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President's Letter | October 2007

Prof. Susan L. Brantley

Why Geochemists Never Agree: It's All about the Data!

Susan L. Brantley, President of Geochemical Society

A National Science Foundation program officer once asked me: “Why can't geochemists ever agree?”He intended this question as an indictment of our community. Compared with other kinds of scientists, we geochemists are generally more disorganized and ineffective in promoting our own field. We seem to be uniquely challenged to agree on which programs should be funded, which approaches make the most sense, and what initiatives are the most exciting.

I believe that our failure to unite our voices as geochemists has a simple origin - it is the complexity of our subject. After 2 years as President of the Geochemical Society (GS), I have come to the conclusion that the GS can address this problem by leading the synthesis of geochemical data *because not only will it advance the science but it will unify the voices of geochemists.* In my parting comments here, I will expand on this idea.

The most successfully organized group of earth scientists of whom I am aware are the seismologists who self-organized into IRIS (www.iris.edu). The level of unity within IRIS has led to a global network of seismometers, shared equipment for seismological deployments, and shared data online. I would argue, however, that their data are less complex than our data. Think about it: seismologists measure the amplitude of ground motion versus time at many locations. I do not mean in anyway to disparage seismology; in fact, I am envious of their ability to collect large datasets, share them, and interpret them powerfully.

In contrast, geochemists measure the chemistry of the earth's atmosphere, hydrosphere, biosphere, and lithosphere. The chemistry of these envelopes varies from the relatively well-mixed atmosphere to the extremely poorly mixed lithosphere and biosphere. The parameters that have been measured from all these entities over the last 200 or so years can vary with space and time over a range of more than ten orders of magnitude. I propose that *the reason geochemistry is so complex sociologically and scientifically is the heterogeneity implicit in the chemistry of our world.*

Using a metaphor, physicists look at the *framework* of the earth - they look at the loom and the structure of the loom - while chemists look at the *materials* - the individual threads -- strung across the loom. As chemists, we love the complex beauty of this fabric, including the “threads” consisting of the 100 or so elements and the many species and isotopes per element. Furthermore, this lovely fabric is manifested as individual “cloths” that move around on the planet -- the 4500 or so minerals on earth, the untold numbers of biological entities, and the amorphous, gas, and liquid phases. These entities sequester elements and mix incompletely; therefore, the surface earth demonstrates extreme levels of heterogeneity that changes over space and time. It is precisely this complexity and heterogeneity that geochemists love to study.

The GS can move geochemistry forward scientifically and sociologically by promoting the synthesis of these geochemical datasets with an eye toward finding the important patterns that allow prediction. Specifically, the GS should catalyze the publication of geochemical data on the web.

Does this seem banal and uninteresting? It did to me at first. But now I see it as perhaps the best step toward unifying our disparate thoughts into a coherent voice. The difficult process of organizing all of our data into a useful resource on the web will require collaboration among the professional societies, the funding agencies, and the publishing houses.

Once multiple large datasets are accessible to all, we will have more geochemical minds considering the patterns that are manifest across scales of space and time. Importantly, we will not be able to understand those patterns, so we will rush to create the models explaining the patterns. As models explain the online data, we will notice that some data are missing. That will force us to develop better networks of earth and environmental observing systems. The synthesis of data will highlight inconsistencies in measurements and will force us to grit our teeth and agree how to make standard measurements. We will argue about how long a publicly financed scientist can keep public data private. All of these processes could be - and should be -- promoted by the GS.

To state my thesis succinctly using a paraphrase of a famous line from a recent U.S. Presidential election, “It's all about the data, stupid!”

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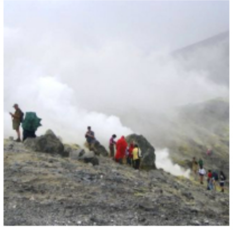
gn133 Featured Article:

Docks at the coast of Vulcano Island.

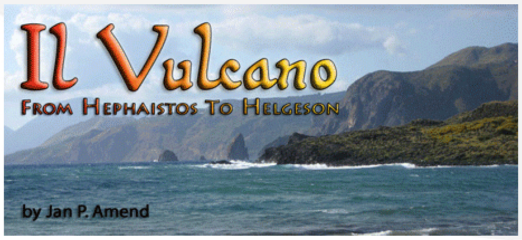
Slopes of Vulcano.

Fumarole vent near Vulcano, encru...

