skills not only can identify when they don’t understand a concept but have strategies for gaining a better understanding, for example by asking questions or seeking help.

Experts display excellent metacognitive skills within their area of expertise. For example, a geoscientist displays metacognitive skills when he or she evaluates if a particular approach to understanding a problem is bearing no fruit and determines when to try a new strategy. A wide variety of discipline-specific knowledge is brought together in this evaluation. Metacognitive skill is key to geoscience research and underpins our ability to decide how to fix an analytical instrument, what steps to take next in a research problem, and when to initiate a new line of research.

Metacognitive skills can also help students transfer learning from one situation to another. For example, a person with strong metacognitive skills, who has learned that the first draft of a paper in English is likely to need revision, would expect that multiple drafts might be needed for a paper in geoscience. And in the geosciences, a student who has learned in one class that a key to effective argumentation is the ability to use multiple lines of evidence would seek a second line of evidence to make an argument in a new situation. A particularly important part of developing
expertise involves teaching students metacognitive skills, both those that are general and those that are specific to geoscience. Teaching students to be independent learners has long been the goal of our PhD programs and is frequently an important goal at the undergraduate level. The important lesson from research on learning is that these skills are more easily developed if they are taught explicitly. An important first step toward teaching metacognition is to recognize your own metacognitive processes in action and then consider how you could convey them to students.

**DESIGNING LEARNING EXPERIENCES**

Most of us are not used to thinking explicitly about students’ prior knowledge, the development of knowledge structures, or strategies for developing metacognition as we design lectures, classes, laboratories, and activities. Fortunately there are well-developed frameworks for curriculum design that are grounded in learning theory (see for example Wiggins and McTighe 1998; Diamond 1998; Edelson 2001). While each of these is unique in its own way, most share some important elements:

**Instructional design needs to be initiated with a firm understanding of the goals of the instruction.** This mirrors the research process where we clarify the goals of our research during the proposal phase. It is equally important in teaching to understand what we are trying to teach our students, and to make these goals clear to our students, and to use them to guide our decision making in class. For example, what do you expect your students to be able to do at the end of your geochemistry class? What are the most important ideas that you want them to be able to apply from your class to their work as they continue their studies? Resources for goal setting include the Course Design tutorial developed by Tewksbury and Macdonald (2006) for geoscientists, which can be found at http://serc.carleton.edu/NAGTWorkshops/coursedesign/tutorial/index.html.

Motivating students to learn is important. Students must be engaged to learn; therefore, considering how students will be motivated to learn is an important element of design. Edelson (2001), an educator who works extensively in the geosciences, provides both an intellectual framework and practical advice for addressing motivation in instructional design. He notes that at any particular moment, a student must be motivated to learn something new, by either a need to know or a curiosity to pursue. There are now a variety of examples of courses and activities intentionally designed to encourage learning by using students’ curiosity about hazards, interest in environmental issues, and fascination with outer space, or by posing an interesting problem for students to investigate, asking students to act out a court case, or engaging them in using geoscience data to make a specific decision, like whether or not to buy a house near a volcano (e.g. Bair 2000; Stanley and Waterman 2004; Savanic 2005; SERC 2006b).

**Instruction, practice, and reflection all need to be part of the instructional model.** Learning requires access to new information, instruction in new skills, opportunities to integrate that information into existing knowledge structures, and practice using new knowledge with existing and new skills. The interplay of instruction, practice, and reflection is often referred to as the learning cycle (Kolb 1984). In our work as scientists we bring together new instruction (often from our colleagues’ papers), practice (our own work in the field, laboratory, or elsewhere), and reflection (the time we spend thinking, writing, and ruminating). Our course work builds on this experiential background, bringing together lecture, laboratory, problem solving, and writing. Edelson (2001) and Wiggins and McTighe (1998) provide structures for thinking more explicitly about the ways to bring these three aspects of instruction together. Wiggins and McTighe (1998) also provide guidance for thinking about strategies for focusing the curriculum in order to open up enough time for practice and reflection. The sophisticated design of learning activities with these three components lies at the heart of improving instruction.

**Assessment of learning is critical to knowing if and how a specific activity, class, or course is meeting the goals of instruction.** We are very familiar with using assessment in our research. For example, we run standards to determine if analytical techniques are running the way we anticipate, we validate our experiments through multiple measurements preferably using multiple techniques, and we seek confirmation of causality in our work. We need to bring this same approach to determining if our teaching is working and to understanding how it causes learning. We often use tests to find out if students are learning from our lectures. The recent introduction of “clickers” allows faculty to obtain real-time feedback on students’ comprehension of the material in a specific lecture segment (McConnell et al. 2006; McConnell and Steer 2006). Assessment of student learning and its relationship to specific aspects of instruction provide the data we need to know when we are being effective and how we need to improve. We have many resources at our disposal for this analysis: exams, graded work, standardized instruments for measuring attitude shifts and learning gains, tools for rapid feedback, and opportunities to talk with our students and to watch them interact. The education literature and geoscience education literature are full of examples of ways in which these tools can be used effectively. A point of entry into this literature is provided by the On the Cutting Edge website: Understanding what our Geoscience Students are Learning (http://serc.carleton.edu/NAGTWorkshops/assess/index.html).

**WHERE NEXT?**

Improving our teaching through goal setting, redesign of instruction, and rigorous evaluation can appear to be a daunting task. However, it will be much more manageable (and fun) if we work together as a community. Improving our instruction rests on two things:

1. Knowing what we are trying to teach
2. Knowing what works in instructing students in these areas

Knowing what we are trying to teach requires an understanding of our expertise. What are the valuable approaches that mineralogists, petrologists, and geochemists bring to problem solving? What are the important features of our knowledge that we want to impart to our students, features that will prepare them for the challenges of the next 50 years? This is an important discussion in which we have not yet fully engaged, either in geoscience as a whole or in our specific disciplines (Manduca et al. 2003; Manduca and Mogk 2006).

The answers to these questions could guide our exploration, individually and collectively, of the questions that we should be framing about our teaching: What do we want our students to learn? To be able to do? This is not to say that we should all be teaching the same course. Just as each of us has unique research experience and talent, so too do we bring to our teaching unique interests, skills, and opportunities for our students. Our institutions and physical setting further shape our teaching. However, a robust articulation of the expertise that we are trying to develop in our students and the learning goals that follow from that
articulation would help us all, both in designing our courses and in demonstrating to our colleagues their importance in the curriculum.

The second point concerning improving instruction is equally important. The mineralogy and petrology communities have thought extensively about their teaching. The Teaching Mineralogy workshop offered in 1996 to faculty members in the United States set a national model for disciplinary workshops focused on sharing teaching materials and discussing teaching methods. The print and web publications following from this workshop (Brady et al. 1997) and subsequent ones on teaching petrology and teaching geochemistry form a collective resource to help faculty new and old around the world improve their teaching (http://serc.carleton.edu/NAGTWorkshops).

The next step we need to take as an international community is to critically evaluate these materials. What do we know about the effectiveness of specific activities? How well are they aligned with the learning theory and educational research described above? What evidence do we have that they lead to the desired learning? This type of analysis would not only identify teaching materials that work particularly effectively, but would also yield some general guiding principles for teaching mineralogy, petrology, and geochemistry. For example, what do activities that are effective in helping students learn to interpret the history of specific rocks have in common? What can we say collectively about field instruction? What aspects of a field activity support learning to observe the salient aspects of minerals and fabrics? What kinds of activities support the integration of field observations and geochemical data? These results would form a knowledge base that would allow individual faculty members to decide wisely as they design courses with their particular students and their strengths as instructors in mind.

To answer these questions, as a community we will need to undertake scholarship on teaching and learning (e.g. Huber and Hutchings 2005) in mineralogy, petrology, and geochemistry. We are often scared of this work. Done rigorously, it is time consuming, and not all of us want to focus efforts in this direction. However, our community collectively contains the resources to do this work and to do it well. There are two requirements:

1. We will have to support intellectually the members of our community who take on rigorous research on our teaching methods—participate in their studies, discuss and review their results, and incorporate those that withstand the rigors of community evaluation. This work is key to moving forward our collective understanding of what works in teaching mineralogy, petrology, and geochemistry.

2. We will have to become adept at evaluating our own students’ learning and its relationship to our own teaching. These observations are essential to testing assumptions about our teaching and improving our abilities as instructors. Sharing these observations also contributes to our collective understanding of what works.

This approach is not radically different from the way we work as a research community. For example, not every scientist is interested in focusing on the detailed testing of a new geochemical method. As a community, we support and build on the work of those who demonstrate the validity of a method. We test our own methodology and results against standards to ensure quality analysis, and we apply the method in new ways to solve important problems. We share these results and use them collectively to understand the limits of the technique. We accept, as a community, basic principles for demonstrating sound experimental method and data validity.

Our community needs to approach teaching in the same ways that it deals with research (Huber and Hutchings 2005; NSF 2006). Community standards for teaching based on research within and beyond our community should evolve and support our work in much the same way that standards for scientific analysis have evolved. Just as our scientific community can make better progress in understanding problems in mineralogy, petrology, and geochemistry than we can make as individuals, our ability to educate the next generation of geoscientists will be stronger if we work collectively than if we each work alone.

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INTRODUCTION
I have been teaching science classes for almost three decades. From the first course on, I sensed that something was wrong. Students were not learning as much and as fast as I expected. Things that seemed straightforward to me were sometimes beyond their comprehension. Some students did not seem to get enthusiastic, and others just did not seem to care about my courses or their education. I tried different approaches, and every class had some students who excelled. Nevertheless, most classes had too many students who just did not seem to get it.

At first, I blamed the learning problems on the students. Later I began to wonder if perhaps I was the problem. So, I began to read books. Then, in 1994, I attended a Chapman Conference (“Scrutiny of Undergraduate Geoscience Education: Is the Viability of the Geosciences in Jeopardy?”) where science educators got together to discuss what was, and what was not, working in their classrooms. This is the same conference that led McManus (2005) to an epiphany and to teaching excellence. Like McManus, that conference convinced me to change the way I teach.

WHAT THE BEST COLLEGE TEACHERS DO
What do the best college teachers do that sets them apart from others? Bain (2004) sought to answer this intriguing question. What he found was that, although they all did different things, there were commonalities. They plan their courses carefully, approaching teaching as they would a research project. They ask themselves key questions:

1. What should my students be able to do intellectually, physically, and emotionally as a result of their learning?
2. How can I best help and encourage them to develop these abilities and the habits of the heart and mind to use them?
3. How can my students and I best understand the nature, quality, and progress of their learning?
4. How can I evaluate my efforts to foster that learning?

Traditional science classes have been taught with the instructor playing the role of an authority who delivers information by lecture, expecting students to absorb it (Fig. 1). This kind of “teacher-centered” instruction (passive learning) is not embraced by Bain’s “best” teachers. Instead, the best classes, says Bain, are “student centered” and the instruction is “student oriented.” The best instructors think of teaching as something they do to help students learn (question 1). They focus on furthering students’ cognitive and intellectual development (question 2) rather than presenting information.

KEYWORDS: active learning, lifelong learning, constructivism, studio teaching, learning portfolios, assessment

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Figure 1 Students “learning” how to use an atomic absorption analyzer. Here we see students watching as the instructor does the work and explains what is going on. Although this sort of passive instruction may be necessary to introduce students to the machine, real learning occurs when students get to use the machine themselves as part of a research project. Photo courtesy of Joseph Hartman
The best instruction involves activities that allow students to create, understand, and connect knowledge. Learning has both a concrete and an abstract dimension. So, successful learning involves observing and reflecting, and also experimenting and testing. For example, getting students involved in authentic laboratory research involves all these dimensions (Fig. 2). Individual learners create knowledge (individually and socially) for themselves as they learn. These ideas are the basis for the “constructivist theory” (constructivism), which holds that students should be exposed to information and should engage in activities that allow them to “construct” knowledge for themselves. Constructivism is a key concept that is part of almost every article published on learning today.

The best teachers are not satisfied with simply teaching. They want to measure how much learning is taking place, and they want to know what they can do to promote even better learning. A successful classroom involves two kinds of assessment: assessment of student learning (question 3) and assessment of teaching effectiveness (question 4). Note the wording of question 3. It says that students, as well as instructors, should assess the nature and quality of their learning.

Successful teachers give students more freedom and more responsibility for their learning. The instructor, therefore, relinquishes some control which, at times, can be quite disquieting. Bain (2004) cites four overriding concepts about learning, shared by the teachers he studied, that explain why they are willing to give up some control:

1. **Knowledge is constructed, not received.** As learners gather information, their brains process it and categorize it to make mental models (schema) describing the way they think the world is. They store specific bits of information as parts of the models. Over time learners develop a library of thousands of models to call on when needed. If they encounter new information, they try to interpret it in light of one of the existing models. Sometimes this leads to misconceptions or false conclusions as they force “facts” to fit what they already “know.”

2. **Unfortunately, mental models are hard to change.** Learning occurs when students modify existing models or create new ones. This will only happen if students encounter information or face a situation where existing models do not work. Additionally, students must care to resolve the situation, and they must have the confidence to deal with something unknown. So, teachers must challenge students but must take care that they can handle the challenge. While students are learning new models, they are storing facts. So, we must introduce new information and challenge students to think simultaneously.

3. **Questions are crucial!** Asking questions, or assigning appropriate problems and projects, can force students to consider issues not previously considered. Questions may point to weaknesses in existing thinking, forcing needed additions or modifications. With further questioning, students may be forced to develop new models. In an ideal case, students become self-motivated and independent learners, asking questions of themselves. Curiosity drives them to seek answers to new questions. Instructors work toward this goal, but short of that, the instructor’s questioning is crucial.

4. **Caring is crucial!** Learning is better if students are considering something they care about. This means that they have some prior knowledge of the matter at hand, perhaps even a personal stake. If they do not care, they will feel no need to reconcile contradictions or seek explanations. They will not construct new models, remaining comfortable with the old ones. Instead, they may simply memorize facts, soon to be forgotten after the course ends.

**ACTIVE LEARNING AND STUDIO TEACHING**

There are many approaches used by student-centered instructors. Most fall under the general category of “active learning.” Field trips (Fig. 3) provide ideal opportunities for active learning, but classroom activities can be tailored to do the same. In truly active classes, students are in charge of learning. They participate in activities, discussions and projects, all of which are designed to help them recognize important information, organize it, analyze it, and make connections to other things they have learned (iSERC 2006). In short, the activities are designed to help them develop their brains. Active classrooms are, to put it simply, exciting classrooms. The students are busy, animated, and happy. All standard measures show that active classrooms are very effective learning environments. For example, after taking a traditional physics class, only 30% of more than 1200 students (in physics courses at five different universities) understood fundamental Newtonian acceleration. When instructors added active-learning kinematics laboratories to the classes, more than 75% of the students understood. When an even greater emphasis was placed on active learning, 93% of students understood the concepts (Laws et al. 1999). See the discussion by Wirth (2007 this issue) for more details.

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“...This class made me work hard. The professor let us try to figure out things for ourselves, but was always there when needed. I think I learned more than in all my other geology classes combined.”
As I struggled to apply constructivist theory and to promote more active learning, I found that typical 50–60 minute classes made it difficult to get students truly engaged in active activities. So, I began experimenting with studio teaching (Perkins 2005). Studio teaching is now a key to successful learning in many of my classes. It is exciting and fun for me and for my students, and I cannot imagine teaching those classes in any other way.

Studio teaching has many manifestations. At the University of North Dakota, our studio courses involve long class sessions (3 hours) with focused, intense student activity. Any disconnect between laboratory and lecture is absent because we combine them. In fact, lectures are rare and generally brief. We base our classes entirely on active and cooperative learning. Students work on in-depth projects, generally in groups. The interactive classroom promotes holistic skills, including thinking, inquiry, creativity, and reflection by students, frequently involving peer review and critiquing. Studio classrooms and active learning, after an initial period of adjustment, seem to promote the best efforts from a wide range of students (Perkins 2005).

Studio teaching is particularly appropriate for classes that cover complex information and ideas. In such classes, students need to “do” the science and really think about what they are doing, not listen to someone talk about it. Additionally, the interaction with their peers can be very important during the learning process. The best learning occurs when students solve problems or discuss things together. The superiority of studio teaching for such upper-level classes is obvious from both the instructor’s and the students’ perspective.

However, studio teaching also works well for entry-level classes. Many introductory science classes are simply surveys. Classes typically include many topics, lots of vocabulary, and little context. In a studio classroom, information is presented in context, and it is used to solve problems or complete projects. Students remember key ideas and concepts much better than if their main learning activities are studying for exams. While doing so, they learn to think and develop other holistic skills.

Since I changed my classrooms to active learning and a studio format, I have seen significant gains in student learning. Measurements using standard tests and knowledge surveys (discussed below) show more than a 25% increase in overall scores compared to the same classes a decade ago. Perhaps more important, the number of students who perform at very low levels (“don’t get it”) has dropped to almost zero. At the same time, the amount of effort that students put forth has increased significantly. A standard refrain from students is that “this class makes me work harder than any other class I have taken … but I am learning a lot more.” Studio classrooms and active learning, after an initial period of adjustment, seem to promote the best efforts from a wide range of students (Perkins 2005).

There are many definitions of learning, but Leamnson (1999) catches the essence of all of them when he says that “learning is stabilizing, through repeated use, certain appropriate and desirable synapses in the brain.” By this definition, learning is different from absorbing information or facts; it is not looking at a rock or mineral specimen, nor is it doing an experiment in a chemistry lab. In fact, learning is a physiological process that is in many ways independent of the topic being learned and the specific “bits of information” being processed by the learner.

Zull (2002) provides an excellent discussion of the workings of the brain and learning. The models we have of the brain today, summarized by Zull, suggest that learning involves neurons growing and spreading out. This process, initially genetically controlled, is a product of learning environments and experience. Neurons bud, producing axons, which grow and branch. When they approach other neurons, the axons establish connections called synapses. The neurons, axons, and synapses organize into complicated networks, with a single neuron sometimes connecting to
more than 1000 others. A key observation is that the number of neurons does not change from childhood to adult. The connections, axons, and synapses do, because new experiences lead to new branching. With enough repetition, the branches become stronger and better connected, and brains get larger. During this process, some things that were once mysterious become routine. So, it is the connections—the network—that promotes thinking, and it is our experiences and interactions that promote brain development.

If genetics provides the building blocks, then experience designs the building. The more experience in a discipline, the better the brain adapts to that discipline. Current thought is that neurons continually bud, creating new axons. New connections are established but if not often used, they soon disappear. Training and repetition help stabilize knowledge or skills, as brain connections that are used become permanent. Repeated work of one sort solidifies and develops specific networks that become the normal (default) thought processes, producing mental models (schemas) for us to use in specific situations. Students use existing schemas to analyze new situations, whatever the specific tasks taking place. New ideas or contradictions may lead to modifications, cross connections, or feedback loops, but the basic schemas remain.

So, when teaching, we are not simply providing knowledge. We are not dealing with students whose brains are already hardwired. We are, instead, helping students redesign their brains and the way they think. This can only occur if students are actively engaged and doing things. Different training in different skills and fields leads to different networks in the brain, and schemas students develop have implications beyond any specific classroom. Dutrow (2007 this issue) discusses how students develop visualization skills—an excellent example.

**DEVELOPMENT OF LEARNING AND INTELLECT**

In their classic study, Bloom et al. (1956) developed a hierarchical scheme describing levels of thinking important in the learning process (“Bloom’s taxonomy”). They identified six levels within the “cognitive domain.” The lowest, most basic level was simple recall of knowledge. Moving toward ever more abstract and complex thinking, they listed comprehension, application, analysis, synthesis, and finally evaluation. In a follow-up to Bloom’s taxonomy, Anderson et al. (2001) expanded the original six thinking levels by considering four fundamental kinds of information that students encounter (factual, conceptual, procedural, metacognitive). This results in twenty-four different combinations of thinking and information-type that a student must master, and the ones they need to master depend on what they are studying. It is no wonder that learning is discipline specific (Donald 2002), nor is it surprising when many students struggle in classes such as organic chemistry or calculus. The material is not intrinsically difficult, but the students have not had the training necessary to establish the requisite neural pathways.

William Perry, Blythe McVicker Clinchy, and several others have investigated stages of intellectual development in undergraduates (Bain 2004). Their findings, in many ways, mirror the conclusions of Bloom and others. These investigators describe four principle stages that characterize intellectual development. At the basic level, learning involves collecting information from expert sources. The source could be an instructor, a book, or a talking-head on television. The information is collected, inventoried, organized, and stored.

As students’ thinking and learning mature, they may become subjective knowers. Experts sometimes disagree, information may be contradictory, and subjective knowers conclude that knowledge is a matter of opinion. Feelings and emotion then become important in making judgments. Some students may progress beyond this and become procedural knowers. These individuals learn how judgments are made within a discipline. They learn the standard arguments and when to use them, and so are able to make informed decisions within a discipline arena. These students are not, however, able to take their learning a step farther and apply it outside their classroom or discipline. They have learned to “play the game” in a particular environment (FIG. 5).

At the highest level students become independent, critical thinkers capable of transferring knowledge and thinking from one arena to another. They become introspective and aware of how they learn and think. As college teachers, our goal must be to move students from the lowest of the four levels to the highest. Our classes must not be focused on the lowest levels of Bloom’s taxonomy but, as much as possible, on the highest. Only then, will we be helping students develop the skills (develop their brains) needed for later life. Students will be able to enter new situations and environments and learn quickly. They will be able to evaluate facts, make inferences, and recognize errors in logic. They will also be able to analyze divergent views and deal with uncertainty. While learning all these things, they will learn specific information in their field of study. In short, they will have the skills and knowledge needed to be successful professionally and as citizens.