Fumarole vent located near Vulcan...



Amend research group working on t...



Without Sicily, Italy leaves no image in the soul.Sicily is the key to everything. - Johann Wolfgang von Goethe

Harold C. (Hal) Helgeson was, until the day he died, a practicing theoretical geochemist. While he truly cherished the results from an elegant computation, he also appreciated the messy reality of chaotic field data and the need for carefully crafted laboratory experiments. Helgeson was an ardent supporter of the notion put forth in 1943 by the microbial ecologist Claude ZoBell of "bacteria as geologic agents" (ZOBELL, 1943). This respect for the outcrop (where Helgeson claimed he could see the chemical potential axis coming at him) and an infatuation with the geo-bio interface conspired in 1991 to beckon Helgeson (with me in tow) to the hydrothermal system of Vulcano Island (Italy). During the 1980s, another microbial ecologist - Karl Stetter from the University of Regensburg in Germany - cultured many heat-loving microorganisms from Vulcano, discovering some of the highest temperature archaea and bacteria in the process. For decades, a cadre of geochemists had monitored and modeled the volcanic activity in southern Italy, especially at Mt. Vesuvius, Mt. Etna, and the Aeolian Islands. These predominantly Italian geochemists included Marco Leone, Marcello Carapezza, Mariano Valenza, Mario Nuccio, and Sergio Gurrieri, and they were close personal friends to Helgeson from an 'earlier life'.

The geochemists, however, were unaware of the thermophilic microorganisms in their volcanic back yard, and the microbiologists were equally unaware of the geochemistry that defined the thermophile habitats. Helgeson tried to change all that. He introduced his Sicilian friends to the literature of Stetter, John Baross, Wolfram Zillig, and other thermophile enthusiasts; and he visited Stetter in Bavaria to lecture him on the importance of geochemistry in microbiology - that meeting did not go well - Helgeson told anyone who would listen that the best, and perhaps only, way to really understand these extremophilic organisms in their natural environments, required an integration of quantitative geochemical methods with the myriad molecular methods that were revolutionizing (geo)biology. And for reasons scientific, pragmatic, historical, geographic, and culinary, Vulcano was the site of choice. What follows here is an introduction for some, an update for others, and perhaps a lesson for all of Vulcano's unique place in the geobiology and geochemistry of hot life.

Vulcano is the southern-most of the seven islands that, together with several seamounts, form the ~200 km long Aeolian arc in the Tyrrhenian Sea north of Sicily. This arc and associated back-arc basin are part of a complex that includes the subducting African plate under the southern part of the Italian peninsula (BARBERI et al., 1973; BARBERI et al., 1974; DE ASTIS et al., 1997; ELLAM et al., 1989; KELLER, 1974). Structurally, Vulcano and the islands of Lipari and Salina form a ridge inside a roughly NW-SE trending graben that dissects the volcanic arc (BARBERI et al., 1994). This ridge and graben system is part of the Tindari-Letojanni right-lateral strike-slip fault system that dominates the regional tectonics in northern Sicily (MAZZUOLI et al., 1995; VENTURA et al., 1999). Along the entire Aeolian arc, shallow-sea hydrothermal sources are ubiquitous (GUGLIANDOLO et al., 1999), and at Vulcano, can be readily accessed in geothermal wells, heated sediment seeps, and two-phase submarine springs. Subaerial volcanic activity in this region is limited to Stromboli and Vulcano. At Stromboli, this is manifested as small, short-lived explosions of viscous lava ("strombolian"), and at Vulcano, as high temperature fumaroles around the rim and on the flank of La Fossa caldera. Vulcano, in particular, has experienced a complex volcanic evolution that has produced lavas ranging in composition from tephrites and shoshonites to trachytes and rhyolites (DE ASTIS et al., 1997; KELLER, 1980), with the oldest lavas geochemically dated to only 120 ka (DE ASTIS et al., 1989) and the youngest recorded in black-and-white photography.

In fact, for the past circa 2500 years, Vulcano's eruptive history has been recorded directly by human observation, starting with the Greeks who settled these islands around 580 BC. Highlights of this recent history include the first eruption of the current active cone of La Fossa around 475 BC; the emergence from the sea of the small edifice of Vulcanello in 183 BC, followed by many hundreds of years of relative quiescence punctuated by occasional explosive activity from Vulcanello and La Fossa; the formation of an isthmus that joined Vulcano and Vulcanello in 1550, thereby creating the famous Baia di Levante (see below); and the final eruptive period that ended 22 March 1890. Vulcano so impressed the ancient Greeks that they considered it the home of Hephaistos - god of fire, son of Hera, husband of Aphrodite, master smith, and patron of craftsmen. In his fiery home beneath Vulcano, Hephaistos designed an invisible net that entangled his wife with her lover Ares, he made the armor for the warrior Achilles, and hammered out lightning bolts for Zeus. Greek mythology also tells of King Aeolus - for whom these islands are named - who was appointed by Zeus as

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keeper of all the winds. It was Aeolus who presented Odysseus with a bag of wind for his voyage home to Ithaca after the Trojan War.

Vulcano is famous as the namesake of all the world’s volcanoes, as a centerpiece in Greek (and Roman) mythology, and, because of the more than ten thousand tourists who arrive every summer, as arguably Italy’s most dangerous volcano. But in biogeochemistry, Vulcano is famous as home to more cultured hyperthermophiles than any other place on Earth. Hyperthermophiles are organisms with optimum growth temperatures of at least 80 °C. In fact, the first isolated organism to thrive at temperatures above 100 °C was the sulfur reducing archaeon *Pyrodictium occultum* (STETTER, 1982). Later, the furious fireball, *Pyrococcus furiosus*, was cultured and characterized; it is the source of a very thermostable, commercially available DNA polymerase (FIALA and STETTER, 1986). *Archaeoglobus fulgidus* still holds the record as the highest temperature marine sulfate reducer (STETTER, 1988; STETTER et al., 1987), and *Ferroglobus placidus* couples nitrate reduction with iron oxidation to drive its biochemical machinery (HAFENBRADL et al., 1996). Two of the deepest, most slowly evolving, and highest temperature lineages in the domain bacteria are *Thermotoga maritima* (HUBER et al., 1986) and *Aquifex aeolicus* (DECKERT et al., 1998) - their genomes were among the first from any organism to be fully sequenced. Aquifex, Latin for the ‘water maker’, can extract energy from the Knallgas reaction, in which molecular hydrogen and molecular oxygen are combined with a bang (‘Knall’ in German). An isolate from a geothermal well, *Palaeococcus helgesonii*, may provide insight into the shallow subsurface biosphere (AMEND et al., 2003a), and it is also one of the rare oxygen tolerant hyperthermophiles. These, and other thermophilic and hyperthermophilic strains, were discovered, and in some cases found only at Vulcano. In other words, the hydrothermal system at the Baia di Levante could be considered the type locality of these heat-loving archaea and bacteria.

The thermophile diversity at Vulcano is, of course, far greater than that represented by these cultivated strains. Sequences of DNA extracted from water and sediment samples documented that most of the archaea and bacteria belong to phylogenetic groups made up entirely of uncultured organisms (ROGERS, 2006). As just one example, the archaeal DNA from a geothermal well (Pozzo Istmo) points to more than a dozen crenarchaeal, euryarchaeal, and korarchaeal lineages belonging to phylogenetic groups that have no cultured representatives at all (ROGERS and AMEND, 2005). It was, however, comforting to observe that one of the sequences from Pozzo Istmo was nearly identical (99%) to *Palaeococcus helgesonii*, the euryarchaeon isolated previously from this well (AMEND et al., 2003a).

Other studies further demonstrated the phylogenetic diversity at Vulcano, but also provided insight into the catabolic diversity. Using fluorescent labels to tag specific subgroups of archaeal and bacterial cells in Vulcano sediments, all of the key thermophilic and hyperthermophilic groups (except methanogens) were identified. These included the fermenting Thermococcales and Thermotogales, and the sulfate reducing Archaeoglobales (RUSCH and AMEND, 2004). These results matched beautifully with a laboratory incubation study, where 14C-labeled substrates were fermented by the naturally occurring hyperthermophile community to yield carboxylic acids and H2 (TOR et al., 2003). These fermentation products then served as key reactants in sulfate reduction, the predominant terminal electron accepting process in the heated Vulcano sediments. Carbon-14 labeled methane was not detected, which is entirely consistent with the absence of methanogens in the culturing trials, gene surveys, and fluorescent labeling studies mentioned above.

Why does Vulcano harbor so many thermophiles?