**FIGURE 5** These upper-level geology majors are mapping and interpreting an outcrop of layered ultramafic rocks at the Stillwater Complex near Nye, Montana. The students have already learned to identify various types of igneous rocks, they are familiar with the principles of magmatic differentiation, they know where ultramafic rocks occur, and they have constructed geologic maps before. This project provides them with an opportunity to combine several different kinds of information and skills to create new knowledge.

“In this class we did many different kinds of projects. If we didn’t learn things one way, then we learned them some other way.”
HELPING STUDENTS BECOME BETTER LEARNERS

Students learn specific content and skills in our classrooms, but the vast majority of them will make little use of the content and skills later on. All of our students are different, and we have no way of predicting who should learn what. If we teach them to be better learners, however, we will have taught them something that will serve them for the rest of their lives, no matter what they do. Indeed, Fink (2003) identified “learning to learn” as a fundamental component of significant learning. So, a fundamental goal of our teaching should be to help students become better learners. We can do this by helping them “learn to learn”—helping them develop the confidence to learn independently and the skills to do it successfully. Knowing how to learn will allow our students to be accomplished lifelong learners, adapting to changes in their work, family, society, and the world. These skills are keys to a successful life and essential for responsible citizens in a democratic society. Helping students become better learners is the single most important thing we can do in our classrooms.

Learning how to learn takes time and is an evolving process. Students progress at different rates depending on background, age, experience, specific talents, competition for their time, and many other things. Although all students are different, learning to learn is a cooperative project, involving student–student interactions and student–teacher interactions. Often it involves interactions outside the classroom.

One way we help students become better learners is by getting them involved in active learning activities and invoking the principles of scaffolding (Perkins 2004). Another excellent approach is to use knowledge surveys (Wirth and Perkins 2005). In our department we started using knowledge surveys because we wanted a way to measure learning in our classrooms. Subsequently, we found that surveys give students a way to assess their own learning. The surveys, introduced by Nuhfer and Knipp (2003), evaluate student learning, from basic knowledge and comprehension through higher levels of thinking. Besides allowing students to measure their learning, the surveys provide students a clear view of course objectives and a guide for activities during the semester.

If an important goal of our classes is for students to become better thinkers and learners, we need to discuss this goal with our students and tell them how our classroom activities will move them toward that goal. They should be exposed to the underlying principles of learning and pedagogy (c.f. question #3 of Bain 2004). It just does not make sense to have students do things without telling them why, and it does not make sense to try to help them develop better learning skills without discussing what those skills are.

Karl Wirth at Macalester College has developed a learning document that students read at the beginning of his classes (see discussion by Wirth 2007). My students read Wirth’s document, and we discuss it in class. During the semester, we refer to the document several times. So, students understand why we are doing what we do in the classroom—what the larger goals are and why certain strategies are being used.

Another excellent way to help students develop learning skills is to have them compile learning portfolios. Some advocate using portfolios to show or document student learning (e.g. Slater 2004). We use them mostly to promote student self-reflection about learning (SOT 2001). In their portfolios, students reflect on what they have learned, its value, the learning activities, which activities have worked best, and what they can do to improve their learning. They relate these things to the learning document they read at the beginning of the semester. They may go farther and discuss the intrinsic value of what they are learning—perhaps its relevance to other courses or the impact it may have in the future. They combine this self-reflection with material that supports their conclusions—usually work they have done in the class but sometimes including letters of commendation or recommendation or other things. Students turn in portfolios several times during the semester and then produce a final reflective essay just before taking the final exam.

ASSessment

According to Bain (2004), one of the key questions that excellent teachers ask themselves is “How can I evaluate my efforts to foster that learning?” Evaluating teaching is a difficult and multidimensional problem that requires the same kind of rigor we use when doing scientific investigations. To really assess teaching involves careful evaluation of student learning, and establishing the connection between that learning and the specific things that the teacher does (NAGT 2006).

Ideally, we want to evaluate our teaching in a way that will benefit other teachers. This requires what Boyer (1990) called the “scholarship of teaching.” Boyer was short on specifics, but others have expanded on his idea. Cross and Steadman (1996) pointed out that the scholarship of teaching is intimately connected with what they call “classroom research.” “Teachers,” they said, “have an exceptional opportunity to engage actively in the scholarship of teaching by using their classrooms as laboratories for the study of teaching and learning.” In “The Scholarship of Teaching: New Elaborations, New Developments,” Hutchings and Shulman (1999) said the same thing and further point out that to be of greatest value, assessment of teaching must be public, reviewed, and transferable.

Boyle (2007 this issue) provides an excellent example of classroom research. Unfortunately, most college teachers do not have the time to conduct in-depth investigations like Boyle’s, and of the sort that Boyer and others would like. There are generally no material rewards (promotion, pay raises) for conducting this kind of research. So, we use less time-consuming proxy methods to assess student learning and assume, probably correctly, that the learning is a reflection of how well we teach. This can be done in many ways (Angelo and Cross 1993; Huba and Freed 2000; Slattery 2006). Besides knowledge surveys and portfolios, already discussed, effective assessment strategies include concept maps and concept tests, peer review, written reports, oral presentations, case studies, and more traditional exams.

For reasons that are not completely clear, many instructors shy away from assessing their teaching. Yet, the information to be gleaned is exciting and can guide class planning. Finding out that something is working, or not working, making adjustments, and gathering more feedback is invaluable. Careful assessment is a fundamental part of good teaching if instructors use it to adjust the way they teach.
run their classrooms. Additionally, it has direct benefits for student learners. “Assessment doesn’t take time away from learning, assessments can be learning experiences in themselves. Active assessment strategies enhance student content understanding and promote skills that will be beneficial to students throughout their lives. The ability to see the big picture, develop effective oral and written reports and the ability to work cooperatively with their peers are skills that are promoted by active assessment” (Slattery 2006).


Huba ME, Freed JE (2000) Learner-Centered Assessment on College Campuses: Shifting the Focus from Teaching to Learning. Allyn and Bacon, Boston, 286 pp


Leamnson R (1999) Thinking About Teaching and Learning: Developing Habits of Learning with First Year College and University Students. Stylus, Sterling, 256 pp

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A growing body of research confirms that active approaches to learning offer many advantages over traditional instructional methods, including improved retention of information, conceptual understanding, and problem-solving skills. Content coverage in active-learning courses can be facilitated through careful selection and design of activities that guide student learning. Importantly, activities should engage groups of students in cooperative questioning, problem solving, analytical reasoning, and critical thinking. Focused instruction and reflection on thinking and learning help students develop as intentional learners.

**INTRODUCTION**

In an increasingly complex and interconnected world, students need to be “intentional learners” who are purposeful and self-directing, empowered through intellectual and practical skills, informed by knowledge and ways of knowing, and responsible for personal actions and civic values (AACU 2002). Self-directing learners “diagnose their learning needs, formulate learning goals, identify resources for learning, select and implement learning strategies, and evaluate learning outcomes” (Savin-Baden and Major 2004). Numerous studies have shown that lectures are relatively ineffective in helping students develop higher-order thinking skills (e.g. Hake 1998). Yet, despite recent advances in cognitive psychology, neuroscience, and education that provide new insights into thinking and learning (e.g. Bransford et al. 2000), many college-level courses are taught using traditional methods (e.g. Macdonald et al. 2005). The goal of this paper is to highlight recent research on learning and instructional practices (particularly active learning, cooperative learning, and problem-based learning), to provide examples of mineralogy and petrology courses that utilize active-learning approaches, and to advocate more purposeful curricula that provide students with skills for lifelong learning.

Active learning provides foundational skills for the development of intentional learners. In its simplest form, any instructional method that involves the learner in active questioning or reflection is active learning (e.g. Bean 1996). In contrast with lecture-based methods of instruction, in which knowledge is transmitted to the student, active learning facilitates development of higher-order thinking skills (e.g. building, testing, and refining mental models) through genuine engagement with the learning process (Mogk 2007 this issue; Manduca 2007 this issue). In an extensive review of the research on active learning, Prince (2004) found near-universal support for the efficacy of this approach. In particular, active learning results in significantly improved knowledge retention, conceptual understanding, engagement, and attitudes about learning (McConnell et al. 2003). Importantly, the responsibility for learning in active-learning pedagogies is shifted from instructor to learner (Michael and Modell 2003); the learner literally “constructs” his/her own knowledge. Results from neuroscience research confirm that this approach also has a biological basis in the ways that new neural pathways are established (Zull 2002).

A commonly used approach in active learning is cooperative learning (e.g. Srogi and Baloch 1997). In cooperative learning, students work together in small groups to accomplish a common goal. Cooperative learning typically includes the following elements: (1) positive interdependence, (2) individual accountability, (3) face-to-face promotive interaction, (4) appropriate use of collaborative skills, and (5) group processing. An enormous body of research confirms the effectiveness of cooperative learning. Compared with more traditional individualized and competitive models of learning, students who learn in cooperative groups exhibit markedly higher individual achievement, metacognitive thought, willingness to assume difficult tasks, persistence, motivation, and transfer of learning to new situations (e.g. Johnson et al. 1998; Prince 2004). Cooperative learning also improves relationships among students and between students and faculty, and it generally improves self-esteem and attitudes toward learning.

Problem-based learning (PBL) integrates much of what is known about effective teaching from learning theory, epistemology, neuroscience, and cognitive psychology. Widely implemented in medical schools, the methods of PBL are among the most thoroughly studied approaches to active learning (e.g. Barrows and Tamblyn 1980; Barrows 1983; Boud and Feletti 1997; Duch et al. 2001; Savin-Baden and Major 2004). A defining characteristic of PBL is the utilization of problems to stimulate, engage, and organize student learning.

**Keywords:** active learning, problem-based learning, cooperative learning, mineralogy, petrology

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The Romans taught their children nothing that was to be learned sitting.

– Seneca
Too often students are given answers to remember, rather than problems to solve.

– Roger Lewin

learning, so careful problem design is a vital part of course development. Student engagement with PBL follows a cycle that begins with an ill-defined problem. Initially students work to clarify the nature of the problem, formulate hypotheses, and identify their learning needs. They then gather information and reconvene as a group to integrate their new knowledge, formulate the problem, revise their hypotheses, and develop new learning strategies. Results from each group are commonly shared with the entire class in oral presentations and written reports. Self- and peer-assessment are conducted throughout each problem cycle. The emphasis on iterative learning that builds and tests mental models results in richer links between new and previous knowledge and in knowledge that is more readily transferable in new contexts (Michael and Modell 2003). Numerous studies of the effectiveness of PBL in medical programs note significantly improved positive student attitudes about learning, clinical performance, long-term knowledge retention, problem solving, and study habits (e.g. Prince 2004). The emphasis on problem solving, self-directed learning, and reflection (metacognition) likely also results in improved skills for lifelong learning.

**ACTIVE APPROACHES TO LEARNING MINERALOGY AND PETROLOGY**

**Course Design and Structure**

In the active-learning environment, the primary responsibilities of the instructor are to (1) identify the key learning objectives and enduring concepts, (2) determine acceptable evidence of student mastery of these concepts, and (3) design the learning experiences that will bring about the desired learning. This approach follows the “backward design” process of Wiggins and McTighe (2001) and results in clearer learning objectives, improved organization of course materials, and greater alignment of assessments with learning goals.

The introduction of active learning into the mineralogy and petrology curriculum at Macalester College occurred gradually and resulted in several other modifications to these courses. The typical 50–60-minute lecture period provides barely enough time for students to set up a problem or complete an activity. For this reason a studio format (Perkins 2005) was adopted, and students in both courses now meet for three two-hour sessions per week. This not only provides greater flexibility, it also provides larger blocks of time for completing activities that often include laboratory or analytical work. Another change that has greatly facilitated the implementation of active learning has been the adoption of course management software (e.g. MOODLE). Because class time is typically used for doing activities rather than listening to a lecture, it is critical that students come to class prepared and ready to actively engage new material. Reading reflections (submitted electronically before each class) are an effective way to encourage students to think more deeply about assigned readings before each meeting.

Because considerable in-class time is spent on problem solving, there is less time available for content coverage than in a lecture-based course. As a result, some course content is encountered by students only in readings assignments (Fig. 1). Other content is addressed in readings, activities, and problems, so the depth of coverage is not always equal. To some degree, concerns about content coverage can be addressed with knowledge surveys (Nuhfer and Knipp 2003; Perkins 2007 this issue), which consist of a series of items that cover the detailed content and skill objectives of a course. Knowledge surveys facilitate and support learning in a number of ways: (1) they help instructors design, organize, and assess courses; (2) they provide full disclosure of course learning objectives; (3) they serve as study guides and focus student learning on important concepts; and (4) they help students develop self-assessment skills and better habits of mind.

**Mineralogy**

The learning goals of the mineralogy course at Macalester College state that students will (1) recognize common minerals and be able to identify others; (2) understand the

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**Diagram illustrating coverage of content in the mineralogy course**

Shaded regions in the four right columns illustrate how different instructional methods are used to address topics covered in the textbook. Shaded regions in the four right columns illustrate how different instructional methods are used to address topics covered in the text and are not proportional to the time spent on each topic. This graphical representation provides a means for analyzing content coverage and instructional methods in a course.
principles that govern the composition, structure, and physical properties of crystalline materials; (3) understand the use of instrumentation (optical microscope, XRD, SEM-EDS) and literature resources to study minerals; (4) understand the physical conditions that affect the stability and association of minerals; and (5) have the research skills necessary to investigate minerals and rocks in new contexts. These goals are accomplished with readings and a mix of active learning (guided activities and projects) and just-in-time instruction (<20% of class time). Student progress toward the learning goals is formally assessed with a number of activities, three exams, a project report and oral presentation, and an oral exam.

The structure of the mineralogy course (Fig. 1) generally parallels the organization of a standard mineralogy textbook (e.g. Nesse 2000). Most activities in the first portion of the course are designed to introduce concepts and skills. For example, the course begins with an activity on physical properties and classification (Mogk 1997). This exercise helps make students (and the instructor) aware of their previous knowledge and helps motivate students to understand the theoretical aspects of mineralogy. In another example, the optical properties of biaxial minerals are introduced with a hands-on activity that uses baking potatoes as analogues for the biaxial indicatrix (Selverstone 2006). Students determine the principal vibration directions and optic axes of potatoes, mark them with toothpicks, and then check their work by cutting cross-sections through the potatoes with a knife (Fig. 2). This activity is followed by microscope exercises and a short lecture to further develop the concepts of biaxial minerals (Fig. 3).

The second portion of the mineralogy course emphasizes systematic mineralogy and the application of concepts learned in the earlier portions of the course. Students work individually and in small groups to identify common rock-forming minerals using instrumentation. The last four weeks of the course are spent solving a PBL problem in which students investigate changes to sulfide-bearing waste rocks as part of an ongoing study by the Minnesota Department of Natural Resources on the mitigation of acid mine drainage. Working cooperatively, students use a variety of tools (optical microscopy, scanning electron microscopy, X-ray diffraction) to study the original and reacted minerals and to relate these to water chemistry, water:rock ratio, and mitigation approaches. The acid mine drainage problem helps students to think about minerals in new ways by emphasizing processes (e.g. equilibrium, chemical reactions) and systems (mineral grains, alkaline additives, and leachate solutions). The project not only provides a context for learning mineralogy, students are motivated by the opportunity to contribute solutions to geological problems that are of interest to the local community.

**Petrology**

The petrology course at Macalester College contains many of the same basic elements described above, but it is fundamentally different in that the entire course is designed around a single problem (Table 1): the origin and evolution of a small, ultramafic to mafic, layered intrusion — the Sonju Lake Intrusion (Miller and Ripley 1996). The learning goals for the course state that students will (1) be able to describe and interpret common igneous and metamorphic rocks; (2) understand how rock suites are related by process, tectonic setting, and source; (3) know how to use multidisciplinary approaches to investigate petrologic problems, and understand the complementarity of these approaches; (4) be able to work with large sample suites and field data; (5) be comfortable using computers and modern instrumentation to study rocks; (6) have experience working with large datasets and database software; (7) know how to prepare a professional report and give a professional presentation on petrologic problems; and (8) understand the use of chemical tracers to investigate natural systems.

As in the mineralogy course, students in petrology are introduced to course content through a series of readings, short lectures, and classroom activities and projects. For example, students are introduced to phase diagrams through hands-on experimental determination of phase relations in the NaCl–KCl system (Brady 1997). Students determine the liquidus and solvus curves in this system using a muffle furnace and X-ray diffractometer. Through exploration of the phase relations of the halide system over a range of temperatures and compositions, students gain first-hand knowledge of the physical basis and meaning of phase diagrams. The petrology students then apply their knowledge to phase diagrams of other systems in short lectures and readings, and through the Sonju Lake Intrusion (SLI) project. Other classroom activities address topics such as nucleation and crystallization; major and trace element compositions; CIPW norms; mantle melting and phase relations using MELTS software; generation of alkaline melts using
trace element modeling; major element fractionation during crystallization using an M&M magma chamber analogue (Fig. 4; see Wirth 2003); and the evolution of isotopic systems during melting, crystallization, and radioactive decay. Frequent reference is made to the SLI throughout the course as students learn the fundamental skills and concepts of petrology.

The Sonju Lake Intrusion project is designed to introduce students to integrative methods of problem solving. In my early experiences teaching petrology, I utilized separate activities to teach petrography, phase equilibria, mineral chemistry, whole-rock major element chemistry, whole-rock trace element chemistry, and isotope geochemistry, but students rarely appreciated the complementarity of these approaches to understanding natural rock systems. By learning each of these topics in the context of understanding a common suite of rocks, students acquire a much better understanding of how to integrate field and petrographic observations, phase equilibria, mineral compositions, and whole-rock chemistry into petrologic models. Following the PBL method, students cooperatively investigate the origin and evolution of the SLI, including (1) the magmatic evolution of the SLI; (2) the roles of crystallization processes, magma recharge, and assimilation; (3) the parental magma composition; (4) the melt source(s); and (5) similarities with other well-known layered mafic intrusions. Granted, students who complete this course are exposed to a more limited variety of rock types, but they leave with a much deeper understanding of how to solve petrologic problems. Similar observations were reported by Gonzales and Semken (2006) for their field- and project-based petrology course.

A CO-CURRICULUM FOR LIFELONG LEARNING

Active-learning pedagogies require that students “take charge” of their learning by setting their own goals, develop learning strategies, monitor their thinking, and evaluate their learning. Students do not always embrace these new responsibilities and often require considerable support, at least initially, in the active-learning classroom. The transition from being a dependent to an independent learner involves major changes involving not only how students think, but also who they are (Kegan 1994). If the goal of education is to help students become intentional learners, then helping students to think more deliberately about learning should be an essential element of all courses. To help students develop into self-directing learners, I include explicit instruction about learning in all my courses. Throughout each mineralogy and petrology course, this “co-curriculum” on learning is interwoven with the mineralogical and petrological content. The goals of the learning co-curriculum are (1) to encourage students to be more intentional about their learning, (2) to help students develop their skills for self-assessment and teamwork, and (3) to help students construct greater personal meaning with their new knowledge and understanding. This co-curriculum helps provide structure, or scaffolding, and is an important component of active and cooperative learning (Perkins 2007).

I have also developed several instructional materials and activities that help students become more intentional learners. After searching for a summary article for students on the essential elements of learning and finding none, I prepared (with D. Perkins) a document entitled “Learning to Learn” (Wirth 2005; available at www.macalester.edu/geology/wirth/CourseMaterials.html). This document,
which is the first reading assignment in all my courses, explores various meanings of learning, understanding, and thinking. It also highlights research on the brain, learning styles (Boyle 2007 this issue), intellectual development, metacognition, collaborative learning, and the behavioral dimensions of grades. The learning document not only serves as a reference for classroom activities, it also helps establish that my expectations for student learning in the course go far beyond memorizing content.

Many students are interested to learn about thinking, learning, and development. Learning how to learn, an essential element of significant learning (Fink 2003) and of being an intentional learner (AAAU 2002), includes planning one’s approach to learning tasks, monitoring thinking, and evaluating understanding. Fink’s (2003) taxonomy of significant learning emphasizes change in the learner, it integrates foundational knowledge with learning how to learn and the affective domain (feelings, values, motivations, and attitudes of the learner). After an introduction to the elements of metacognition, students reflect on their learning strategies, attitudes, and motivations in regular online journal entries (Perkins 2007). I also have them conduct formal self-assessments of their own work and assessments of the contributions of other team members to group projects.

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Greater participation, and the associated increase in student diversity, has changed university education worldwide. The old ways of teaching a small number of well-qualified committed students do not work as well with large classes and more diverse student needs. This essay documents one approach to this challenge. It involves understanding student needs and preferences better, developing a range of ways to deliver learning and assess the results, and finally reflecting on the outcomes. The annual process of reflection allows changes that improve alignment of course aims with their delivery and assessment, and results in improved student learning and perception of the subject.

INTRODUCTION

Increased participation in university-level education worldwide in the late twentieth century (Scott 1995) involved a change from education for the elite to education for the masses. In the UK, participation increased from 6% of under-21s in the 1960s to about 43% of 18–30-year-olds in 2003. At the same time, funding per student in the UK fell by 36% in real terms between 1989 and 1997 (Department for Education and Skills 2003). Increased participation means greater diversity in student abilities, experiences, preconceptions and misconceptions, learning expectations, and career intentions (Archer and Hutchings 2000; Leathwood and O’Connell 2003; Jones and Thomas 2005). In this diversity with fewer resources, there are challenges. How can they be successfully addressed?

An added challenge: how to help students engage with a diversity can be ethnic or cultural, but in education it means greater diversity in student abilities, experiences, preconceptions and misconceptions, learning expectations, and career intentions (Archer and Hutchings 2000; Leathwood and O’Connell 2003; Jones and Thomas 2005). In this diversity with fewer resources, there are challenges. How can they be successfully addressed?

An added challenge: how to help students engage with a subject they consider boring (see 1998 student comments on mineralogy in Table 1)? Students must learn much factual mineralogical information that they will need to succeed in subsequent petrology and geochemistry courses (e.g. chapter 3 in Bransford et al. 2000, for a discussion of knowledge transfer), even if some may consider such knowledge irrelevant to today’s students (Eaton 1995).

This essay is based on the changes made to improve a first-year University of Liverpool course in which mineralogy is introduced together with aspects of petrology and geochemistry. Almost all of the enrolled students are geoscience or ocean science majors, though the majority have never studied geology before. My solution involved determining how my students wanted to receive learning material while making sure they understood what was expected of them in terms of commitment, how I would help them learn, how assessments would demonstrate it had happened, and how this course would help them in the future.

This approach, I subsequently learned, had much in common with Biggs’ theory of Constructive Alignment (Biggs 1999, 2003), which has had great credence at all levels of UK education. Biggs’ premise is that curricula should be designed so that the learning activities and assessment tasks are aligned with the intended learning outcomes (e.g. an essay is a great tool to assess students’ ability to evaluate concepts such as uniformitarianism, but not a good tool to assess their ability to recognise minerals). Reflection on what happened will help formulate modifications, which in turn will improve alignment and promote better learning (was the assessment unintentionally confusing in some way?). The constructive part means that students construct their own learning from the learning activities (e.g. active learning or problem-based learning), rather than just being guided by an expert (e.g. lecture). My course design took on the concept of alignment, but did not take a strictly constructivist approach. My instinct was to guide students through their learning (lectures) and give them opportunities to practise the required skills (formalised practicals) rather than use a purely constructivist learning approach. In recent publications on guided versus constructivist approaches (e.g. Jervis and Jervis 2005; Kirschner et al. 2006), it has been suggested that the advantage of guided over unguided problem-based approaches begins to diminish only when learners have sufficiently high prior knowledge to provide their own “internal” guidance. First-year students need help and guidance.

GET TO KNOW YOUR STUDENTS’ LEARNING PREFERENCES

Diversity can be ethnic or cultural, but in education it includes variations in student learning styles and preferences. Most teachers know, anecdotally, that different students learn differently. Much research has been done on this topic (e.g. Kolb 1984; Gardner 2000; Entwistle 2001), and studies suggest that learning-style differences do affect how learning takes place, such that some students may be advantaged or disadvantaged by a particular learning mode (i.e. lecture). However, setting up individualised learning for each student’s preferences is not the answer pedagogically or logistically (see Coffield et al. 2004 and Draper 2005 for excellent reviews). A better approach is to bear in mind student diversity but not be a slave to it; as Sadler-Smith
(2001, p. 300) noted, student and teacher awareness of learning preferences can help in “enabling individuals to see and to question their long-held habitual behaviours”. In other words, individuals can be taught to reflect on why they selected a particular learning style or strategy, to understand if it was the right choice, and to change if necessary. It is no longer good enough to say, “I see recent graduates from my courses talking at international conferences so my teaching must be OK”. These are the students who will succeed however they are taught and are not representative of the whole student body. The challenge is to enable all students to succeed, and for this, educators need to “question their long-held habitual behaviours”.

My department uses the VARK questionnaire (Fleming and Mills 1992, http://www.vark-learn.com) as part of its new-student induction programme. VARK is a simple questionnaire that assesses preferences for four sensory modes of learning (Visual, Aural, Read/write, and Kinaesthetic) through 16 everyday questions. For example, if someone asked you for directions somewhere, would you draw a map (visual), tell them (aural), write a list of instructions (read/write), or take them there (kinaesthetic)? After answering the questions, students apply a simple algorithm to ascertain their preference, which may be unimodal if they choose one particular type of preference (e.g. read/write) or a more complex polymodal preference. Figure 1 summarises the diversity of VARK outcomes for 114 Liverpool Earth science students surveyed in 2001, using an earlier 13-question version of VARK. 29% of students showed single preferences, with most being kinaesthetic. Multimodal preferences were more common, but none of the students expressed a bimodal visual–aural preference (videos?), and listening generally scored low. This mix of learning-mode preferences – 24% of students have preferences that do not include kinaesthetic and 42% prefer not to read (Fig. 1) – suggests that learning delivery should be multimodal. Although the same caveats apply as for learning styles discussed above, recent technological developments make it easier to design teaching for multimodal delivery, and this approach was adopted.

![Exploded pie chart summarising 114 student responses to the VARK questionnaire.](image_url)

**DESIGNING A MULTIMODAL COURSE**

The learning outcomes in introductory mineralogy are constrained by what students need to know, understand and be able to do before taking up subsequent petrology courses. In particular, they should (1) know the properties of common rock-forming minerals, (2) understand common classification schemes for minerals and rocks, (3) understand how minerals may be interpreted to infer geological conditions and processes, (4) know how to use a hand lens and a petrological microscope and (5) acquire the skills needed to be able to recognise minerals and make proper drawings of them in hand specimen and thin section.

To find out if these outcomes were achieved, an existing paper-based multiple-choice examination was converted to run as a computer-aided assessment (CAA) in January 2000 using the TRIADS engine (Boyle 2002; MacKenzie et al. 2004). Some other types of questions were added, taking advantage of text-entry, drag-and-drop, hot-spot and sequencing functions in the TRIADS engine, for example, to test for understanding of mineral and rock classification schemes, the determination of plagioclase composition from extinction angles, and features in hand-specimen and thin-section images. The CAA primarily addressed learning outcomes 1 to 3, above. All questions in the CAA were objectively graded with multiple-choice questions negatively scored, in line with departmental policy. Thus, a correct answer to a multiple-choice question with four possible answers would score 100%, an incorrect answer ~33.3% and no answer 0%. The CAA was worth 60% of the course credit and ran as a formal time-limited examination in a large computer laboratory. Outcomes 4 and 5 were assessed via work completed by students in a practical handbook and in a 45-minute thin-section examination in the last practical session. Marks were awarded using subjective grade descriptors, and will be referred to henceforth as coursework marks.

Having decided on the intended course outcomes and how to assess them, it was then straightforward to devise the curriculum. The mineralogy course consists of 12 lectures and 6 three-hour practical sessions, and the design aim was to deliver the material in a variety of sensory modes: predominantly visual–aural–read/write in lectures and visual–read/write–kinaesthetic on the Web and in practicals. Lectures were converted to PowerPoint to make use of digital resources, such as the Open University virtual microscope, movie clips of microscope images and 3D animations of crystal lattices (Fig. 2). This format “livened them up” and helped guide student understanding of difficult concepts, such as the interaction of polarised light with minerals and the plagioclase binary phase diagram (see Dutrow 2007 this issue for other examples of visualisations). PowerPoint presentations are available with other resources on the Liverpool Virtual Learning Environment, before, during and after lectures, to help students with a read/write modal preference. Lectures favour students with visual–aural–read/write preferences.

Practicals allow students to work through the lecture material and learn how to use a petrological microscope and a hand lens. A shortage of study material for the number of students involved (60–110) requires practical sessions to be run in parallel (e.g. a third of students study olivine and orthopyroxene, another third study clinopyroxene and amphibole and the rest study garnet and micas). It also requires students to share the material in groups of about four, which fosters collaborative learning. One outcome of this arrangement is that students may study the practical material before or after the relevant lecture. The 60-page practical handbook provided to each student is thus a key
component. It enables students to study a group of minerals in a practical before the relevant lecture. It provides information on course structure, a glossary of terms, standard mineral abbreviations, how to describe minerals in hand specimen and thin section, and how to use minerals to classify igneous and metamorphic rocks. Subsequent chapters cover each of the practical sections: olivine and orthopyroxene, clinopyroxene and amphibole, phyllosilicates and garnet, feldspars, quartz and calcite, and opaque/ore minerals. Students can record their own observations (e.g. Fig. 3), and they are reminded that the handbook will be their personal resource to help them transfer their knowledge and skills when they move on to petrology courses.

REFLECTING ON STUDENT PERFORMANCE

Five years’ worth of data have been collected both for student performance in assessments and for student perceptions of the course, and reflection on these data has been key in improving the course. In my approach to analysing assessment marks, I use student performance in concurrent courses as a pseudo-independent variable: the “independent grade” (it is assumed that assessment in all concurrent courses is a valid independent measure of each student’s overall academic ability). Since mineralogy is 1/16 of a student’s first year of study, the independent grade represents the remaining 15/16 year of study. Reference comparisons are made against related courses taken by the same students (referred to as courses X, Y and Z) to check that any changes are not just cohort related (e.g. is one cohort significantly better than another across all courses?). For reference, assessment in course X comprised a final examination covering knowledge, technical ability and problem solving; course Y used the same 60 multiple-choice question examination each year; and course Z used a combined theory and practical examination.

In the first year of the redesigned mineralogy course (1999–2000), the CAA examination produced a wide range of marks with about 25% failure (mainly due to poor marks in negatively scored multiple-choice questions, which students complained about bitterly), whereas the coursework assessment produced a narrower range of marks with few failures (Fig. 4, year 2000). The CAA and coursework marks in 2000 (Fig. 4) show ordinal interaction (regression lines have different slopes but do not cross within the data range), consistent with some learning-style or teaching-preference effect (Draper 2005). Although coursework marks were generally higher, they correlated poorly ($R = 0.44$) with independent grade marks (Fig. 5), and the CAA correlated little better ($R = 0.56$). Combining the coursework and CAA marks (40:60) to produce an overall mineralogy course mark gave the best correlation with the independent grade ($R = 0.62$), but worse than reference courses X and Y in Figure 5. This poor outcome was not expected, and reflection led to the formulation of two interventions.

First, many of the low-scoring multiple-choice questions in the CAA were replaced with multiple-response questions that required no negative scoring. For example, the multiple-choice question “Which mineral has the composition $\text{BaSO}_4$?” (answer: barite) can be recast as “Which elements are normally present in the mineral barite?”, with the student selecting the elements from a matrix of 24 element choices.
The question does not indicate how many correct choices there are. The correct choices (Ba, S and O in this case) score 100% (33.3% for each), whereas incorrect choices score minus half the score of a correct choice (-16.7% in this case). A student selecting just the three correct items would get 100%, three correct and one incorrect 83%, just two correct 67%, two correct and two incorrect, 33% and so on. An overall negative score is awarded zero. Each multiple-response question thus provides a range of marks, not the usual binary range in multiple-choice questions. Details of question item analysis and changes are discussed in Boyle (2002).

Second, marking the practical handbooks revealed a number of common student misconceptions. Both “good” and “poor” students were adversely affected by ambiguous instructions, which needed to be revised to improve clarity.

For example, in a section asking students to record hornblende pleochroic colour variations using drawings in three circles, the following instruction proved ineffective:

“Sketch the three orientations (one basal and two prismatic) showing the three colours (shade or label them) together with cleavages in the correct orientation. Indicate optic orientations of the minerals in each sketch.”

Reflection resulted in a much better instruction:

“Find a single field of view that shows a basal section (two cleavages at 124°) and a range of prismatic sections. Check that all three pairs of pleochroic colours are seen when the stage is rotated. Sketch and label the same field of view in different orientations to illustrate colour changes. You will need at least two sketches, but may need three. Indicate optic orientations of the minerals in each sketch. Remember, pleochroism is seen in plane-polarised light (PPL).”

Assessment results for 2001 (Figs. 4 and 5) show improved student performance in the CAA, with a much-reduced failure rate. The coursework and CAA grades also correlated better with the independent grades (R = 0.60 and 0.64 respectively), and the overall mineralogy module grade correlation improved to R = 0.8 (greater than reference courses X, Y and Z). The interventions had a positive effect on measured student performance; changes to the assessment materials made them better aligned with the intended learning outcomes. This process of reflection on outcome, individual question performance and possible ambiguity in the handbook has been repeated annually. Correlations of mineralogy assessment results with independent grades have generally improved from 2000 to 2004 (Fig. 5). Interestingly, while the CAA generally ranks students better than coursework, combining the two into a final course grade consistently provides better ranking, indicating both assessment methods are necessary.

Ordinal interaction between coursework and CAA is less evident in later years (smaller angle between slopes in Fig. 4), but coursework grades are still higher. This is particularly so for lower-ability students, whose better performance at coursework than final examination implies they benefit most from task-based and problem-solving approaches to learning rather than recall-knowledge approaches. By contrast,
the most able students perform well with both approaches. See Threadgill 1979, for an interesting mathematical-logic study in which she concludes (p. 343) “...educators might be better advised to ask higher order questions of low ability students, and be less concerned about the type of questions given to high ability students, who are often better able to function regardless of the instructional questioning technique”.

Comparison with related modules (X, Y and Z in Fig. 5) indicates the general improvement in the performance of mineralogy students from 2000 to 2004 is not cohort related, and so must reflect real changes in the mineralogy course. The student view in 2002, collected after their CAA examination, was almost universally positive (see Table 1). I do not believe there is one single change that has had more effect than any other. Rather, it is the system-style approach entailed in seeking alignment that has resulted in a better course, which is also appreciated and seen as fair by students.

Last, it is noteworthy that other strategies continue to be used to address this same problem (see Journal of Geoscience Education, volume S2, number 1, for example). More and more university teachers are recognizing something needs to be done and are looking at ways to improve (e.g. Brady et al. 1997; Dutrow 2004; Dyar et al. 2004; Wulff 2004). Virtually all higher education mineralogy, petrology and geochemistry teachers are trained researchers. They could improve their course performance by using their research skills to analyse and understand the teaching and assessment have on student learning and perception of their subject (see also Manduca 2007 this issue).

My recommendations include the following: ➊ use a questionnaire like VARK to understand student needs and question your own beliefs, ➋ think about how the different parts of a course align with each other, ➌ be aware that different styles of assessment can grade students differently, ➍ reflect using science research skills to analyse what happened and initiate changes to be made (even small ones), ➎ be multimodal in teaching and assessment.

### Table 1

<table>
<thead>
<tr>
<th>1998</th>
<th>2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Could do with livening up somehow.</td>
<td>A good course. Could have been dull, but wasn’t.</td>
</tr>
<tr>
<td>At best the content was “dry”.</td>
<td>Found the teaching material very good compared to some other courses.</td>
</tr>
<tr>
<td>Not the most interesting course I am doing.</td>
<td>Great presentation, keep access to lectures on the web.</td>
</tr>
<tr>
<td>Lectures were quite boring and hard to follow, often using new complex terminology – difficult to grasp.</td>
<td>Content presented clearly on the net, but not in lectures.</td>
</tr>
<tr>
<td>Very enjoyable. Hard, as new to me, but fascinating.</td>
<td></td>
</tr>
</tbody>
</table>

### ACKNOWLEDGMENTS

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Visual Communication: Do You See What I See?

Barbara L. Dutrow*

Visual displays of data, images of subatomic to planetary-scale features, and animations of geological processes are widely used to enrich our disciplines. However, their communicative power may be dramatically different to a student and to an expert because of the need for prior knowledge and inference when interpreting visuals. To “see” equivalent visual information, the non-expert must learn the visual language of the expert. Teaching visual literacy is important to instruction at all levels and is as fundamental to a discipline as its vocabulary. The underlying foundations of visual literacy and the recognition of what one “sees” and interprets in a visual depiction are critical for enhancing student learning and for effective communication in our visually rich discipline.

Keywords: Teaching, visuals, visualization, visual communication, images

INTRODUCTION

Since prehistoric times (e.g. cave paintings), visual images have been used to inspire and to communicate information. The first stunning image of our planet, “Earth Rise,” is considered to have raised social consciousness—an awakening that grew into the environmental movement (Gore 2006). Our knowledge of the world around us and our everyday decision making commonly rely on visual information. With new measuring and imaging devices capable of nanoscale resolution, remote sensing on the planetary scale, Google Earth®, and more powerful computers for modeling geo-hydro-biosphere processes, our world is increasingly filled with visual displays (e.g. Domik 1999).

The fields of mineralogy, petrology, and geochemistry (MPG) are particularly rich in visual imagery (Fig. 1), the visual display of quantitative information (Fig. 2; Tables 1 and 2), and the application of visuals to communicate in both teaching and research. These images extend our ability to see across many scales of observation (planetary to atomic) and over time intervals inaccessible to direct human observation (e.g. computational modeling of processes from femtoseconds to billions of years). Visual display of data is a powerful tool for cognition, facilitating comprehension, learning, and memory (e.g. Levie and Lentz 1982; Tversky 1995; Tversky et al. 2002). In addition, visuals are used as a key to problem solving (e.g. determining the reaction path on a phase diagram) and to test hypotheses (e.g. by graphically representing relationships to determine cause and effect; Tufte 1997). Well-designed graphics can accelerate data transfer (i.e. the amount of information transferred at a single time) and provide a second mode to convey information (i.e. a combination of text and visual communication is better than a single mode; e.g. Tversky et al. 2002). Computational models of complex Earth processes may produce giga- to terabytes of data that can only be analyzed, interpreted, and comprehended by utilizing computer visualization methods.

Each of these visual depictions requires a special set of cognitive skills to interpret and understand. While these skills may be intuitive to experts (professors and technical workers) in the field, non-experts (students and non-technical employees) may lack the prerequisites necessary to extract meaning from the representation if they must understand how the visuals are created and how to appropriately use and interpret them. This, in turn,
creates additional barriers to communication and learning. Because the preferred learning style of over 60% of students is visual (e.g. Felder and Spurlin 2005; Boyle 2007), visual literacy is essential. To think like a scientist requires visual literacy, a skill that is continually acquired (Stonehill 1994). “People learn to do well what they practice doing” (AAAS 1996).

As a result, teaching visual literacy is necessary because it is as fundamental to our discipline as is our discipline’s vocabulary. The ability to know what, and what not, to look for and to derive meaning from in visual representations are skills that are practiced and valued across the MPG disciplines and can be used to teach attributes of lifelong learning (see Wirth 2007). But do we use methods that help students develop skills of visual literacy? What do we know about the effectiveness of visual representations in teaching and in communicating during our professional presentations?

### VISUAL LITERACY

For any type of visual representation, the associated learning and communication derive from prior knowledge and experience (e.g. Larkin and Simon 1987; MacEachren 2004). As we continually learn how to read visual signals, translate these into understandable information, form a mental image, and commit to long-term memory where it is stored as knowledge, visual literacy gradually develops (e.g. Larkin and Simon 1987; Stonehill 1994; Perkins 2007). This visual memory is then invoked to analyze new data structures, to recognize relevant information, and to draw inferences for interpretation and understanding (e.g. Larkin and Simon 1987; Barry et al. 2002).

Consequently, in a given discipline experts and non-experts do not “see” equivalent meanings in the same visual. The information conveyed to each audience is vastly different because of the requirements for prior knowledge, association, and inference (e.g. Larkin and Simon 1987). To underscore the non-equivalence in “seeing” a single image, consider an unlabeled polished rock slab containing several copper-bearing minerals (Fig. 3a). A beginning geology student might “see” the cross-cutting relationships and recognize that there are different minerals. A second-year mineralogy student might recognize these minerals by color and determine the sequence of formation. A third-year geochemistry student, or an expert, might infer the decrease in log $\text{PCO}_2$ of the fluid phase as required by the transition from azurite to malachite (Fig. 3b). To evaluate the level of insight and to identify the appropriate use of visuals, specific assignments can be developed that require visual interpretation. This recognition of non-equivalence is especially relevant as our research and teaching become increasingly multidisciplinary.

Awareness of prior knowledge and the need for a visual understanding are critical when developing and utilizing visuals for teaching (see also discussion of constructivist theory of learning in Manduca 2007, Perkins 2007, and Wirth 2007). Otherwise, one is unable to recognize relevant information, the visual representation is largely meaningless, and learning fails. One such example is the high-resolution transmission electron microscope (HRTEM) photographs included in some introductory mineralogy books. To view and accurately interpret these images requires an understanding of (1) how crystals are constructed (e.g. crystal structures, symmetry, axes, periodicity), (2) the analytical technique and acquisition of the data to supply context, (3) the projection of a 3D image onto a 2D surface, (4) the meaning of black and white in the image, (5) the visual appearance of this mineral in HRTEM, and (6) how to differentiate “atypical” features from the “typical” features.
of an HRTEM image. Although each of these aspects is easily understood and interpreted by an expert crystallographer, to a non-expert HRTEM photographs may appear to be nondescript black and white clusters with little relevance. Instructors can use these images more effectively by adding a superimposed crystal structure and thus address the high level of background required by 1, 4, 5, and 6, above (Fig. 4). Together with a concomitant verbal explanation of the visual, and perhaps a physical structure model, the non-expert gains the visual literacy to interpret and appreciate these complex images—the natural progression from simple to complex.

To bring non-experts to the expert level, visual literacy must be practiced at appropriately more complex levels during the teaching and learning cycle. This is clear when one considers the range of visuals, their uses (see Introduction), and the inferences needed to understand, interpret, and communicate Earth’s processes and products. These visuals portray both (1) spatial data, where space is used to represent changes in inherently spatial data (Table 1), and (2) non-spatial data, which is organized in a spatial context (Tversky 2004; Table 2). For many of these data-rich spatial representations, no number of words could capture the relations displayed in the images (e.g. Fig. 5). In some cases, there is considerable visual “noise” (e.g. in a landscape or thin section), which requires one to make cognitive decisions about what to “see” and what is irrelevant to the question (e.g. Reynolds et al. 2006). Could this explain why so few passengers in the window seat of an aircraft observe the ground below? Expert geologists can readily recognize and interpret the geologic features in the vast landscape below, but non-experts are awash in visual clutter. For non-spatial representations, it is commonly the pattern developed in the spatial arrangement that becomes the basis for communication and interpretation of the data (e.g. a powder XRD pattern or an isochron plot; Fig. 2). Thus, knowing what to look for and what to ignore in the visual are also important attributes that must be specifically taught.