The expansive thermophile diversity at Vulcano may be enabled by the vast menu of available redox reactions. Life, whether microbial or macrobial, photosynthetic or chemosynthetic, lithotrophic or heterotrophic, runs on energy harvested from electron transfer. Redox disequilibria equate to potential catabolic energy. The heated sediments, shallow-sea vents, and geothermal wells in and around the Baia di Levante are characterized by hundreds, perhaps thousands, of such redox disequilibria among organic and inorganic aqueous compounds, gases, and minerals (AMEND et al., 2004; AMEND et al., 2003b; ROGERS and AMEND, 2005; ROGERS and AMEND, 2006; ROGERS et al., 2007; SKOOG et al., 2007). Many such reactions are now well-documented catabolisms, including aerobic respiration, sulfur and sulfate reduction, the Knallgas reaction, fermentation, and iron redox.

However, many other redox reactions that are also energy-yielding at Vulcano, are completely unknown as catabolic strategies. Thus, they can be viewed as potential catabolisms.Their potential as microbial food is based on thermodynamic principles, i.e., a negative Gibbs energy of reaction (ΔGr) at the temperature, pressure, and chemical composition that obtain at the site of interest. While some will cringe at the thought of using thermodynamics to predict biochemistry (‘isn’t it all about kinetics?’), it should be reaffirmed that such an approach has a long and successful track record. For example, the existence of anaerobic ammonia oxidation (anammox) was hypothesized from negative Gibbs energies (BRODA, 1977) nearly 20 years prior to its experimental confirmation (VAN DE GRAAF et al., 1995). It took even longer to demonstrate the anaerobic oxidation of methane (AOM) (BOETIUS et al., 2000; HINRICHS et al., 1999; ORPHAN et al., 2001), which, also had been predicted on thermodynamic grounds (BARNES and GOLDBERG, 1976). Simply put, a redox reaction with a negative ΔGr is in the running as a potential energy source for life, but one with a positive ΔGr is not.

It is certainly not surprising that the reduction of elemental sulfur (S0), written as

H2(aq) + S0 ? H2S(aq), (1)

is exergonic (energy-yielding) at Vulcano. After all, the widespread yellow sulfur crystals and pervasive sulfidic odor hint instantaneously at its occurrence. The knowledge that numerous Vulcano thermophiles make their living by mediating this seemingly simple reaction lends further support (FISCHER et al., 1983; STETTER, 1982; STETTER et al., 1983). However, it is perhaps surprising how little energy is released from this apparently ecologically important process. Gibbs energy calculations (AMEND et al., 2004; AMEND et al., 2003b; ROGERS et al., 2007) show that in the hydrothermal sites around the Baia di Levante, reaction (1) yields only 8-21 kJ per mole of electrons transferred. The energy yield is even less impressive from lithotrophic sulfate reduction

(3-18 kJ/mol e-),

SO42- + 4H2(aq) + 2H+ ? H2S(aq) + 4H2O, (2)

and sulfur disproportionation (<12 kJ/mol e-),

4S0 + 4H2O ? SO42- + 3H2S(aq) + 2H+, (3)

to name but two documented catabolisms in Vulcano thermophiles. Compared with the aerobic respiration of glucose, which yields about 115 kJ/mol e-, these chemolithotrophic energy sources are truly anemic.

This raises the question if all heat-loving microbial residents of the Baia di Levante survive on such paltry fuel supplies? And further, if perhaps a large array of redox reactions, each with low energy-yields, are a prerequisite for the broad diversity observed at Vulcano? The answers are clearly ‘no’. In situ, the aforementioned Aquifex could gain ~100 kJ/mol e- from the Knallgas reaction, and Ferroglobus might extract as much as 55 kJ/mol e- from the oxidation of ferrous iron with nitrate (AMEND et al., 2003b; ROGERS et al., 2007). This is not to mention the energy from aerobic respiration of organic compounds, which releases as much 120 kJ/mol e- (ROGERS and AMEND, 2006). Of the many hundreds of potential catabolisms at Vulcano (redox reactions with negative ΔGr), only a small subset are currently known as actual catabolisms. However, recall that despite the success in culturing heat-loving archaea and bacteria from Vulcano, most of the microbial diversity still is known only as gene sequences; there is no physiologic information for most of the microbial community. Perhaps culturing these “unculturables” requires media recipes that rely less on what has worked previously in microbiology, and more on what is plausible from geochemistry arguments.