With careful and detailed explanations complementing each new diagram or representation, the fundamentals of visual messages and objects are conveyed. When each representation is constructed with enlightening annotations and when assignments are specifically generated to develop...
Diagrams have the origin increasing to communicate and facilitate teaching visual literacy. Nevertheless, a high level of background knowledge may be required for interpretation.

**Keep it Simple and Task Oriented**

Studies have shown that one focuses attention on that portion of the diagram specific to the task, directing more attention to salient features (e.g., Larkin and Simon 1987). Consequently, it is necessary to identify the goal and task of the visual and to develop the visual in this context (i.e., to test a specific relationship, to motivate, to engage, to test an hypothesis). The more one knows what to look for, the more attention focusing increases (see also Johnson and Reynolds 2005). Thus, simplified graphics may communicate more effectively than realistic representations (e.g., Dwyer 1978; Tufte 1983; Tversky et al. 2002). To strengthen visual thinking, assignments requiring the use of various task-specific visual representations will be given. Those graphics that are goal oriented and provide a clear depiction of a single concept are the most valuable.

**Congruence Principle**

Diagrams constructed to be consistent with physical reality are more intuitive and more readily accessible (e.g., Tufte 1997; Tversky et al. 2002). This congruence explains why some pressure-temperature ($P$–$T$) diagrams have the origin on an x, y relational plot at the upper left with $P$ increasing downward, congruent with Earth’s physical system. This principle also requires that if one names a formation “the red unit,” the unit be colored red on a diagram (see Fig. 3). Congruence is also embedded in the principle of “graphical integrity,” that is, the effect in the data should match the effect portrayed graphically (developed and discussed by Tufte 1983). The literature contains numerous instances of overemphasizing a conclusion by enhancing a graphic. For example in a recently published article, circle sizes were used to portray the area ($A = \pi r^2$) burned by various fires (Running 2006). However, the circle representing a 200,000 ha fire is twice the diameter (radius) of a 100,000 ha fire ($r_2$), although it should have been $1.41 \times r_1$. Thus, the resulting graphic portrayal is larger than that shown by the data.

**Apprehension Principle**

Visually familiar forms are more “accurately perceived and comprehended” (the apprehension principle of Tversky et al. 2002). If a new visual representation that is not accessible via prior knowledge is presented, communication typically fails as the observer searches for meaning. The response to these abstract visuals can be confusion, a sense of being overwhelmed, or worse, distrust. Such negative responses decrease motivation and learning. With computational experiments prevalent in our disciplines, mapping of data into new graphical spaces using visualization techniques provides a mechanism for discovery and data analysis. However, these new depictions present unique challenges for presentation and communication.

One such example is shown in Figure 6. To communicate the duration and spatial region of heating surrounding a pluton as calculated from a series of computational experiments, 3D visualization was developed (Dutrow et al. 2003). This graphic was constructed from individual x–y planes extracted from a 3D volume at specific z coordinates ($z'$) for a set of times $(t_1, t_2, \ldots, t_n$; Fig. 6x). The slices were then stacked vertically to depict the x–y–z’ region through time, with time increasing upward along the vertical axes. Once compiled, colored isosurfaces contour and highlight regions of heating (red) and cooling (blue), and mark the
change from one regime to another (beige, \(dx/dt = 0\)). By developing these types of images for a series of calculations, the impact of various controlling parameters on the duration of heating (or cooling) can be observed at a specific \(z'\) (cf. Figs. 6b, 6c, 6d). While this graphic revealed new behavior and provided insight to the analyst, it had the undesired consequence of invoking negative responses when presented to an audience. These ranged from “Can you explain that again?” to “I don’t trust fancy graphics.” Such negative reactions inhibit effective communication and impede learning.

These graphics fail the apprehension principle, in part, because they are newly developed depictions. The observers (some experts) had no prior knowledge with which to interpret the figures, resulting in the negative emotional responses. This highlights the point that it takes time for an audience, including our students, to absorb the visual nuances and understand the relationships. However, despite being poor presentation graphics, they are excellent analysis graphics.

**Animations Commonly Fail the Apprehension Principle**

With the ease of creating movies and their coherence with time (time is used to portray time), geoscience animations are now widely used for portraying the evolution of systems, for providing multiple viewpoints by repositioning an object within the observer’s frame, and for teaching processes that occur over unattainable time scales. Animations capture the fine as well as the coarse features of a process, not apparent from a few motionless graphics (e.g. Tversky et al. 2002.) Because more information is contained in an animation, superior communication can result.

Although animations may be appealing, their ability to improve communication and learning is equivocal (e.g. Tversky et al. 2002 and references therein). While they maintain coherence with time, they commonly fail the apprehension principle. Many animations involve multidimensional data representations of a complex system. The graphical illustration used to portray the system may be new and abstract; thus not only are the concepts embedded in the animations difficult, there is the compounded complexity of both new concept and new data display that requires new inference. Additional difficulties may arise because animations commonly lack scales (spatial and temporal), orientations, and annotations. They may be too complex and, with saturated rainbow color palettes, may be unpleasant for viewing. Only experts in the field may adequately comprehend the elegant visual and the underlying causality.

Research does suggest that simple schematic animations, removing non-task-oriented features, are better than complex, realistic animations (e.g. Tversky et al. 2002.) These researchers also found that animations must be sufficiently slow and clear to allow movements, timing, and relationships to be perceived. Adding a series of stationary images provides easily accessible, but restricted, information for extended viewing, comparison, and comprehension of the fleeting animation.

Interactivity is known to facilitate learning (e.g. Schnitz and Grzondziel 1999). The ability to stop, start, review, and view different perspectives increases the utility of an animation. This self-guided exploration of processes and products is different from choosing among a number of “canned” options that may not actually be interactive. Are students simply being entertained by animations that enable “passive” learning, or can the visualizations be effectively incorporated into active-, discovery-, and inquiry-oriented exercises? Providing the opportunity for students to construct animations develops insight into the topic’s essential steps; otherwise the sequence of events portrayed would not mesh together and flow continuously (K. Kastens pers. comm.) Because of the time and cost to produce these learning aids and the need to sacrifice valuable class time to appropriately explain and comprehend them, great care must be taken to assure learning occurs. Research into how students view and learn from animations, if they learn at all, is a growing field of scholarship (e.g. http://serc.carleton.edu/files/research_on_learning/ROL0304_2004.pdf), and contributions from the geosciences should be beneficial to this effort.

Bearing in mind these few principles, visuals for teaching can be developed to clearly communicate a message and assure that it is accurately perceived and quickly comprehended. These visuals can then be used in a variety of teaching exercises to strengthen visual literacy. Suggestions for using visuals are found in the figure captions and include such tasks as compare and contrast, sketch and label, interpret, generate hypotheses, and predict behavior of systems. (Additional exercises can be found at

**Figure 6** Visualizations displaying regions of heating and cooling located 0.5 km above a pluton through time. (A) Diagrams are constructed by extracting an x-y slice from a 3D volume at \(z'\) for specific time intervals (\(t_1, \ldots, t_n\)), stacking planes with time increasing vertically, and coloring the volume with isosurfaces to highlight regions of heating and cooling. (B-D) Variations in the diagrams developed by this method result from using different permeability and geothermal gradient parameters in the calculations. While these visualizations are excellent analysis graphics, they fail the apprehension principle for effective communication because of their unfamiliar form.
Maximize Ink Used for Data

To draw attention to the relevant purpose and to help “see” meaning, ink in graphics should be devoted to display of data or “that portion of the non-erasable essence of a graphic” (Tufte 1983; cf. Chabris and Kosslyn 2005). An X-ray powder diffraction pattern and the many spectra of, for example, counts versus energy use most ink to convey data (“data ink”). In turn, ink without information (“chartjunk” of Tufte 1983) causes visual clutter (cf. Figs. 7A, 7B). Commonly, this occurs when analysis graphics are used (inappropriately) for presentation. Chartjunk has proliferated as computer drafting allows the developer to easily add “fill patterns.” Too often, these are constructed from parallel black lines that activate the intervening white space resulting in vibration and movement that makes the visual difficult to observe (Tufte 1990). As Tufte highlights, this is a useful attribute for artists (www.haring.com) but detrimental for scientific communication. Removing visual clutter focuses attention on the relevant data, minimizes translation and interpretation time, and produces a more informative diagram (Fig. 7B).

Maximize Data Density

It follows that space in graphics is best used for the display of data (Fig. 8). Maximizing the amount of data over the area covered by the graphic also maximizes information transfer. The discipline of geology creates some of the most data-dense images, such as topographic maps, digital elevation models (DEMs), and overlays of geologic maps onto digital elevation models (Fig. 8). These representations allow unprecedented amounts of data to be communicated within a single eye span.

Color

Color can be a powerful tool in visual communication. Whether using color to attract and maintain the viewer’s attention, to enliven and motivate, or to differentiate data elements, deliberate and careful use of color is essential. Colors of nature rather than saturated color schemes reduce tension and minimize graphical puzzles (e.g. Tufte 1990; Light and Bartlein 2004). A superb use of color is found in the topographic map (Tufte 1983), where color differentiates the underlying substrate of glaciers (white), rivers (blue), forested areas (green), and rocky areas (brown). These colors also imitate reality (coherence principle) and improve the aesthetic qualities, while dark contour lines add a further dimension by providing altitude and steepness (e.g. Tufte 1983). Such clarity improves visual messaging, and the use of multiple methods to convey the same information allows different audiences to be reached.

Maximize Data Density

Placing saturated colors from opposite ends of the visible spectrum near one another (or on one another), such as saturated red next to blue, results in a fuzzy, blurry image because our eyes cannot focus on these widely different wavelengths at once. About 15% of the population has deficiencies in color recognition, and critical data should not be encoded in green and red (http://vis.sdsc.edu).

Explain the Data, Add Annotations

Because we manipulate data into forms that are familiar or functional in an attempt to understand the heterogeneous, open, and complex world around us, a clear understanding of the graphical input is necessary to establish limits of certainty and credibility. This is extremely important for computational models of complex systems, i.e. explain the boundary conditions, simplifying assumptions, limitations, etc. (e.g. Figs. 4, 6).

http://serc.carleton.edu/NAGTWorkshops/visualization). While we readily provide instruction about the use of a graphic (e.g. tracing a reaction path on a phase diagram), spending time to teach what makes an effective graphic to communicate the requisite information helps students to improve their visual literacy and to prepare their presentation graphics. This procedure can be incorporated into each class as new diagrams are introduced.

CREATING VISUALS FOR EFFECTIVE COMMUNICATION: PRACTICAL ASPECTS

By embracing a few easy suggestions, an instructor can improve the effectiveness of his or her graphical communication. Detailed explanations can be found in, for example, Tufte (1983, 1990, 1997, 2006) and Ware (2004).

Keep Quantitative Data Quantitative

Numerical data, whether derived from a computer simulation or from a laboratory measurement, are key to understanding and communicating MPG processes. As such, the display of quantitative data should remain quantitative by including error bars and scales, grids, dimensional aspects, and reference frames when appropriate (e.g. Tufte 1983). These annotations allow a quicker interpretation and a more complete understanding of the image (e.g. Figs. 4, 5). Every field geologist takes photographs with a scale specifically to maintain the quantitative aspect of the image.

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Creating eye-catching, message-rich visuals engages students in the exploration and development of visual communication. When visuals inspire, they can tap into positive emotions and improve learning. “The most important visuals in science are the images in our minds” (Barry et al. 2002).

SUMMARY

Visuals are essential for teaching, problem solving, hypothesis testing, and communicating in the MPG disciplines. Teaching non-experts to “see” the visual language of the experts is an essential element of learning and a foundation for visual literacy. By incorporating specific explanations as new visuals are introduced into our courses, visual literacy is attained in parallel with conceptual material. Alternatively, one can specifically design a communications course that encompasses visual literacy (e.g. http://geol.lsu.edu/dutrow/presn). Research on learning from visuals provides a firm foundation for instructors to improve learning and communication through effective visuals (problem sets, visual aids). When we use appropriate annotations, scaffold layers of meaning and interpretation, and incorporate elements and concepts of good design, visual literacy is more easily attained. This challenges us to design appropriate, effective, task-oriented visuals and animations that utilize prior knowledge and impart meaning in appropriate context. In addition, teaching why these visuals communicate efficiently enables students to develop the necessary skills to create their own visuals (e.g. instructors can discuss font size, labels, data density, relevance of ink, etc.). Visual literacy can be an explicitly stated course goal, and activities can be chosen to allow direct assessment. Assignments and exams can include specific questions requiring use of these visuals. In concert with this, instructors can design appropriate interactive learning activities, not simply passive watching, that allow hypothesis testing and discovery, and also inspire inquiry.

ACKNOWLEDGMENTS

I thank Dave Mogk for inviting me to contribute to this issue and for his insightful and motivating suggestions. Collaborative research with C. Gable on computational heat and mass transport (funded by DOE EPSCoR/BES grant DE-FG02-03ER46041) inspired my quest into visual communication. I extend my appreciation to the other contributors of this issue, to K. Kastens, D. Henry, Eric Riggs, and M. Hochella for thoughtful and helpful reviews; to P. Tremblay for careful editing; and to T. Foster, O. Huh, S. Sorensen, Ren Thompson, S. Schilling, and S. Utsunomiya, who generously provided graphics.

REFERENCES


The 2006 Kimberlite Emplacement Workshop, convened by Roger Mitchell and Barbara Scott Smith, was held in Saskatoon, Saskatchewan, Canada, from September 7 to 14, 2006. It was sponsored by the 8th International Kimberlite Conference, under the auspices of the International Association of Volcanology and Chemistry of the Earth’s Interior (IAVCEI). There were approximately 40 participants, representing a wide range of disciplines, including kimberlite petrology and volcanology. Major industry representatives covered specialties ranging from exploration to evaluation and mining. For the several young scientists in attendance, the workshop was an amazing opportunity to listen to experienced kimberlite geologists. Two half-day field trips were included, one to study drill cores of volcaniclastic kimberlite from the Fort à la Corne kimberlites, and a second to the De Beers Joint Venture Fort à la Corne field site, located approximately 200 km northeast of Saskatoon. The workshop format allowed many viewpoints to be presented and debated, and although consensus was not reached on all topics, key issues relating to kimberlite geology and emplacement were addressed with a more extensive, well-rounded group of scientists than ever before. Animated discussions were very effective in providing a framework for moving forward. The topics discussed included kimberlite models and economic evaluations, a review of classical kimberlite petrology and emplacement ideas, primary kimberlite magma chemistry, volatiles and transport properties, magmatic and phreatomagmatic eruption processes, and new ideas on emplacement processes from analogue experiments and rock mechanics of kimberlite pipes. Tuffisitic kimberlites, juvenile pyroclasts, and issues associated with volcanological models and terminology for kimberlites were also discussed. Case studies were presented from southern Africa, the Canadian Plains, Canada’s Slave and Superior cratons, Yakutia (Russia), and Brazil.

The discussions identified issues where there is substantial consensus and several that remain contentious. Key issues that emerged were the following:

1. Descriptive nomenclature used in current kimberlite studies needs modification to provide some consistency with volcanological terminology and to avoid making genetic implications at the documentation stage.

2. Further studies are being undertaken on the physical and chemical properties of kimberlitic magmas, particularly on the solubilities of CO2 and H2O in relation to ambient chemistry, and how these solubilities affect the magma’s near-surface behavior.

3. Further studies on the nature and significance of post-emplacement alteration fluids (e.g., deuteric, hydrothermal, meteoric, diagenetic) are crucial to reconstructing emplacement processes.

4. The mechanisms behind the explosive fragmentation of kimberlite magma were discussed extensively, and a consensus was reached that both magmatic and phreatomagmatic processes are possible, and that both may occur within the eruption history of a single pipe. Pipe excavation and emplacement processes are poorly understood, but new experiments and detailed field studies are providing fascinating insights into these issues.

5. Tuffisitic kimberlites emerged as the most contentious topic, with regard to both terminology and the origin of their defining characteristics and features. Experiments related to emplacement processes of these types of massive volcaniclastic kimberlites are being undertaken by the Volcanology and Geological Fluid Dynamics Group based at the University of Bristol and are providing significant new insights.

Significant differences in approach and opinion remain between some groups concerning kimberlite nomenclature and ideas on kimberlite emplacement processes. Moving forward will require improved cooperation and understanding between volcanologists and kimberlite scientists. This will be best achieved by the traditional kimberlite scientists continuing to engage with the volcanological community and volcanologists continuing to gain first-hand experience of kimberlite deposits. A follow-up workshop of similar design has been proposed following the 9th International Kimberlite Conference (9IKC) scheduled for Frankfurt in 2008.

A volume of abstracts has been published, and submission of full manuscripts is scheduled for March 1, 2007, for inclusion in a special publication volume of the Journal of Volcanology and Geothermal Research. Please see the following links for the long abstracts presented at the 2006 Kimberlite Emplacement Workshop and for information on the 9IKC: www.venuewest.com/9IKC/9ikc.htm and www.9ikc.com/.

Margaret Harder
(Mineral Services Canada Inc.), Adrian Pittari (Monash University), Stephen Moss (University of British Columbia), and Thomas Gernon (University of Bristol)
New Editor-in-Chief Sought for Clays and Clay Minerals

Following seven sterling years of service, Derek Bain is to stand down as editor-in-chief of Clays and Clay Minerals, and now, we seek a highly motivated individual to replace him. The successful candidate must have a PhD, have expertise in clay science, have excellent organizational/management skills and have superior communication skills (oral and written). The editor should be even handed, independent minded, and tactful. Editorial experience, the ability to help supervise the online version of Clays and Clay Minerals, and a willingness to develop a strategy for continued growth of the journal leadership are desired. The editor will select and work closely with a board of associate editors whose function will be to assist with the review of manuscripts submitted for publication. The editor will also appoint and supervise a managing editor, who will be responsible for technical aspects of journal copy preparation and other assigned tasks. Development and management of the editorial office budget is also a duty of the editor, in conjunction with the Society treasurer. Reasonable overheads (including the managing editor’s salary) and travel expenses to attend professional society meetings will be reimbursed. This is a three-year renewable appointment with a starting date of January 1, 2008.

Individuals interested in this opportunity are invited to submit a letter of interest that specifically identifies the candidate’s (1) knowledge of clay science, (2) editorial experience, and (3) organizational/management skills. Along with this letter, please send a curriculum vitae, a list of three referees, and a proposed budget for the editorial office to: David Laird, USDA, ARS, National Soil Tilth Laboratory, 2150 Pammel Drive, Ames, Iowa 50011, USA; tel.: 515-294-1581; fax: 515-294-8125; e-mail: Laird@nstl.gov.

Potential candidates are urged to contact David Laird for more information, including a list of duties for the editor-in-chief and a copy of the current budget. Consideration of applications will start March 1, 2007, and will continue until the position is filled.

Electronic Submission and Tracking of Manuscripts

Papers for Clays and Clay Minerals should now be submitted by electronic means. Go to www.clays.org/journal/journal.html and click on the “submit paper” icon. You will first need to become a registered user of the site, but your username and password will be the same for all subsequent submissions. The steps you will need to take are explained on screen, but help is available from the managing editor should you run into difficulty (kmurphy@iol.ie). We look forward to receiving your comments, and your papers.

Forthcoming Papers in Clays and Clay Minerals

Phil G. Slade and Will P. Gates
HDTMA in the interlayers of high-charged Lloano vermiculite

Tarmo Kõlpi, Enli Kõlpi, Toivo Kallaste, Rutt Hints, Peeter Somelar, and Kalle Kirsmae
Altered volcanic ash as an indicator of marine environment reflecting pH and sedimentation rate – example from the Ordovician Kinnekulle Bed of Baltoscandia

Daniel Tunega, Bernard A. Goodman, Georg Haberhauer, Thomas G. Reichenauer, Martin H. Gerzabek, and Hans Lischka
Ab initio calculations of relative stabilities of different structural arrangements in dioctahedral phyllosilicates

Brian J. Teppen and Vaneet Aggarwal
Thermodynamics of organic cation exchange selectivity in smectites

T. Grygar, D. Hradil, P. Bezdekka, B. Doulová, L. Capek, and O. Schneeweiss
Fe(II)-modified montmorillonite and bentonite: synthesis, chemical and UV-Vis spectral characterization, As sorption, and catalysis of oxidative dehydrogenation of propane

Jennifer E. Kyle and Paul A. Schroeder
Role of smectite in siliceous sinter formation and microbial texture preservation: Octopus Spring, Yellowstone National Park, Wyoming, USA

Mikhail Y. Gelfer, Christian Burger, Pranav Nawani, Benjamin S. Hsiao, Benjamin Chu, Mayu Si, Miriam Rafailovich, Grazyna Panek, Gunnar Jeschke, Alexander Y. Fadeev, and Jeffrey W. Gilman
Lamellar nanostructure in Somasibased organoclay

Steven M. Kuznicki, Christopher C.H. Lin, Junjie Bian, and Alejandro Anson
Chemical upgrading of Bowie, Arizona, sedimentary sodium chabazite

Sven Sinderén, Helge Stanjek, Christoph Hilgers, and Yvonne Etoundi
Short-term hydrothermal effects on the ‘crystallinités’ of illite and chlorite in the footwall of the Aachen-Faille du Midi thrust fault – first results of the RWTH-1 drilling project
Clay Mineralogy: AN INTRODUCTORY COURSE

This is the first in a new multimedia series of educational materials to be sponsored by The Clay Minerals Society. The CD contains material used to support a graduate-level course on clay minerals taught by Professor Ray Ferrell at Louisiana State University. The content is presented in six modules that cover basic mineralogy and classification, geologic origin, aqueous solubility and ion exchange, waste isolation and fluid flow, and X-ray powder diffraction methods for the identification and quantification of clay mineral assemblages. The general objectives of this presentation are to foster a greater understanding of clay mineral reactions in the environment and the processes controlling their geologic distribution and industrial utilization. It produces an increased awareness of the relationship between structural/chemical characteristics of the diverse clay minerals present in rocks, soils, and sediments and their physical and chemical properties.

“Every now and then, something comes along that is both great value and extremely useful. ‘Clay Mineralogy: An Introductory Course’ falls into that category.” – Clays and Clay Minerals

The CD is available at $10 per copy (add $10 for mailing outside of the US and Canada). Send your order (with check or credit card authorization, including card verification number) to The Clay Minerals Society, 3635 Concorde Pkwy Ste 500, Chantilly, VA 20151-1125, USA. Tel.: (703) 652-9960; fax: (703) 652-9951; e-mail: cms@clays.org.

Workshop Lecture Series Volumes The Clay Minerals Society


$26 ($21)


$18 ($13)


$23 ($18)


$23 ($18)


$20 ($15)


$26 ($21)


$23 ($18)


$23 ($18)


$26 ($21)


$26 ($21)


$26 ($21)


$26 ($21)

A New Morphology for Deep Marine Resources

Professor Garrison Sposito, of the University of California at Berkeley, has investigated a new morphology for methane hydrate crystallization by computational modeling of clay minerals. Methane hydrates are a major potential natural gas resource, but they are primarily found in very low-temperature, high-pressure environments in deep marine sediments. They usually form either as pore-fillings within granular sediments or as coatings on grain boundaries. New Monte Carlo and molecular dynamics simulations have been used to investigate methane hydrate crystallization and stabilization within the interlayers of hydrated Na-montmorillonite, a 2:1 clay mineral observed in oceanic sediments with naturally occurring hydrates. Interlayer methane hydrate model structures are predicted to occur at pressures from 10 to 30 atmospheres and at temperatures up to 300 K. The hydrate can exist in a three-layer structure with Na-montmorillonite containing 0.5, 1.0 or 2.25 CH₄ per clay mineral unit cell. The modeling strongly suggests that only the 0.5 CH₄/clay mineral unit-cell geometry is stable. The molecular dynamics simulations suggest that the mechanism for stabilizing the hydrate is a repulsive “guest-host” interaction.

Nanotech Tools Made from Clay

A Rochester, N.Y.-based company has found a way to use halloysite as an unobtrusive carrier in metals, perfumes and other substances. NaturalNano says that by filling halloysite tubes with copper and then mixing the tubes into a polymer, a manufacturer could make an electrically conductive plastic. If filled with fungicides, the halloysite particles could be swirled into paint to make it more resistant to mildew and mold. Time-released coatings could also be added to make all-day deodorant. There are also potential agricultural uses—spreading pesticides from the halloysite nanotubes could potentially reduce the amount sprayed on agricultural land by up 70 or 80%—and even medical uses, where the tubes could be used for drug delivery in humans. Naturally occurring halloysite tubes are much cheaper than synthetic equivalents, e.g. carbon nanotubes which cost up to $250 a gram and are made in furnaces in labs. Halloysite mined and purified by NaturalNano retails at $3.50–$20.00 per pound, depending on function and complexity.

44th Annual Meeting “Enchanted Clays” 2–7 June 2007 Santa Fe, New Mexico

The 44th annual meeting of The Clay Minerals Society will be held in early June 2007, in beautiful and historic Santa Fe, New Mexico, USA. Santa Fe provides an idyllic location in the southwestern United States for attendees to enjoy technical and social sessions while soaking up the diverse culture and wonderful climate of New Mexico – The Land of Enchantment. We encourage you to attend, share knowledge and ideas, benefit from technical interactions, and relax in the wonderful historic and enchanted environs of Santa Fe.

The meeting includes two and a half days of technical sessions and symposia, with oral sessions scheduled all day Monday, Tuesday morning, and all day Wednesday. Poster presentations are scheduled for Monday afternoon and Tuesday early evening. The following technical sessions and symposia are planned:

- Carbon Sequestration • Carbon Stabilization by Clays • Characterizing Clay Minerals • Clays in Soils and Sediments • Clays and Environmental Processes • Clays and Archeology • Clays and their Role in Protolife • Clays as Nanomaterials • Clays in Extreme Environments • Clays in Oil Shale • Molecular Simulation of Clays • Zeolites

Go to www.sandia.gov/clay/ for more information. The meeting registration deadline is 3 April 2007.
Mineralogical Society of America

PRESIDENT’S LETTER

Educational Resources at MSA

The health and vitality of our discipline and our organization rely on educating future generations of mineralogists, petrologists, and geochemists. However, as our mineralogy and petrology courses are continually squeezed in the curriculum, it is ever more pressing to reach out to our colleagues and connect our discipline with theirs. In addition, highlighting our discipline’s importance in everyday life helps students understand its broader relevance. It is critical to train our students not only for a future in academics but also for occupations in which routine decision making requires understanding science and how the Earth works.

The Mineralogical Society of America has numerous educational resources available that span all levels. These are easily accessed via our website at www.minsocam.org under the main heading “Education and Outreach.” “Mineralogy for Kids” is the most visited portion of our website, with 2.3 million requests last year. The popular “Collector’s Corner” (1.5 million requests) contains a wealth of information ranging from mineral and rock identification to virtual field trips. “Ask-a-Mineralogist” provides answers to questions posed by the public (0.3 million requests). Our Society’s journal, American Mineralogist, received 1.5 million requests and is used by undergraduates as well as professionals. One-page mineral descriptions of silicate minerals taken from volume II, Silicates, of the Handbook of Mineralogy, are available online. Topical issues of Elements can be accessed via the MSA site and bound copies can be purchased for use in classes. For those interested in pegmatites, PIG (Pegmatite Interest Group) has stunning images of pegmatitic minerals posted together with short descriptions of pegmatites and their localities.

Links to other educational resources include the “American Mineralogist Crystal Structure Database,” with its wealth of content and visualization capabilities. Perhaps the best-known item in our educational arsenal, the Reviews in Mineralogy & Geochemistry series serves primarily graduate students, offering an extensive resource base accessible at a click, linking you to mineralogy and petrology databases, dictionaries, mineral-specific sites, and other mineral and rock topics.

Generous volunteers oversee many aspects of our educational resources, which are maintained financially through the outreach fund. If you would like to contribute your resources and ideas, please contact our outreach coordinator, Dr. John Rakovan, or Dr. David von Bargen, who oversees the Collector’s Corner. Together, we can make a difference.

Barb Dutrow
2007 MSA President

NOTES FROM CHANTILLY

- MSA will again use electronic balloting for the 2007 election of MSA officers and councilors. The candidates are Peter Heaney for president; Nancy Ross and Jeffrey Post for vice president; Mickey Gunter and Phil Brown for secretary; and Bruce Marsh, Carol Frost, Lee Groat, and Peter Burns for the two councilor positions.

- MSA members will receive voting instructions at their current e-mail addresses in May. Make sure MSA has your most recent e-mail address! Those who do not wish to vote online can request a paper ballot from the MSA business office. As always, the voting deadline is August 1. The individuals elected to office decide on the direction of the Society. Voting is an important responsibility for all MSA members.

- While no one wishes to receive yet more electronic mail, if you or your institution has a rather aggressive spam-blocker and you have not been getting the few announcements from MSA about new issues of American Mineralogist online, voting, your renewal, or confirmation of your online orders, you may wish to see about allowing such messages to reach you. Otherwise, you will need to watch for such information on the MSA website.

AMERICAN MINERALOGIST UNDERGRADUATE AWARDS FOR OUTSTANDING STUDENTS

The Society welcomes the exceptional students listed below to the program’s honor roll and wishes to thank the sponsors for enabling the Mineralogical Society of America to recognize them. MSA’s American Mineralogist Undergraduate (AMU) Awards are given to students who have shown an outstanding interest and ability in mineralogy, petrology, crystallography, or geochemistry. Each student is presented a certificate at an awards ceremony at his or her university or college and receives an MSA student membership, as well as a volume in the Reviews in Mineralogy & Geochemistry or Monograph series chosen by the sponsor, student, or both.

Past AMU awardees are listed on the MSA website, where instructions on how and when MSA members can nominate their students for the award are also available.

Nicholas Groves, Texas A & M University, sponsored by Dr. Robert K. Popp
Benjamin C. Herrmann, Oklahoma State University, sponsored by Dr. Elizabeth Catlos
Jason Huberty, University of Wisconsin–Madison, sponsored by Dr. Huifang Xu
Charlotte King, University of Otago, sponsored by Dr. J. Paln

IN MEMORIAM

Arthur F. Hagner (Life Fellow – 1936)
Vernon James Hurst (Senior Member – 1955)
Alfred A. Levinson (Life Fellow – 1959)
Leonard A. Morgan (Life Fellow – 1930)
Louis Moyd (Life Fellow – 1939)
Edwin W. Roedder (Life Fellow – 1939)
J.-P. G. Saeueus (Life Member – 1967)

Amy Lasseigne, Louisiana State University, sponsored by Dr. Barb Dutrow
Angelica Lange, Mount Holyoke College, sponsored by Dr. Steven R. Dunn
Amy Elizabeth Nixon, University of Calgary, sponsored by Dr. David Pattison
Andrew L. Masterson, University of Maryland, sponsored by Dr. Michael Brown
Noriyuki Masuda, Oklahoma State University, sponsored by Dr. Elizabeth Catlos
Joanna R. Morabito, Lafayette College, sponsored by Dr. Guy Hovis
Andrew Vincent Mott, Lafayette College, sponsored by Dr. Guy Hovis
Samuel E. Tuttle, Williams College, sponsored by Prof. Reinhard Wobus
Michelle L. Tebbe, Central Washington University, sponsored by Dr. Paul Hoskin
A short course on neutron scattering in the Earth sciences was convened by Rudy Wenk (University of California at Berkeley) and Nancy Ross (Virginia Tech) on December 7 and 8, 2006, in Emeryville, California. It attracted 65 participants, including 16 students. Generous support from the DOE-BES, as well as from COMPRES, LANSE, and SNS made it possible to keep registration costs at a minimum, particularly for students.

Lectures given by a group of international experts covered a wide range of topics, from diffraction to inelastic scattering. During the two-day course, background and classical applications of neutron scattering as well as new opportunities were reviewed. With intense and focused beams at time-of-flight (TOF) sources as well as reactors, the kinetics of reactions can be studied in situ. Structures and phase transformations in clathrates and other gas hydrates are new and exciting fields of study in mineralogy. Possibilities for high-pressure experiments at the future SNAP beamline of the Spallation Neutron Source raised much interest. Outstanding progress has been made in the use of inelastic and small-angle neutron scattering at TOF sources to capture details of clays and poorly crystalline materials such as liquids, melts, glasses, and interfaces. This will surely become an important field for future applications where neutrons have unique advantages. The low absorption of neutrons makes them an ideal tool to study properties of bulk materials, including internal stresses and textures, and to apply radiography to investigate grain structures and fracture patterns.

A volume covering the various topics (#63 in the Reviews in Mineralogy & Geochemistry series) was distributed at the meeting and will no doubt become a useful introduction to neutron scattering for mineralogists and materials scientists. If the response from participants is any indication, the short course will hopefully stimulate new neutron users in the Earth sciences, particularly as new facilities become available worldwide.

Rudy Wenk
University of California at Berkeley

The following individuals will reach 50 or 25 years of continuous membership in the Mineralogical Society of America during 2007. Their long support of the Society is appreciated and is recognized in this list and by the awarding of 25- and 50-year pins, mailed in early January. If you should be on this list and are not, or if you have not received your pin, please contact the MSA business office.

50-Year Members
Mr. John L. Baum
Dr. Jan Bernard
Mr. Forrest Cureton II
Dr. H. Roberta Dixon
Prof. Fredrik Paul Glasser
Dr. Edward J. Olsen
Mr. Richard W. Thomassen

25-Year Members
Dr. J. Lawford Anderson
Prof. Ross John Angel
Dr. Thomas Arnbuster
Prof. Gilberto Artioli
Dr. Michael B. Baker
Dr. Gray E. Bebout
Prof. Achille Blasi
Prof. Michael R. Carroll
Prof. John D. Clemens
Dr. Tamara Dickinson

Dr. Rona J. Donahoe
Dr. Melinda Darby Dyar
Mr. David C. Elbert
Mr. James A. Ferraiolo
Dr. Jeffrey A. Foley
Dr. Miguel Angel Galliski
Dr. Juergen Glinnemann
Mr. Robert E. Goddard Sr.
Dr. L. Peter Gromet
Dr. Donald D. Hickmott
Dr. Thomas D. Hoisch
Dr. Lindsey Keller
Dr. William M. Lamb
Dr. Kenneth J.T. Livi
Mr. Aubrey L. Long
Mr. Michael E. Madison
Prof. Emil Makovicky
Dr. Diane E. Moore
Dr. H. Richard Naslund
Dr. Roberto T. Pabalan
Prof. Andrew Putnis
Mrs. Daphne R. Ross
Prof. Roberta L. Rudnick
Dr. Martha W. Schaefer
Dr. Prof. Hartmut Schneider
Prof. Jane Seltzer
Dr. Hiroshi Shimizu
Dr. Shu-Chun Su
Dr. Takao Tanosaki
Dr. Reidar G. Tronnes
Mr. Arnold Van Herreweghe
Dr. Yasuhiro Wakiyama
Dr. Hirohsia Yamada
Prof. Atsushi Yamazaki

The Mineralogical Society of America is again offering a program for the 2007–2008 academic year with the arrangement that the MSA will pay travel expenses of the lecturers, and the host institutions will be responsible for local expenses, including accommodation and meals. The program will include three lecturers, one of whom resides in Europe. Depending on the response, one or more lecture tours will be arranged outside North America.

Names of the 2007–2008 distinguished lecturers and their lecture titles are not yet available, but they will be posted soon on the MSA website. If your institution is interested in requesting the visit of an MSA distinguished lecturer, check the website for lecturers and titles and e-mail your request to the lecture program administrator: Dr. Cameron Davidson, Carleton College, Dept of Geology, 1 N College St, Northfield, MN 55057-0001, USA; e-mail: cdavidso@carleton.edu; tel.: (507) 646-7144; fax: (507) 646-4400. The Lecture Program is designed to run from September 2007 through April 2008. Lecturer requests received by May 12, 2007, will be given priority. Late applications will be considered on a space-available basis.

In making your request please include (1) airport proximity from, and travel time to, your institution; (2) the name of a contact person at your institution for the months of May and June (when schedules will be assembled); (3) contact e-mail addresses and phone numbers; and (4) flexibility on lecturer preference. Schools outside the United States should indicate starting and ending dates of academic terms. Because of travel and schedule constraints it is normally not possible to satisfy requests for tightly constrained dates such as seminar days.
NEWS FROM LONDON

New MinSoc Offices

By the time you receive this, the Society should be firmly ensconced in its new offices in Twickenham. The address of the Society for all correspondence is now Mineralogical Society, 12 Baylis Mews, Amyand Park Road, Twickenham, Middlesex TW1 3HQ; tel. +44 (0)20 8891 6600 and fax +44 (0)8891 6599. We will continue to have mail re-directed from 41 Queen’s Gate for six months, but after that we will only be reached using the new address. Our e-mail addresses of course remain the same, with general enquiries handled at info@minersoc.org. We are always happy to see members at the office (coffee is provided free), so come and visit our new premises if you are in the area, and even better save yourself the cost of postage on some of our publications by collecting them personally! A location map of the new offices can be found on the website www.minersoc.org.


As of press time, registration is now officially closed for this joint meeting of the Mineralogical Society, the Mineralogical Society of America, the Mineralogical Association of Canada and the Société Française de Minéralogie et de Cristallographie, but the local organizing committee is looking into ways to accommodate more registrants. So if you were interested in attending, please contact Michael Carpenter (mc43@esc.cam.ac.uk). For the more than 350 registrants, a preliminary programme has now been posted on the Society website. Full details on how to get to Cambridge and the location of the conference venue are available on the conference website. Enjoy the delights of an evening banquet in Magdalene College fellows’ garden on the banks of the river Cam, an evening punting, or sample one of the excellent restaurants in this ancient city. During the days at the conference, you will be able to catch up on all the recent developments and research advances in the mineral sciences.

Adrian Lloyd-Lawrence

WINNERS OF THE 2007 SOCIETY MEDALS

The Schlumberger Medal 2007 to Roger Powell

Roger Powell of the University of Melbourne has greatly advanced our understanding of the conditions of metamorphic rocks through his work on mineral equilibria. Even more significantly he has designed and produced computational tools that allow metamorphic petrologists worldwide to investigate mineral assemblages quantitatively. Some of this work was carried out in collaboration with Tim Holland of Cambridge University (Schlumberger medallist 2001). This pioneering work has developed into a veritable petrological industry, permeating through the academic community at all levels. It has resulted in a thermodynamic database and computer program THERMOCALC, which ranks amongst the most used resources in geoscience, let alone petrology. During his career Professor Powell has published over 150 papers and in 2004 was named the ISI Citation Laureate as the most highly cited author in the geosciences in Australia. He is an editor of the Journal of Metamorphic Geology.

The Max Hey Medal 2007 to Michele Warren

Michele Warren graduated with a first-class-honours degree in physics from Cambridge University and a PhD in condensed matter physics from the University of Edinburgh, all achieved by the age of 23. Following a period of post-doctoral work at Cambridge on cation ordering in silicate minerals (pyroxenes, amphiboles and micas), Michele moved to the University of Manchester and is now a lecturer in the Department of Earth Sciences where she works with Professor David Vaughan. There her interests diversified to comprise computer modelling techniques in the study of the structure and reactivity of mineral surfaces, including interactions with biomolecules and microbes. Michele is the author of 29 original research papers published over the past 10 years in highly cited international journals. Through these publications Michele has made important contributions to our fundamental understanding of the stability and elastic properties of a range of minerals.

TO BE PUBLISHED SOON by The Mineralogical Society

Landmark Papers on Structural Topology

selected by

F.C. Hawthorne

Series Editor: B.J. Wood
At the end of this year, Prof. Ben Harte will retire as president of the Society, and Dr Neil Fortey will retire as treasurer after six sterling years. Nominations are now being sought to fill these vacancies and two vacancies for ordinary members of Council upon the retirement of Prof. P.W. Scott and Dr A.C. Kerr at the end of the year. Nomination forms can be found at www.minersoc.org. Nominations must be endorsed by four fellows or members of the Society, and nominees must be fellows or members of the Society. Nominations should be sent to the new Society office at 12 Baylis Mews, Amyand Park Road, Twickenham, Middlesex TW1 3HQ to arrive by 31 May 2007 for consideration by Council at their meeting on 14 June 2007.

**TRAINING WORKSHOPS FOR MINERAL SCIENTISTS**

Over the last three years, the Mineralogical Society has combined with the Natural History Museum, London, to run a series of four-day training courses in electron probe microanalysis (EPMA). A maximum of six participants are enrolled in each course, ensuring that no more than three are on one of the microprobes at any one time. The course combines a series of lectures and practicals covering the theory and practice of EPMA including beam–sample interactions, energy-dispersive versus wavelength-dispersive analysis, and data presentation. Two variable-pressure analytical SEMs and two wavelength-dispersive microprobes are available for the course, and with three course tutors, a wide range of practical exercises are possible.

The course is aimed primarily at PhD students who use electron microprobe techniques in their research studies, but the course has also attracted technical and academic staff from universities and research organisations, and from industry. To date, participants from 11 countries have attended the course, mainly from Europe but including South Africa and Thailand.

Some 50 years after the first commercial instrument, electron probe microanalysis is still widely used in mineralogical studies in both academia and industry. However, understanding of the theory behind the technique and knowledge of its many applications in Earth and environmental sciences have increasingly been squeezed out of undergraduate course work. The Mineralogical Society aims to run a series of instrument-based courses to provide users with the relevant theoretical and practical perspectives necessary to utilize a range of techniques currently available in mineralogy. The EPMA course is the first in this series.

Terry Williams
The Geochemical Society
www.geochemsoc.org

SOCIETY NEWS

Are You a Student Going to the Cologne Goldschmidt Conference?
The Geochemical Society provides at least US$10,000 of support annually to deserving international students attending the annual Goldschmidt Conference.

For details and application requirements, visit www.geochemsoc.org/announce/2007goldtravel.html.

Welcome, Drs. Fogel and Krishnaswami!
Dr. Marilyn Fogel and Dr. Seth Krishnaswami are the newest members of the GS board of directors. Brief biographies and photos are provided in the sidebar. For a full list of 2007 committee officers visit www.geochemsoc.org/aboutgs/personnel.html.

Thank You for your Contributions!
Thank you to the members who donated to the Geochemical Society in 2006. Although we have always accepted donations, 2006 marked the first year we were proactive. Your response was well received, as we raised nearly US$1700 from 42 members. For 2007, we have added the option to contribute online, either with your membership renewal or simply as a donation. If you would like to make a donation to the Geochemical Society, please visit our website at www.geochemsoc.org.

Contributions received between January 1, 2006 and December 31, 2006:

Prof. Robert C. Aller
Mr. Aria Amirbhman
Prof. John Ayers
Dr. Harald Biester
Mr. Martin M. Cassidy
Dr. Thure E. Cerling
Dr. William S. Cordua
Dr. Ghislaine Crozaz
Dr. Henry Dick
Dr. Geoffrey P. Glasby
Dr. Robert T. Gregory
Dr. Gudmundur Gudfinnsson
Dr. Jan Hertogen
Prof. Bor-ming Jahn
Dr. Blair F. Jones
Dr. Adam J.R. Kent
Dr. Yousif K. Kharaka
Prof. Yehoshua Kolodny
Dr. Rama K. Kotra
Dr. Thomas Krogh
Dr. Kenneth M. Krupka
Mr. Mark J. Logsdon
Barbara J. MacGregor
Jura Majažan
Prof. Edmond A Mathez
Prof. Alan Matthews
Prof. William McDonough
Prof. Valeria Murgulov
Dr. Klaus Neumann
Dr. Paul Northrup
Dr. Lindsay P. Oberem
Prof. Peggy A. O’Day
Dr. Radomir Petrovich
Dr. Erik Sherer
Dr. Nobumichi Shimizu
Dr. E. Craig Simmons
Dr. Brian J. Skinner
Dr. Wolfgang Sturhahn
Dr. Lawrence A. Taylor
Dr. Fangzheni Teng
Dr. George R. Tilton
Dr. Yumiko Watanabe

Seth Davis
GS Business Manager

Marilyn Fogel has been a staff scientist at the Carnegie Institution’s Geophysical Laboratory since 1979. Her undergraduate, graduate, and postgraduate research has spanned the spectrum of biology, chemistry, and geology. She graduated with honors with a BS in biology from Pennsylvania State University and went on to get her PhD at the University of Texas Marine Science Institute. Fogel’s current research projects include the following themes: astrobiology: distinguishing biotic from abiotic signatures; paleoclimate of Australia; isotopic composition of nitrate as a tracer of denitriﬁcation; paleoecology of mangrove peat islands in Belize; AMASE: Arctic Mars Analogue Svalbard Expedition; and isotopic studies of organic matter in meteorites. Recent awards and honors include a Senior Specialist Fulbright Award in 2006 (University of Oslo, Physics of Geological Processes), appointment as a GS/EAG Fellow in 2003, and Mellon and Loeb Fellowships from 1999 to 2003.

Seth Krishnaswami graduated in chemistry from the University of Kerala, India (1960). After a year of training at the Atomic Energy Training School, he joined the Tata Institute of Fundamental Research (TIFR), Bombay (1964) and obtained a PhD (1974) from Bombay University. Krishnaswami moved to the Physical Research Laboratory, Ahmedabad, in 1973, where he is currently a visiting professor. Krishnaswami is a fellow of all three scientiﬁc academies in India, the Third World Academy of Sciences, AGU, and the Geochemical Society – European Association for Geochemistry. He received the S.S. Bhatnagar Prize (Earth Sciences, 1984) from the Council of Scientiﬁc and Industrial Research, India. Krishnaswami has served in a number of national and international scientiﬁc committees, including as an ofﬁcer in the IGBP-SC, the Scientiﬁc Committee on Oceanic Research (SCOR). Currently Krishnaswami is a member of the editorial boards of Geochimica et Cosmochimica Acta, the Geochemical Journal, and the Journal of Earth System Science. Krishnaswami’s research interests include the application of natural radionuclides and radiogenic isotopes in the ﬁeld of low-temperature geochemical processes. He has also made signiﬁcant contributions to the understanding of marine and lacustrine ferromanganese nodules. His current focus is chemical weathering in the river basins of the Himalaya and the Deccan traps.

GEOCHEMISTRY AT THE SPRING AGU

Listed below are sessions sponsored and cosponsored by the Geochemical Society at the upcoming AGU Joint Assembly (Acapulco, Mexico, May 22–25, 2007).

Sessions Sponsored by the Geochemical Society

(GS01) Geochemical Society general contributions
(GS02) Coastal Lagoons Geochemistry and Pollution
(GS03) Petrography, Microstructure, Textures, and Reactivity of Swelling Clays
(GS04) The Role of Radios isotopes in Geologic Environments
(GS05) Fluid Geochemistry (associated with fluid–rock interactions, gas clathrate CO2 sequestration, and fluid inclusions)
(GS06) Uranium in the Environment

Sessions Cosponsored by the Geochemical Society

(U18) Global Geodynamics: Core, Mantle, and Crust
(H38) Natural Contaminants in Groundwater Resources: Occurrence, Geochemistry, Health, and Remediation

(W11) Establishing the Scientific Basis for Reliable Predictions of the Geochemical and Hydrologic Consequences of Mining Projects
(P04) East Paciﬁc Tropical Cyclones: Past, Present, and Future (Cyclones Tropicales del Paciﬁco Este: Pasado, Presente y Futuro)
(T06) Mexican and Central American Subduction Zones: Bringing Together Seismology, Petrology, Geology, Tectonics, and Geodynamics
(V03) The Origin, Evolution, and Tectonic Signiﬁcance of Coeval Magmas of Differing Parentage
(V08) Diversity of the Subarctic Mantle – Insights from Studies of Peridotite Xenoliths, Ophiolites and Metamorphic Rocks from Subduction Zones
(V11) Deep Subduction Zone Metamorphism and Rheology: Role of Fluids
(V18) High-Mg Andesites, Slab Melts, and Wedge Melts – Signiﬁcance for Crustal Genesis
(V21) Volcanoes, Plutons, and Ore Deposits: What’s the Connection?

See www.agu.org/meetings/ja07 for more information.
The 17th annual V.M. Goldschmidt Conference will take place August 19–24, 2007, on the campus of the University of Cologne in Germany. The local organizing committee invites you to come and discover the unique blend of geology and culture that Cologne has to offer. The conference will be located in the heart of Europe, and the organizing committee has striven to keep costs low (310 for members and 200 for students), in order to attract students and younger scientists to this major crossroad of transport, culture and, we hope, geochemistry.

### Program

The organizing committee and the international program committee have been working on making the scientific content of the meeting the most exciting yet. Sixteen broad themes have been selected covering the full range of geochemical research, from the formation of the solar system to environmental research, and from biogeochemistry to mineralogy. Details of these themes and registration information are given on the Goldschmidt 2007 website www.goldschmidt2007.org.

The conference will begin late afternoon on Sunday with registration and an icebreaker in the mensa building. Scientific sessions will start at 8:30 a.m. on each of the following days. A plenary lecture each day will track the origin and evolution of the Earth, commencing at its dusty beginning on Monday and concluding with the appearance of life on Friday. Late mornings and early afternoons will be devoted to symposia in some 14 lecture halls. Poster sessions will be held in the late afternoon of Monday, Tuesday and Thursday. An area of 1200 square meters on the second floor of the mensa building will be reserved for posters, with beer from Cologne (Kölsch) on hand to facilitate the free flow of ideas. Wednesday afternoon will be free for visiting the city and for short excursions in the surrounding area, e.g. visits to Bonn or the Neanderthal Museum near Düsseldorf. The conference dinner will be served in the Güterzenich, the traditional ballroom and reception hall of the City Council (dating from 1444), which was restored after the war and renovated in 1996–1998. Award ceremonies of the sponsoring societies will be held before the dinner. The two Crafoord Prize winners in Earth sciences from 1986, C. J. Alègre and G. J. Wasserburg, have promised to come to the meeting and address the audience. The conference will end Friday afternoon with a farewell party. Details of the program are available on the conference website (www.goldschmidt2007.org).

We look forward to seeing you all in Cologne.

H. Palme, S. Chakraborty, P. Kegler, A. Hofmann, C. Münker

### Dates

Please do not forget the key dates for the meeting:

**April 19**
abstract submission deadline

**1 June**
end of early registration

**1 August**
end of pre-registration

**19–24 August**
Goldschmidt 2007

### Field Trips

- A one-day trip to the 13 ka Laacher See volcano and the Quaternary East Eifel volcanic field
- A one-day trip to the West Eifel volcanic field
- A one-day hike to see the Tertiary Siebengebirge explosive, subaqueous volcanic eruptions, syn-volcanic intrusions, and medieval castles
- A three-day trip to the impact structure at Nördlinger Ries, southern Germany
- A five-day trip to examine a crustal cross-section in the Ivera Zone, northern Italy
- A ten-day trip to Santorini and Crete (Greece) on the themes of Quaternary arc volcanism and Tertiary high-P–T metamorphism in the South Aegean

Details are posted on the website www.goldschmidt2007.org
European Association for Geochemistry

EAG NEWS AND ANNOUNCEMENTS

EAG Website
The EAG website has been and continues to be a great success since its relaunching last fall, with the site receiving over 1000 “hits” per month. The site continues to be upgraded and revised each month, providing the latest geochemical news, EAG developments, updates on conferences, and useful links. We invite everyone to visit and contribute to our website: www.eag.eu.com.

EAG Seeks New Committee Members
As part of the revised EAG bylaws, several new committees have been formed, including the EAG Communications Committee, the EAG Program Committee, and the EAG Publication Committee. Several positions are still available in these committees. We invite motivated geochemists to volunteer to serve on these committees to help promote geochemistry through the EAG. Further information can be found on the EAG website: www.eag.eu.com. To volunteer to serve, please send an e-mail to eag@lmtg.obs-mip.fr.

Gearing Up for the 2007 Goldschmidt Meeting
The 17th annual Goldschmidt Conference will be held in August 2007 at the University of Cologne in Germany. It will be held in conjunction with the annual meeting of the German Mineralogical Society. This will be the second German Goldschmidt Conference, after the 1996 meeting in Heidelberg. See previous page for more details.

EUROPEAN GEOCHEMICAL NEWS

European Union Funding Opportunities
The long-awaited Framework 7 Programme of the European Commission was published in December 2006 and includes vast new funding opportunities for European and international researchers. Below are abbreviated descriptions of current opportunities for individuals and groups in a number of different programmes.

Marie Curie Actions “People” Programme
The “People” programme is entirely dedicated to human resources in research and has an overall budget of more than 4.7 billion over the next seven years. The main strategic objective is to make Europe more attractive to the best researchers. Resources are available to encourage young researchers and support the early stages of scientific careers, as well as to reduce the “brain drain” from Europe.

This programme includes funding for Marie Curie Initial Training Networks, a programme funding a network of researchers from different European countries, thereby allowing Europe-wide training in active research areas. A total of 240 million is to be awarded this year, and the deadline for preliminary proposals is 7 May 2007. Researchers whose proposals pass the first round will be invited to submit a full proposal by 25 September 2007.

Another program, called European Reintegration Grants (ERG), provides funds to help reintegrate scientists who have worked elsewhere in Europe. 9.5 million are to be awarded, and the application deadline for the initial short proposal is 25 April 2007; full proposals will be due 17 October 2007.

International Reintegration Grants (IRG) are aimed at encouraging European researchers who have carried out research outside Europe to return to the European scientific community. 14.5 million are to be awarded in 2007; the application deadlines are 25 April 2007 for the preliminary proposal and 17 October 2007 for the full proposal.

Ideas Work Programme
The “IDEAS” programme is administered by the European Research Council (ERC), an organisation designed to support cutting-edge science and scholarship. Two types of ERC grants will be available:

1. The ERC Starting Independent Researcher Grants (ERC Starting Grants). These grants are to help young scientists establish and carry out their first research programmes.

2. The ERC Advanced Investigator Grants (ERC Advanced Grants). These grants support more senior scientists in cutting-edge research in any scientific field.

Only ERC Starting Grants will be awarded in 2007. A total of 289.5 million will be awarded in 2007; the deadlines are 25 April 2007 and 17 September 2007. The ERC Advanced Grants programme will begin in 2008.

Further details on all EU funding programmes are available at http://cordis.europa.eu/fp7/home_en.html.

WORKSHOP ANNOUNCEMENT

SUMMER SCHOOL ON GEODYNAMICS AND MAGMATIC PROCESSES
Lake Myvatn, near Krafla volcano, Northern Volcanic Zone, Iceland
August 20–29, 2007

T he summer school is a venue for graduate students and post-docs to meet with an international group of researchers with the aim of gaining further insights into geodynamics and magmatic processes. The summer school is a mixture of talks by invited speakers, presentations by participants, and field trips to relevant geological localities in the Northern Volcanic Zone of Iceland. The school opens on the evening of August 20, 2007, in Reykjavik; following by a field trip from south to north across Iceland on August 21. The following seven days will include four days of oral and poster presentations, and three field trips (including visits to the site of the 1975–1984 Krafla rifting episode, the Askja caldera and its 1875 eruptive products, and a unique subaerial rift–transform intersection in northern Iceland). The school will end with a field trip back to Reykjavik on August 29. All graduate students and post-docs with an interest in the theme of the summer school are invited to apply.

The application deadline is April 25.

Further details and information can be found on the Nordvolk home page: www.norvol.hi.is.
WITOLD ŻABIŃSKI – IN MEMORIAM

Famous Polish mineralogist and geochemist – a man of merit

Witold Żabiński was a member of the Polish Academy of Arts and Science and past president of the Committee of Mineralogical Sciences of the Polish Academy of Science. He was a co-founder of the Polish Mineralogical Society, its past president, and finally an honorary member. He was a founder of Mineralogia Polonica and its editor in chief for many years. Witold Żabiński was the former director of the Institute of Geology and Mineral Raw Materials (1982–1988) and head of the Department of Mineralogy at the Academy of Mining and Metallurgy (1969–1992) and of the Department of Mineralogy and Petrography of the Jagiellonian University (1998–2001) in Kraków. The author of several academic books and hundreds of papers, he received numerous decorations and awards, both Polish and international. He was a member of several Polish and foreign scientific societies and Polish representative to the International Mineralogical Association. He was known to his collaborators and students for his fine qualities as a teacher and for his gentlemanly and modest ways.

Witold Żabiński died on January 15, 2007. Although we see him no longer, he will remain with us in spirit forever.

THE POLISH CLAY GROUP

The Polish Clay Group has the formal status of a group in the Mineralogical Society of Poland. It was founded on March 22, 1973 in Kraków and in 1998 formally joined the European Clay Groups Association (ECGA). It has about 40 members and meets once a year for a one-day session in June. A grant supporting young scientists from the former Soviet Block wishing to participate in EUROCLAY conferences was established in 2000 as the Polish Clay Group Award. The first awards (two persons from Poland and Russia, 500 Euros each) were granted to support attendance at EUROCLAY 2003 in Modena. Information on the next award has been placed on the EUROCLAY 2007 and ECGA websites (www.euroclay2007.com/ and www.ing.pan.pl/ecga_js/ecga1.htm).

In 1999, the Polish group formed a federation with Slovak, Hungarian, and Croatian partners, for the purpose of jointly holding the Mid-European Clay Conference (MECC). MECC conferences have taken place in Stara Lesna (Slovakia 2001), Miskolc (Hungary 2004), and Opatija (Croatia 2006). The next conference will be organized by the Polish Clay Group and held in 2008, probably in Kraków.

PUBLISHING ACTIVITIES OF THE MINERALOGICAL SOCIETY OF POLAND

Mineralogia Polonica – Geochemical, Mineralogical, Petrological Research

This publication is the official journal of the Mineralogical Society of Poland. Since its foundation in 1970, all papers have been published in English. Two issues have been printed every year to date. It is planned to increase the number of annual issues to four. All abstracts are available on the Society web page (www.ptmin.agh.edu.pl) as well as, since 2004, free access to full texts. Full texts are also available in the Directory of Open Access Journals (DOAJ). Mineralogia Polonica is abstracted in MinAbs Online and in Georef. Instructions for authors and editorial information are available on the Society web page.

Mineralogia Polonica – Special Papers

(formerly: Polskie Towarzystwo Mineralogiczne – Prace Specjalne)

This is an irregular series in which extended abstracts of conferences co-organized by the Polish Mineralogical Society are published. Currently it is published in English.

1st CENTRAL EUROPEAN MINERALOGICAL CONFERENCE

A new series of conferences with this title was initiated in 2006. The first conference, organized by Daniel Ozdin, Pavel Uher, and Juraj Majzlaj, was held on 12–14 September 2006 in the picturesque village of Vyšná Boca in central Slovakia. This conference was a loose continuation of previous meetings in the Czech Republic and Slovakia. It included two keynote lectures on the crystallography and mineralogy of sulfosalts and Tatric hydrothermal ore deposits, presented by Emil Makovický, and Martin Chovan, as well as over 70 plenary lectures and posters. Over one hundred participants from nine countries (Slovakia, Czech Republic, Poland, Hungary, Serbia, Russia, Germany, Austria, and Denmark) took part in the conference. The geology, mineralogy, and petrology of the Vyšná Boca area was the focus of a field excursion. Moreover, participants could view an exhibition of rare Slovak sulfosalts, local ore minerals, and mining history lore. A book of extended abstracts was published as volume 28 of Mineralogia Polonica – Special Papers (Pavel Uher and Daniel Ozdin, editors). The 2nd Central European Mineralogical Conference will be organized by the Mineralogical Society of Poland and held in September 2008. The first circular will be distributed in May 2007.
THE ANTONIO FELTRINELLI AWARD FOR 2006 TO ANGELO PECCERILLO

Angelo Peccerillo received the Antonio Feltrinelli Award from the Accademia Nazionale dei Lincei for his outstanding contributions in the general field of geology, paleontology, mineralogy, and applications. The award ceremony was held in Rome on 10 November 2006.

Angelo Peccerillo is a full professor of petrology at the University of Perugia. He has also worked as assistant professor, associate professor, and full professor at the universities of Florence, Messina, and Cosenza. His research activity has focused on the petrology and geochemistry of magmatic processes with applications to volcanology and geodynamics. A large part of his work has concerned the development of evolutionary models for recent and active magmatic systems, with special reference to the Aeolian Arc, the Roman Magmatic Province, and the Ethiopian Rift Valley.

His studies have allowed the detailed definition of the physical and chemical mechanisms characterizing these magmatic systems, with the aim of better understanding their evolution and thus be able to forecast future behavior. Petrological and geochemical data have been integrated with geophysical and fluid chemistry data to develop holistic models for a complete understanding of the behavior of highly dangerous active volcanoes, such as Vulcano (Aeolian Islands).

Angelo has been a member of numerous national and international academic committees, editorial boards, and working groups. He has been president of the National Group of Petrography (Gruppo Nazionale di Petrografia). Currently he is an associate editor of Lithos, and chief editor of the European Journal of Mineralogy. He has authored more than 140 research papers, published mostly in peer-reviewed international journals, and several didactic and popular publications. In 2005 he authored the book Plio-Quaternary Volcanism in Italy: Petrology, Geochemistry, Geodynamics, published by Springer-Verlag.

With apparent ease and equanimity, Angelo Peccerillo has been prolific and effective in applying physical and chemical principles to understanding the Earth, and has been eminently successful in establishing productive, long-term collaborations. Few deserve an award honoring outstanding contributions to fundamental petrology, geochemistry, and geodynamics and unselfish collaboration in research more than Angelo Peccerillo.

SIMP PRIZES IN 2006 FOR PhD STUDENTS

Every year SIMP awards prizes for the best PhD dissertations by young researchers who have completed their doctorate. In 2006, the winners were Consuelo Fortina (Univ. of Siena), Maurizio Petrelli (Univ. of Perugia), Salvatore Sciarrino (Univ. of Palermo), and Simone Tumiati (Univ. of Insubria–Como).

Consuelo Fortina “Architectonic Study of Glazed Ceramics in Siena and in Southern Tuscany: Reconstruction and Technological Advancement in the Middle Ages (X–XIV Centuries)”

This PhD thesis focused on the scientific methodologies applied to the study of archaeological materials. The study used a multianalytical approach, from conventional analyses up to more powerful techniques requiring a synchrotron radiation source, to carry out mineralogical and petrographical characterizations of archaeological artefacts derived from geological materials.

Salvatore Sciarrino “Organic and Inorganic Geochemical Forms of Trace Elements in Soils and Sediments from Sicily”

In this thesis, organic and inorganic geochemical forms of some trace elements (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn) in soils and sediments from Sicily were assessed. Attention was paid to the relationships between soil and sediment composition and metal sequestration capacity, particularly with respect to organic matter.

Simone Tumiati “Geochemistry, Mineralogy, and Petrology of the Eclogitized Manganese Deposits of Praborna (Valle d’Aosta, Western Italian Alps)”

The study concerned one of the most famous manganese ore deposits in the world, in which a sedimentary cover of unusual composition overlies Alpine meta-ophiolites and shows features of high-pressure metamorphism. The main achievements of the study were (1) the thermodynamic modeling of Mn-rich systems, (2) the identification of new minerals, and (3) the recognition of a hydrothermal origin for the proto-ore.

Maurizio Petrelli “Developments of Non-Linear Dynamics during Mixing of Magmas: Transition to Chaos and Implications for Timescales of Magma Hybridization”

This PhD project mainly involved modeling of magmatic systems and developing new petrologic tools based on chaos theory and fractal geometry, with emphasis on timescales of magma hybridization.
The IAGC welcomes Clemens Reimann to the position of vice-president. He replaces Russ Harmon who took over the position of president upon the resignation of John Ludden. Technically speaking, Russ is only interim president until his position is ratified by IAGC Council, but in the few months leading up to the next Council meeting, he has certainly demonstrated his ability to generate ideas and get things moving!

A lot is happening in the applied geochemical field this year. Two major conferences are taking place: the 12th Water–Rock Interaction Symposium, July 31–August 5, in Kunming, China, and the 7th Applied Isotope Geochemistry Symposium, 10–14 September, in Stellenbosch, South Africa. In addition a one-day symposium (August 18) will pay tribute to Al Levinson at the Goldschmidt meeting in Cologne, Germany.

Mel Gascoyne
Business Manager

To officially acknowledge its 40th anniversary, the International Association of GeoChemistry will hold a special one-day celebration on Saturday, 18 August at the University of Cologne, immediately prior to commencement of the 17th Annual Goldschmidt Conference. All IAGC members and Goldschmidt Conference participants are cordially invited to attend this event. Further details can be found in the accompanying box.

During the celebration, the IAGC will honour past presidents and other important figures in IAGC’s history. The recipients of the inaugural set of IAGC awards—the Vernadsky Medal, the Ebelmen Medal, the Faure Award, and the Hitchon Award—will be formally presented during the Goldschmidt Conference at the joint society awards ceremony. Certificates of Recognition to acknowledge special service to IAGC will also be presented at the anniversary celebration.

The chair of the Organizing Committee for the IAGC 40th Anniversary Celebration and Symposium is Jochen Hoefs. Any IAGC member wishing to join the committee or otherwise volunteer to assist with the organization and implementation of the event should contact Prof. Hoefs (jhoefs@gwdg.de).
DMG – DEUTSCHE MINERALOGISCHE GESELLSCHAFT – THOUGHTS AND GOALS

In compliance with the DMG elections of 2005, president Gregor Markl and I have switched offices as president and vice-president. I would like to thank all DMG members for their vote of confidence, and Gregor Markl, on behalf of all DMG members, for his great work and enthusiastic commitment to the DMG. Gregor’s central interest has always been that all geoscientists should share a common goal and that the national and international visibility of the DMG should be clear. With the unanimous decision to join Elements, the council and members of the DMG clearly support Gregor’s vision of a multidisciplinary approach and international presence.

The international commitment of our society will be accentuated by this year’s combined DMG and Goldschmidt meeting in Cologne, Germany, under the title “atoms to planets.” We ask all DMG members to help us create a great meeting by attending in large numbers and participating actively. We should also encourage our young members to take advantage of this chance to present their work to the international community and to forge international links. One of the DMG’s primary aims is to further the work and development of young students and scientists. Therefore we will be supporting the attendance of young scientists at future international meetings as well. A second focus is the sponsoring of DMG postgraduate courses at various universities and research centers in order to introduce students to new scientific research directions and their methods and techniques. During the past years the spectrum of topics has continually evolved, thanks in part to close cooperation with other societies, and the attractiveness of these courses has clearly increased. DMG postgraduate courses close gaps in the routine university education of our young scientists, often caused by the lack of appropriate financial and human resources and by heterogeneity in local BSc and MSc syllabuses. The program and financial support to the local organizers are coordinated by the DMG Research Committee under the chairmanship of Hans Keppler. These courses are demonstrably highly effective and successful, and thus they represent a rewarding path that the DMG will continue to follow.

Although various initiatives exist to further excellence at the end of a university education, the lack of basic mineralogical knowledge acquired in schools remains problematic. I ask all DMG members for support in our efforts to reach school teachers and those responsible for teacher education in order to convince them of the significance of mineralogy in the geosciences and its importance in linking neighboring disciplines. Mineralogical topics can be taught in conjunction with school subjects like geography, chemistry, and physics. I ask our members to strengthen the foundations of our society by clearly identifying yourself with mineralogy and by recruiting new members to the DMG. We now offer students the possibility of becoming joint members of the DMG and the Geologische Vereinigung (Geological Union) for the price of only 40 Euros a year, which includes all publications offered by these two societies.

In a letter to the membership in the year 2000, then DMG president Friedrich Seifert offered a definition of mineralogy that fittingly describes the research and work we do without erecting barriers to neighboring disciplines: Mineralogy relates materials science to geoscience and explores the chemical, physical, and biological properties of matter and their role in the Earth System.

Ulrich Bismayer
President

INTERNATIONAL SHORT COURSE AT THE BAYERISCHES GEOINSTITUT

“High-Pressure Experimental Techniques and Applications to the Earth’s Interior”

Since 1999, the Bayerisches Geoinstitut, University of Bayreuth (Germany), has been running an annual short course on high-pressure experimental techniques and how results of such experiments can be used to understand the structure and properties of the Earth’s interior. This course is one of a number of postgraduate courses that are sponsored by the German Mineralogical Society.

The 9th short course took place on 19–23 February 2007 in Bayreuth with 21 participants, 11 of whom came from Germany and 10 from seven other European countries. While the participants were mainly PhD students, several undergraduates and one senior scientist (from industry) also took part. The participants represented not only the Earth sciences but also chemistry and physics.

As in previous years, the course consisted of a combination of lectures and laboratory-based practical sessions, which were given and organized by staff scientists of the Bayerisches Geoinstitut. The short course topics included not only high-pressure experimental techniques but also computational mineral physics and a broad range of techniques for characterizing the properties of samples, such as scanning and transmission electron microscopy, X-ray diffraction, and spectroscopy (optical, infrared, Raman, and Mössbauer).

High-pressure aspects included synthesis at high pressures and temperatures (using multianvil, piston-cylinder, and diamond anvil cells) and in situ methods (in situ X-ray diffraction, high-pressure crystallography). Theoretical sessions covered thermodynamics, phase equilibria, crystal chemistry, equations of state, and reaction kinetics with emphasis on the mineralogy and structure of the Earth’s mantle.

The next short course will be held in February 2008, and details will eventually be available at www.bgi.uni-bayreuth.de/.
A core activity of the International Association of Geoanalysts is the support of the society’s official journal, *Geostandards and Geoanalytical Research*. In this article, I highlight the history of the journal and report on recent, important developments regarding its publication.

By the mid-1970s, an urgent need had arisen for a journal devoted to fundamental research into the chemical characterization of reference samples for use in geochemistry and geological sciences. Thanks to the foresight and commitment of its founding editor, Dr. Kuppusami Govindaraju, who assembled an international editorial board, attracted top-name contributors, and worked to establish a strong subscriber base, *Geostandards Newsletter* was established in 1977. Dr. Govindaraju continued in his role as editor-in-chief of *Geostandards Newsletter* for the next 20 years until he retired as director of the Service d’Analyse des Roches et des Minéraux of the CNRS at the Centre de Recherches Pétrographiques et Géochimiques (CRPG) in Vandoeuvre-lès-Nancy, France.

His retirement provided an opportunity to relaunch the journal on a number of fronts. Thus, in 1997 the scope of the journal was widened to include contributions on the latest developments in laboratory techniques applied to the analysis of geological and environmental samples, an expansion that was reflected in the retitling of the journal as *Geostandards Newsletter, The Journal of Geostandards and Geoanalysis*. Also at this time the journal was recognized as the official journal of the then newly established International Association of Geoanalysts, with members of the IAG taking a leading role in the editing of the relaunched publication. Philip Potts (The Open University, Milton Keynes, UK) and Mireille Polvé (Université Paul Sabatier, Toulouse, France) became the new editors-in-chief of *Geostandards*, both of whom continue in their roles to this day. Despite all these changes, the editorial office and the publication operations of *Geostandards* continued to be based at the CRPG. In 2001 the publication schedule was increased from two to three issues per year, and in 2004 the journal was renamed *Geostandards and Geoanalytical Research*. By this point the journal had achieved an ISI-JCR impact factor of 2.4, reflecting the growth in the journal’s importance as a vehicle for communicating the latest information and trends in the chemical analysis of geological materials.

The phenomenal growth of electronic publishing over the past decade has exerted new pressures on the independent publishing sector. The demand for both searchable electronic content and online subscriptions has compelled many small-scale publications to merge with established publishing houses. Furthermore, large publishing houses can offer valuable synergies through the bundling of journals from across broad scientific disciplines, leading to a potentially much larger audience for any given manuscript. Such realities of modern-day scientific publishing have brought a further wave of changes to *GGR*. At the beginning of 2007, the IAG took a formal role in the running of the journal and will work with Blackwell Publishing Ltd (Oxford, UK) as its partner. Blackwell will be responsible for the production and distribution of the journal, as well as internet access to all scientific content. This tie-up with a highly reputable publishing house, initially until 2016, is expected to bring many benefits to *Geostandards and Geoanalytical Research*, including a growth in readership within the broader geochemical community. The format of the journal will remain largely unchanged, though publication will now be quarterly. With the journal’s publication office remaining at the CRPG and with a largely unchanged editorial team, the quality of the journal is now assured well into the future.

Speaking on behalf of the IAG Council, I hope that the readers of *Geostandards and Geoanalytical Research* will be pleased with these new arrangements and that they will find the new electronic access, ultimately to stretch back to the very first issue of the journal, a valuable tool for your future research endeavours.

**Michael Wiedenbeck**
President, IAG
In general terms, contamination is the process of making an originally pure material impure. For this to happen, an originally pure material must be open to the influx of foreign materials. In igneous petrology, contamination of magma involves the incorporation of foreign solid materials, normally consisting of the rocks through which the magma passes or in which it comes to reside. It may also involve the incorporation of other molten materials (more commonly known as magma mingling) and even aqueous fluid phases introduced at temperatures above the solidus. From the standpoint of the felsic magma, contamination by a foreign solid removes heat, whereas contamination by a foreign mafic melt adds heat. Because the original magma and the contaminants have different compositions, they almost certainly react. Assimilation is the sum of all the reaction processes that work together to eliminate the physical evidence of contamination, leaving only chemical evidence of its former occurrence, rather like the grin on the Cheshire cat.

The “Contaminated Granites” issue begins with a theoretical overview of the principles governing the assimilation reactions (redox, thermal decomposition, melting, ion exchange, dissolution) that take place between foreign material and the silicate melt. The issue continues with a case study in which textural and chemical criteria are established for the recognition of ilmenite and rutile xenocrysts in granites: this task is easy if the xenocrysts are minerals that do not crystallize from granitic magma, but extremely difficult if they do. One of the problems associated with studying the reaction history of foreign materials in the field is that we are never certain whether, for any given set of xenoliths, the protoliths were the same. One paper tackles this particular problem experimentally, with controlled magma and contaminant compositions, and demonstrates that some of the enigmatic variations in mineral assemblages and textures in natural rocks have their origins in contamination by country rock.

Three papers address the physical mechanisms and consequences of incorporation of country-rock xenoliths. One draws parallels between style of granite emplacement and the endogenous and exogenous growth of volcanoes, and assesses the probability of incorporation of xenoliths as a function of the style of intrusion. Two others look in detail at the mechanisms by which country rocks become included in the granitic magma, how foreign fragments are distributed in the plutonic body, and what we can learn from their shapes and sizes about the processes of disintegration of country rock and emplacement of granitic magma.

Two papers deal with the added complication of contamination by mafic magma. Not only do many granites undergo reactions with the wallrocks and roofrocks, but they also receive an influx of mafic material and a thermal boost to enable them to conduct these reactions more effectively. The path to chemical equilibrium in such systems is complex, and retention of mingling textures demonstrates that many granitic magmas do not achieve that equilibrium.

The issue concludes with a detailed review of enclaves in the S-type contact-aureole granites of southeastern Australia and a reclassification of most of the enclaves as foreign contaminants. This paper suggests that large, high-level S-type granites may originate in deep, low-pressure–high-temperature granulite facies sources (possibly varieties of “MASH” zones), rather than in typical mid-crustal migmatite complexes. A possible example of the upper part of such a melting zone may be the Hidaka Metamorphic Belt, Hokkaido, Japan.

Petrogenetic investigations should always consider granites not so much as the products of crystallization of pristine melts but as mixtures of such melts and a variety of other components that have contaminated them. Only when we can confidently determine the magnitude of contamination and subtract its effects, will we be able to understand what the granitic magma has to say. This issue of The Canadian Mineralogist was edited by Barrie Clarke, Scott Paterson, Ron Vernon, and Robert F. Martin. Copies of thematic issue 45-1 may be ordered from the MAC business office (www.mineralogicalassociation.ca).

Barrie Clarke
Dalhousie University
We gratefully acknowledge financial contributions from the following members. Thanks to these generous donors, we have been able to enlarge our travel and research grant programs this year.

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Many of our short course volumes make fine teaching manuals for upper undergraduate and graduate level courses.

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- Silicate Melts
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The Geology of Gem Deposits
MINERALOGICAL ASSOCIATION OF CANADA SHORT COURSE

21–22 MAY 2007, YELLOWKNIFE, CANADA
SHORT COURSE ORGANIZER: Lee Groat, University of British Columbia

This two-day short course will look at gemstones from a geological perspective. It will precede Yellowknife 2007—the joint annual meeting of the Geological Association of Canada and the Mineralogical Association of Canada, in Yellowknife, Northwest Territories, Canada. It will be a unique opportunity to experience a change of climate and a meeting north of 60°. A special session entitled “Diamonds: Exploration to Production – A Northern Canada Perspective” and a post-conference field trip to the Canadian diamond mines, sponsored by BHP and Diavik, will complement the short course.

Gem deposits are rare because in general the conditions that promote their formation are unusual and thus worthy of scientific study. Recently modern geological and analytical techniques have been applied to gem occurrences in Canada and elsewhere, and our models and understanding of their formation are being radically altered. This short course will review our current understanding of diamond, ruby, sapphire, and emerald deposits but will also examine the lesser-known coloured gems.

1. INTRODUCTION
2. DIAMOND DEPOSITS (Thomas Stachel, University of Alberta)
3. GEM CORUNDUM (Ruby and Sapphire) Deposits (Gaston Giuliany, IRD and CRPG/CNRS)
4. GEM BERYL (Emerald, Aquamarine, etc.) Deposits (Dan Marshall, Simon Fraser University)
5. PEGMATITE GEM DEPOSITS (Skip Simmons, University of New Orleans)
6. JADE DEPOSITS (George Harlow, American Museum of Natural History)
7. CANADIAN COLOURED GEM OCCURRENCES (Brad Wilson, Alpine Gems Ltd.)

Registration fees: CDN$425 (professional) and CDN$250 (students)
For more information, e-mail Lee Groat at lgroat@eos.ubc.ca or visit the conference website at www.nwtgeoscience.ca/Yellowknife2007

Yellowknife 2007
GAC-MAC / L’AGC-AMC
May 23 – 25 / du 23 au 25 mai

CANADA’S NORTH...
ITS CLIMATE, ITS CULTURE,
ITS MINING HERITAGE, AND ITS FUTURE!
LE NORD CANADIEN...
SON CLIMAT, SA CULTURE,
SON HÉRITAGE MINIER ET SON FUTURE!

VISIT OUR WEBSITE - VISitez NOTRE SITE INTERNET
www.nwtgeoscience.ca/yellowknife2007
The 23rd International Applied Geochemistry Symposium (IAGS) will be held in Oviedo, Spain, from June 14 to 19, 2007. With its 215,664 inhabitants, Oviedo is the capital of Asturias in northern Spain. The symposium will take place in the Conference Hall of the City, in the heart of Oviedo and within walking distance of hotels and amenities. The organizing committee has planned a varied program on applied geochemistry, covering the latest advances in geochemical techniques for mineral exploration and the environment. Pre- and post-symposium field trips will combine technical and tourist visits to Spain and Portugal. A full slate of workshops will take place on the weekend before the symposium (June 16 and 17). An exciting social and cultural program for participants and accompanying guests includes several one-day tours to places of interest in the region.

Twelve special sessions are planned on themes ranging from the health-related issue of metals in the environment to new research in surface and lithogeochemical exploration methodology. Four short courses, given by recognized experts, and four field excursions are also planned.

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<td>Dr. Eduardo de Miguel</td>
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<tr>
<td>Excursion 2</td>
<td>Almaden (Hg), Rodalquilar (Au), La Unión (Pb)</td>
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<tr>
<td>Excursion 4</td>
<td>Reocín (Zn–Pb), Bilbao (Fe)</td>
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On behalf of the organizing committee and the Association of Applied Geochemists, it gives me great pleasure to invite you to participate in the 23rd IAGS and I look forward to seeing you in Oviedo.

Jorge Loredo
23rd IAGS Chairman
E-mail: iags2007@innova.uniovi.es
Web: www.uniovi.es/IAGS2007

Las Médulas is one of UNESCO’s 730 World Heritage Sites (WHS) and one of 37 WHS in Spain; Spain has the most WHS of any country in the world. Accepted in 1997 into the WHS list, Las Médulas is a spectacularly preserved alluvial gold mining area (2000 hectares) with more than 50 archaeological sites recorded. Wonderful landscape and architecture typify the region, and numerous museums have information on Las Médulas. Las Médulas is one of the stops on two of the field excursions and is considered a must-see for geologists in Spain. There is abundant information in Spanish on various websites and links through UNESCO’s WHS list.

During the reign of Augustus, the Roman Empire went to a gold standard (7.8 gram gold coin, the aureus), thus increasing the demand for the metal. The Asturs, the last peoples to be enslaved by the Romans in Spain and Portugal, were forced to mine in various parts of their region. Las Médulas was probably the largest gold-mining area in the Roman Empire for almost 200 years, ending in the early part of the 3rd century AD; it contributed over 5% of the wealth of the Roman treasury.

The alluvial gold deposits are hosted in the conglomeratic parts of the Miocene red fluvial (or glacial–fluvial) deposits; gold-bearing quartz, dust, platelets, and nuggets were described. Obviously, these deposits formed from the intense weathering and subsequent erosion of the Hercynian gold deposits, which are famous in northwestern Spain. In fact exploration in the historical areas of mining by the Asturs during Roman times has led to more recent gold discoveries in the region.

The geographer and naturalist, Pliny the Elder (who died near Pompeii in the 79 AD eruption of Vesuvius and whose nephew, Pliny the Younger, recorded the “Plinian” eruptions west of Vesuvius) noted in his book Naturalis Historia that this region supplied over 6500 kg of gold per year. In the same book, Pliny detailed the mining methods of the region, which included building huge canals (400 km of canals) from the mountain tops and rerouting rivers (River Oza) in order to wash the mined material into the panning fields near the town of Las Médulas, at the base of the mountain. Between 100 and 230 million cubic meters were mined from the area, and tailing heaps typify the lower regions. Interestingly, this was one of the main arguments against making this a WHS, because it was argued that it represented the ecological destruction of the region. Rather, what is left is a snapshot of the region’s mining heritage and economic endowment. Earlier estimates of gold grade indicated about 1 ppm gold per tonne, with up to 10 ppm (probably locally); recent estimates are much lower, averaging about 50 mg/m³ (several hundred ppb). Therefore the amount of gold extracted is probably much lower than once thought. Mining ended abruptly as a result of the problems in the Roman Empire and the change from the gold currency standard.
Elements cover image September 2005 highlighting environmental mineralogy and geochemistry. The image shows low-pH acid mine drainage and reddish Fe-oxyhydroxide precipitates at the periphery of a tailings impoundment in the Joutel area, Quebec. The tailings are from a former copper producer, and the site has since undergone remediation. Photo courtesy of John Jambor.

Two conference sessions sponsored by the WGEMG have already been held: “Mineralogy and Geochemistry of Acid Mine Drainage and Metalliferous Minewastes” at Goldschmidt 2005, Idaho, USA, which resulted in the publication of a collection of papers as a special part-issue of Applied Geochemistry (volume 21, pp 1249-1334, 2006), and “Environmental and Medical Mineralogy” at the IMA conference in Kobe, Japan, in August 2006. Future plans include sponsorship of a session at Goldschmidt 2007 in Cologne, Germany (“Microbial Biomineralization: From Environmental Processes to New Technologies”) and, in the longer term, sponsorship of sessions at Goldschmidt 2008 (Vancouver) and IGC 2008 (Oslo).

WGEMG now requires national representatives to contribute to its activities. If you are interested in helping, please contact WGEMG Secretary John Jambor or one of the other officers.

For further information see the IMA website www.ima-mineralogy.org or contact a WGEMG officer.

The next Council meeting of IMA will be at the Frontiers in Mineral Science meeting, 26–28 June 2007, Cambridge, UK.

Please see the IMA website www.ima-mineralogy.org and contact one of the councillors if there is an issue you would like the councillors to discuss.

IMA Council is calling for expressions of interest to host the 21st IMA General Meeting in 2014. Recent conferences have taken place in Toronto, Canada (1998), Edinburgh, UK (2002) and Kobe, Japan (2006, with about 1000 attendees; see Elements volume 2, issue 5, October 2006). The next event will be in Budapest, in August 2010, and will be organized jointly by Austria, Hungary, Croatia, Czech Republic, Romania and Slovakia.

The 2018 conference is planned for the USA and will highlight the Mineralogical Society of America centenary in 2019. IMA encourages geographic variation in the venue. If your society is interested in hosting the international mineralogical community in 2014, please contact IMA secretary, Maryse Ohnenstetter, mohnen@crpg.cnrs-nancy.fr, for further details and initial discussion.
The EMU Medal Committee calls upon member societies and all European mineralogists for nominations for the EMU Medal for Research Excellence. This medal is awarded to young scientists who have already made outstanding contributions in research and who have helped further European collaboration in science. Nominations should be sent to the chairman of the EMU Medal Committee, Roland Oberhansli (Universität Potsdam, Institut für Geowissenschaften, Karl-Liebknecht-Strasse 24, Haus 27, D-14476 Golm, Germany; e-mail: roob@geo.uni-potsdam.de).

The officers of EMU are pleased to announce that the next EMU School will be on the subject “Nanoscopic Approaches in Earth and Planetary Science” and will be held August 12–17, 2007, in Munich, Germany. For further details, see the website www.9th-EMU-School.de.

Peter Ulmer, President
David Vaughan, Past President
Herta Effenberger, Secretary

EMU MEDAL FOR RESEARCH EXCELLENCE

This silver medal is awarded to young scientists who have made significant contributions to research and who are active in strengthening European scientific links. In 2006, medals were awarded to Luca Bindi and Bruno Lanson.

Luca Bindi

Luca Bindi was born in 1971 in Prato, Italy. He studied at the Department of Earth Sciences of the University of Florence (1991–1996) and went on to obtain a PhD in mineralogy and petrology at the same university (1998–2000). His research has continued in Florence with various postdoctoral research positions (2000–2006); lately, he has also been involved in collaboration with the scientists of the Division of Mineralogy of the Natural History Museum of Florence.

The research of Luca Bindi has been mainly devoted to understanding structural complexity in minerals (e.g., incommensurate structures, superstructures, twinned structures) by integrating mineralogy and advanced crystallography. His research has also involved the description and characterization of new minerals and the determination of the physical and chemical conditions of minerals in the mantle. His pioneering work on K-rich clinopyroxenes has been widely recognized internationally, and his work on the characterization of minerals in ore deposits has been highly regarded amongst economic geologists. Specifically, he has demonstrated that large amounts of potassium (up to 5 wt% K$_2$O) can enter the structure of natural and synthetic clinopyroxenes and he has discussed the implications of this for the mineralogy of the Earth's deep mantle. Also, he has carried out the first five-dimensional crystal structure refinement of a natural material (mellilite) displaying a two-dimensional incommensurate structure, and he has demonstrated that some natural silver sulfosalts (of the pearceite–polybasite group) are fast ionic conductors, which may have important technological applications. The most impressive features of Luca Bindi's research are the breadth of his work and his extraordinary productivity. At thirty-five years of age, he has published more than 60 papers in internationally renowned journals.

The excellence of his research was nationally recognized when he received, in 2001, an award from the Italian Society of Mineralogy and Petrology (SIMP) for the best PhD thesis in mineralogy or petrology and, in 2004, the Panichi Award from SIMP for outstanding research in mineralogy by a young scientist. For the relevance and international dimensions of his work, Luca Bindi has been awarded the 2006 EMU Medal for Research Excellence.

Bruno Lanson

Bruno Lanson was born in 1965 in Châtellerault, France. After a civil engineering degree from the École Supérieure d’Ingénieurs in Poitiers (1987), he obtained a PhD in geology (1990) in Paris, under the supervision of Bruce Veld. He carried out postdoctoral research at the USGS, Denver (1990–1992) and subsequently at the Mineral Resources Research Institute, University of Arizona, Tucson (1992–1994). Researcher with the Centre National de la Recherche Scientifique since 1995, he is currently head of the Environmental Geochemistry Group at the LGIT (Geophysics and Tectonophysics Laboratory), Joseph Fourier University, Grenoble, France.

The work of Bruno Lanson has aimed at understanding the structures and physical properties, particularly the surface reactivity, of finely divided minerals (phylloliscicates and phyllomanganates). Bruno Lanson’s earliest achievement was the development of a coherent, simple decomposition method of the complex X-ray diffraction spectra obtained from clay mineral mixtures found in sedimentary rocks. This work resulted in a user-friendly computer program which, even after a decade of concurrent development, remains one of the most robust. Since then Lanson has explored and characterized the relationships between the structure and macroscopic properties of clays and phyllomanganates using advanced microscopic and diffraction techniques (TEM-EDS and synchrotron spectroscopic methods (XANES, EXAFS). Questions concerning minor and toxic element capture and release by manganese minerals are of prime importance at sites of industrial pollution. They have been addressed by Lanson through the identification and structural and chemical characterization of oxide nanocrystals produced by bacteria or found on and within root hairs of plants grown under controlled conditions. At the same time, Lanson has been active in solving the problems of clay-mineral evolution under conditions of changing temperature and chemistry. He has linked the quantitative description of complex parageneses to the kinetic processes of clay transformation occurring in natural or perturbed sediments. Some of these studies have involved international collaborations that have spanned Europe, from Karlsruhe to Moscow.

Bruno Lanson has already achieved international recognition as one of the leading workers in his field. He will surely continue to make major advances in the physico-chemical characterization of nanominerals and in the understanding of their interaction with the living world in Earth's surface systems. For the international relevance of his work to key questions in environmental sciences, Bruno Lanson has been awarded the 2006 EMU Medal for Research Excellence.

Stefano Merlino
Chair of the EMU Medal Committee
The study of fluid inclusions—gas, liquid, melt—saw an impressive renaissance after the Second World War, mainly through the efforts of E.W. Roedder in the West and N.P. Ernakov in the former Soviet Union. The use of inclusions as a tool to solve geological and geochemical problems has advanced from simple aqueous–salt systems, to rapidly quenched glass inclusions in extrusive environments, and now to melt inclusions in plutonic rocks. This advance has more or less followed the development of fluid inclusion analytical instrumentation and experimental research designed to elucidate the physicochemical understanding of the inclusions. In 1984, Roedder (in Fluid Inclusions, Reviews in Mineralogy, volume 12, 644 pp) briefly discussed melt inclusions in intrusive rocks and recognized some of the inherent problems: difficulty of recognition, problems with phase interpretation, and the lack of appropriate instrumentation or techniques.

The Mineralogical Association of Canada Short Course Series volume 36, Melt Inclusions in Plutonic Rocks, presents a historical perspective and details the current state of knowledge and potential future developments for this useful petrologic tool. The editor, James D. Webster, has brought together a very well-balanced, well-illustrated group of papers that will be useful to the student as well as the dedicated inclusion worker. This volume shows that the study, interpretation, and use of melt inclusions to understand intrusive rocks has come of age.

R.J. Bodnar and J.J. Student, in chapter 1, provide an excellent discussion of the history of melt inclusion study. They provide details of the fundamental petrographic and interpretative bases, explain what to do if you find inclusions in your intrusive rocks, and conclude with an example from porphyry-type deposits. SIMS (secondary ion mass spectrometry), an analytical technique that allows in situ elemental analysis with low sample destructivity, has been successfully applied to melt inclusions. In chapter 2, G.D. Layne describes the use of this technique for the determination of traditional and non-traditional, light stable isotopes in silicate melt inclusions. Layne clearly details the technical details of the Cameca IMS instrumentation as well as specific techniques and applications. Chapter 3, by T. Pettke, provides an excellent mini-short course on in situ laser-ablation ICP–MS analysis of melt inclusions. Pettke also provides a very important discussion of the statistical relevance and relative strengths of data sets generated by LA–ICP–MS, SIMS, and electron microprobe analysis. He concludes with a section on the potential for this technique to help understand subduction zone magmatism. Some sort of magmatic immiscibility (unmixing) is inevitable during the evolution of most magmas, and V.S. Kamenetsky, in chapter 4, discusses various types of magmatic immiscibility: silicate–silicate, silicate–aqueous saline, silicate–hydrosaline (or salt), silicate–carbonic, and non-silicate melt pairs. This discussion is excellently illustrated with clear and well-documented photomicrographs.

Chapter 5, by I.V. Veksler, provides a very comprehensible and detailed discussion about how crystallized melt inclusions can provide answers to problems concerning melt evolution, magma mixing events, local compositional perturbations, and liquid immiscibility in gabbroic magma chambers. Veksler illustrates these uses with examples from the Skaergaard and similar intrusions. Carbonate–silicate immiscibility provides a fertile environment for using melt inclusion observations and analysis to obtain an understanding of carbonatite petrogenesis. I.V. Veksler and D. Lentz, in chapter 6, not only provide a comprehensive summary of fluid inclusions in carbonatites but also summarize the phase relations most relevant to understanding coexisting silicate–carbonate melts. In chapter 7, W.E. Halter and C.A. Heinrich use their study of porphyry-type environments in the Farallón Negro volcanic complex, Argentina, to illustrate an integrated approach using laser-ablation ICP–MS to help understand magmatic processes and volatile phase generation. The authors focused their work on heterogeneous inclusions, both silicate and sulfide, in this andesitic system. In chapter 8, J.D. Webster and R. Thomas provide a concise review and synthesis of silicate melt inclusions in felsic plutons. They discuss studies in the context of the problems and challenges recognized by inclusion workers. The authors discuss chlorine and water in petrogenetic models involving crystallization and degassing.

R. Thomas and J.D. Webster, in chapter 9, present a comprehensive discussion of a felsic pluton’s more water-rich offspring, pegmatites. They review pegmatite petrogenesis in light of evidence from melt and fluid inclusions, petrography, mineralogy, and phase chemistry. In chapter 10, B. De Vivo, A. Lima, V.S. Kamenetsky, and L.V. Danyushhevsky discuss fluid and melt inclusions in subvolcanic systems near Naples, Italy, including Vesuvius, Campi Flegrei, and Ponza and Ventotene Islands. They point out that studies such as theirs are undertaken for more than academic interest—millions of Neapolitans live near these volcanic systems. The results of years of inclusion studies are well illustrated and summarized. The role of magmatically derived hydrosaline chloride and/or sulfur-rich fluids is emphasized and used to discuss the significance of bradyseismic (slow vertical Earth movement) events.

The collection of references in this volume is also very valuable; in spite of the current Google milieu, the authors provide well-researched, concise, and relevant bibliographies. This short course volume is an educational bargain. It is a very good companion to Mineralogical Association of Canada Short Course Series volume 32, Fluid Inclusions: Analysis and Interpretation. The really lasting contributions to fluid inclusion research are not necessarily the scientific interpretations (which can come and go), but the discovery of new inclusion phenomena, either natural or synthetic, backed up by accurate analyses of carefully collected and documented samples. This volume represents a significant step towards using melt inclusions to understand the characteristics and origins of plutonic rocks.

Harvey E. Belkin
USGS, Reston, VA, USA

Cont’d on page 148

We all know that water is essential to all aspects of life on our planet. Life probably evolved in the oceans, and plants and animals rely on water to flourish. Our hydrology lectures introduced us to the water cycle on Earth. If I recall correctly, water evaporates from the oceans, clouds form, cloud particles collide, grow, and fall out of the sky and eventually, rain distributes water all over the land masses. Having moved to Edinburgh recently, I can report on the latter from much personal experience.

However, over the last few decades, we have learnt that almost all minerals occurring in the Earth’s mantle and crust contain small amounts of hydrogen, even minerals which were previously thought to be ‘bone dry’, or ‘nominally anhydrous’. This may seem unimportant at first sight, but because of their huge mass, the Earth’s mantle and the mantles of other planets may store much more hydrogen than the oceans. 

Water in Nominally Anhydrous Minerals is volume 62 of the much-admired and much-thumbed Reviews in Mineralogy & Geochemistry series, now produced jointly by the Mineralogical Society of America and the Geochemical Society. It provides an up-to-date summary of what is known about the hidden water in deep parts of the crust and the mantle.

The book is divided into nineteen chapters of approximately equal length. The first chapters focus on recent advances in analytical and experimental techniques used for analysis of hydrogen in minerals. In the first chapter, G. Rossman presents detailed information about analytical methods, most of them modern in situ microanalytical techniques. He discusses the pros and cons of each technique and gives a good and comprehensive summary of our current knowledge. Other chapters by E. Libowitzky, A. Beran, J.R. Smyth and K. Wright give detailed and well-researched information about various structural aspects of hydrogen and hydroxyl incorporation in minerals based on both spectroscopy and modelling.

Review articles by H. Skogby, A. Beran, E. Libowitzky and E.A. Johnson focus on our current knowledge of the hydrogen budgets of nominally anhydrous minerals in the mantle and crust. Here we learn that mantle olivines and pyroxenes can incorporate several hundred parts per million of water. Matters are complex, however, and one gets the impression that the last word on hydrogen substitution and concentration has not yet been spoken. Chapters by H. Keppler, N. Bolfan-Casanova, S. Kohn and K.J. Grant deal with thermodynamic aspects of water solubility and the partitioning of hydrogen among minerals, fluids and melts. The authors show that the solubility of water in minerals is a complex function of pressure, temperature and the chemical composition of phases. An excellent chapter by J. Ingrin and M. Blanchard reviews the current knowledge on hydrogen diffusion in minerals. Chapters by D. Frost and T. Kawamoto are on the stability of hydrous minerals in the Earth’s mantle and in subduction zones. Hydrous phases, such as amphiboles and serpentinite group minerals, have been experimentally proven to be stable to enormous depths in subduction zones and may be important carriers of hydrogen from the surface back into the mantle.

The final chapters deal with the consequences of water in nominally anhydrous minerals and rocks for equations of state, rheology and geodynamic processes. S. Jacobsen explains how hydrogen in major mantle minerals may affect their equations of state in ways which are crucial for our interpretation of seismic data. E. Ohtani and K.D. Litasov review the effect of water on phase transitions in the deep Earth. The latter could be important because wadsleyite and ringwoodite in the transition zone may store large amounts of water in their structure, which would significantly expand their stability fields. S. Karato explains how one could use geophysical methods in remote sensing to explore hydrogen in the Earth’s interior, and D. Kohlstedt investigates how water influences the rheologic properties of rocks. The latter is probably of crucial importance as even very low amounts of water weaken rocks dramatically during deformation. B. Marty and R. Yokochi discuss the origin of water on the Earth based on isotopic constraints and, in the final chapter, K. Regenauer-Lieb discusses the effect of water on tectonic processes on a global scale. Regenauer-Lieb’s article nicely explains how small amounts of water in the Earth’s mantle can explain different tectonic styles on Earth and, by extension, on our neighbouring planets Venus and Mars.

Water in Nominally Anhydrous Minerals has been extremely well researched and produced with remarkable care and attention to detail, and there are numerous literature references for the reader who craves further detail. This is an excellent issue of the Reviews in Mineralogy & Geochemistry series, well written and highly accessible to a wide audience of geoscientists. It will also appeal to post-graduate students interested in mantle geochemistry and to advanced university undergraduates seeking good background reading during their last years of study. At only US$40, with discounts available for members of the Mineralogical Society of America and the Geochemical Society, it is extremely good value.

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ST AMPHIBAL: THE PATRON SAINT OF MINERALOGY?

Fishermen have St Peter, blacksmiths have St Dunstan, but who oversees mineralogists as we work in the field or attend our analytical instruments? Geoscientists in mining have sometimes adopted patron saints, such as St Bridget, but I would like to propose that we adopt a figure from Romano-British history. You’ll see my reasons below.

The history of our proposed saint begins around 300 AD in Verulamium, then one of the most important social centres in Roman Britain. This was a time of persecution of Christians by the Roman emperor Diocletian, and in the far-flung parts of the empire, even in the wilds of Britain, explicit instructions were given to root out and execute Christians. Against this backdrop, a Briton in Verulamium named Alban gave shelter to a Christian preacher who was fleeing the authorities. During the evening, the priest made such a strong impression that Alban was converted to Christianity. When soldiers came for the preacher in the morning, Alban took the man’s cloak and presented himself as the priest they sought. This event is celebrated in the annals of the early British church – Alban was subsequently executed and thus became the first British martyr. The site of Alban’s shrine became a place of pilgrimage, and the town and Abbey of St Albans now occupy the site.

But what of the priest? There was no other record of him for 800 years, until Geoffrey of Monmouth described Alban’s martyrdom in 1130 in his History of the British Kings. Geoffrey provided the priest with a name – Amphibal – a name mineralogists will readily recognize. Geoffrey was repeating an account written in the fifth century by the historian Gildas. Rather embarrassingly for Geoffrey, he misread the reference to Alban taking the priest’s cloak (in Latin amphibialis) as a reference to the priest himself. Thus, however inaccurately, the priest who had been central to one of the most celebrated events in early English Christian history now had a name. With late medieval efficiency, Amphibal was soon furnished with other trappings of sainthood. He was given a detailed life history, published as the Acts of Saints Alban and Amphibal. And the final requirement for any medieval saint – a shrine – was provided around 1178 when Abbot Robert of St Albans declared one morning that he had been visited in a dream by St Alban who had divulgmed to him the resting place of St Amphibal. Subsequent excavations led to the discovery of several skeletons, the central of which was buried with a sword. The abbot’s forensic team, fuelled by expectation, declared the site the resting place of Amphibal and his followers, slain and buried with the fatal sword in a mass grave. In all likelihood, the site of the discovery – the Mound of the Banners, in Redbourn just outside St Albans – was an Iron Age burial mound in which modern archaeologists would expect several burials with grave goods including swords and knives. The bones attributed to Amphibal were moved to St Albans Abbey, placed next to his convert, and a small monastery dedicated to his memory was established at the site of the discovery.

Amphibal’s meteoric rise from unnamed priest to a major member of the calendar of British saints was fuelled by more than just heated imagination. In the economic conditions of the late 12th century, St Albans was losing pilgrims (and therefore income) to the new shrine of St Thomas Becket in Canterbury, and the arrival of a headline saint to rank alongside Alban was potentially important to buck the financial decline. It also had another significance for the Abbey – the Mound of the Banners on Redbourn common was land whose ownership had been the subject of dispute between the Abbey and the Earl of Warwick. The fact that Amphibal’s bones had been found on the common was taken as a divine indication that the land should be under the Abbey’s jurisdiction – not even the Earl of Warwick could argue with the word of Alban himself.

Therefore in medieval England the name ‘Amphibal’ was well known, albeit for different reasons than we might expect. He was a central figure among the English saints, and his feast day, June 24, was widely celebrated. Amphibal was not an uncommon Christian name in England. And that would have remained the case had it not been for the English reformation. Henry VIII of England broke links with the Roman Catholic Church, and in 1539 he seized all ecclesiastical possessions, among them the lands of St Albans Abbey. The monks who tended the monasteries at St Albans and Redbourn were evicted, and church lands, including St Amphibal’s monastery, were sold off at bargain basement prices. Henry’s son Edward VI further enforced Protestant philosophies as all the major shrines in the churches of England and Wales were systematically destroyed. Among them were the shrines of Alban and Amphibal: in a few hours the hammers of Edward’s soldiers reduced one of the most holy sites in England to rubble. With pilgrimage now frowned upon and the reverence of saints too close to idolatry for the tastes of the time, one of the most important figures in English church tradition was consigned to obscurity.

Two events have since helped restore the name of Amphibal. In the late 19th century, construction work in the Abbey’s south chapter revealed parts of the shrines of Alban and Amphibal, broken but still recognizable, filling the walls of the church. From these parts, both shrines have been largely reconstructed. Neither is entirely complete, probably since the faithful of the time sneaked in to take pieces as a personal talisman. If you ever visit St Albans, the shrine to St Amphibal is in the south nave.

About the same time, French mineralogist René-Just Haüy identified a dark mineral with two excellent cleavages that closely resembled pyroxene. Haüy was trained at the college of Navarre in Paris in classical languages and theology. He was commonly called Abbé Haüy after he was made an honorary canon of Notre Dame in Paris by Napoleon. Haüy’s choice of new mineral names reflected his classical education in Greek and Latin. However, it is also highly likely that he was familiar with the legend of St Alban, which was widely recounted across continental Europe. Indeed there are several churches dedicated to St Alban in France and Germany and there is a St Alban’s cathedral in Odense, Denmark. Haüy’s official etymology of the mineral name ‘amphibole’ is from the Greek αµφιβαλός (amphibolas) meaning ‘ambiguous’ because of its similarity to pyroxene, but forgive me if I like to think he also named it after the saint.

So if your mass spectrometer or electron probe is not functioning, if your fieldwork is going badly or if your students cannot identify feldspar in thin section, say a short prayer to St Amphibal. He is well placed to help and probably feeling largely forgotten.

Adrian Finch
University of St Andrews

WANTED

The Hudson Institute of Mineralogy, a not-for-profit organization chartered by the Board of Regents of the State University of New York, is seeking used analytical equipment, thin sections, and mineral specimens for its descriptive mineralogical laboratory and educational programs. We are dedicated to classical mineralogical research, preservation of mineral specimens, and educational outreach to primary and secondary school teachers and students. If your institution is upgrading its analytical equipment, we want your used, working devices. Further, if you are disposing of minerals, thin sections, or similar geological artifacts, let us put them to good use; aesthetics are unimportant, labels are! Please contact:

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Recently the Geochemical Society (GS) began to participate in the Council for Scientific Society Presidents (CSSP, Executive Director Marty Apple, Washington DC) on a trial basis. The CSSP (www.cssp.us) is an organization of presidents, presidents-elect, and recent past presidents of about sixty scientific federations and societies whose combined membership numbers well over 1.4 million scientists and educators in the USA. The aim of the CSSP is to provide a strong support voice to science and science education. Members of the Council currently include the Geological Society of America and the American Chemical Society, among many others.

The GS joined this group in order to learn about issues related to outreach and public advocacy of science. As a relatively small society, the GS has not traditionally played a big outreach role. The board of the GS decided to find out more about these issues, and so we have been paying the expenses of the president or vice president to attend the CSSP meetings each year.

Past President Tim Drever attended the CSSP meeting in Washington DC in December 2006. I attended the May 2006 and December 2007 meetings. The meetings are unlike any I have ever attended! In addition to a series of talks by speakers hand-picked by the executive director, we also interact with elected government officials, congressional staffers, directors of institutions such as the National Science Foundation, and pre-eminent scientists and educators.

I find the meetings intellectually stimulating: it has been especially interesting to learn how science is perceived by non-scientists in the US and abroad. I have also used the CSSP as a way to discuss GS problems with other society presidents. I have received advice about audits (we are currently a trial basis. The CSSP (www.cssp.us) is an organization of presidents, presidents-elect, and recent past presidents of about sixty scientific federations and societies whose combined membership numbers well over 1.4 million scientists and educators in the USA. The aim of the CSSP is to provide a strong support voice to science and science education. Members of the Council currently include the Geological Society of America and the American Chemical Society, among many others.

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As an undergraduate student at Université Laval, I walked by this display just about every day and did not realize its historical significance. The display represents what is thought to be the oldest mineral collection in Canada. It was one of the few mineral collections assembled by René-Just Haüy (1743–1822), the father of modern crystallography, and his assistant Henry Lucas and offered to North American teaching institutions. This collection was offered to the Séminaire de Québec in 1816. In 1852, it was transferred to Université Laval and is now part of the Musée de Géologie René-Bureau, housed in the Department of Geology and Geological Engineering.

Haüy, a priest, was a professor at the École nationale supérieure des mines de Paris from 1794 to 1802. Thereafter, he occupied the mineralogy chair at the Musée national d’histoire naturelle until his death in 1822. Haüy was the author of many important works, including *Essai d’une Théorie sur la Structure des Cristaux* (Paris, 1784), *Traité de Mineralogie* (Paris, 1801), and *Traité de Cristallographie* (Paris, 1817). He made important contributions to our knowledge of crystal symmetry and was largely responsible for transforming mineralogy and crystallography into a science. He lived during turbulent times in France. During the Revolution, he was imprisoned for his convictions but was later appointed to the Legion of Honour by Napoleon. It is said that few teachers have so thoroughly gained the affection of their students and the esteem and respect of their contemporaries. I wonder if his efforts to assemble mineral collections and send them to the New World were an 18th century attempt at outreach and public education.

Pierrette Tremblay
Québec, Canada
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