Perhaps some of the “unculturables” extract energy from these potential catabolisms. For example, anaerobic oxidation of sulfides with nitrate or nitrite is unknown in Vulcano thermophily, but organisms with the proper biochemistries could liberate 85-105 kJ/mol e- from these redox couples at the various hydrothermal locations of the Baia di Levante. A second example, and perhaps one of the most intriguing scenarios, relies on ferric iron as terminal electron acceptor in the oxidation of reduced N- and S-compounds. Especially in the acidic parts of the Vulcano hydrothermal system, these redox reactions are highly exergonic, yielding >60 kJ/mol e-. And since FeIII is predominantly in solid form, commonly as (oxy)hydroxides, cells might be physically attached to the terminal electron acceptor while patiently waiting for the electron donor to flow past in the fluid phase. Of course, these few examples barely scratch the surface of plausible catabolisms; heterotrophy, both the respiration and fermentation of organic compounds, introduces near endless uninvestigated possibilities.

Vulcano is a special place, but I do not want to imply that it is uniquely suited for expansive thermophile diversity. Other places have similarly appealing attributes for hot life. For example, the hot springs of Yellowstone National Park (USA) boast an impressive number of exergonic redox reactions (MEYER-DOMBARD, 2004). At one locale, Obsidian Pool, the Gibbs energies of 182 potential chemolithotrophic catabolisms were quantified, with energy yields ranging from near 0 to >100 kJ/mol e- (SHOCK et al., 2005). And, like at Vulcano, gene surveys at Yellowstone have shown that the phylogenetic diversity (and arguably the catabolic diversity) far exceeds what is known based on culturing work (MEYER-DOMBARD, 2004; MEYER-DOMBARD et al., 2005). Deep-sea vent systems are also famous thermophile hunting grounds, but the range of energy-yields from the broad spectrum of redox couples there is generally less than that in shallow-sea and continental hydrothermal systems (AMEND et al., 2004). Deep-sea vent samples are also far more difficult to collect than their surface counterparts, and thus, detailed fluid analyses, including speciation of organic molecules and redox sensitive inorganic compounds, are relatively few. Consequently, redox energy calculations are also relatively few (MCCOLLOM and SHOCK, 1997).

Vulcano is worth a visit. It has subaerial and submarine volcanic activity, it features tremendous geochemical diversity, its broad microbial community structure is documented with culture-dependent and culture-independent methods, its hydrothermal fluids and sediments are easily sampled, and several exploratory geothermal wells drilled in the 1950’s provide access to the shallow subsurface. Helgeson recognized in Vulcano a place where geochemistry and microbiology were inseparable, and where geochemists and microbiologists could in collaboration - and over lunch of insalata di polipo and a bottle of Regaleali - probe the geochemical limits of life and interrogate bacteria (and archaea) as geologic agents of the first magnitude. The ancient Greeks anointed Vulcano with mythical status, and based on high temperature biogeochemical investigations, this stinky little island certainly deserves its special place.

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Book Review: RiMG v. 64

Medical Mineralogy and Geochemistry

Reviews in Mineralogy and Geochemistry, Volume 64
Nita Sahai and Martin A.A. Schoonen, editors

I have thought for years that we (i.e., mineralogist and geochemists) should be spending more of our time looking inward into the human body to better understand the processes that are in operation there, as compared to our efforts to understand the physical systems on the earth. In reality, the knowledge we have gained by studying the latter can be directly applied to the former. Now, I believe, is the time to do such and this book provides a glimpse into how we can work to transfer our well-honed skills, which have developed over the years of study directed toward understanding earth processes, to understanding human processes.

The book is a collection of ten chapters; a brief introductory chapter, three that provide excellent general overviews of differing aspects of medical mineralogy and geochemistry, with the remaining six focusing on more specific issues. The three-overview chapters, in general, discuss: toxicology of earth materials (Plumlee et al.), the role of metal speciation in bioavailability (Reeder et al.), and formation of reactive oxygen species (Schoonen et al.). Also, each of these three chapters provides specific examples as well as some much-needed definitions of the terms used in these areas, which can be somewhat overwhelming to the geologist first starting work in these areas. I won't spend any time discussing these chapters, except to restate they are very well done and will provide a much-needed background information in their specific areas for years to come.

While the content of the above-mentioned chapters seems somewhat obvious, the other six chapters are slightly less so, at least based solely on their titles. Perl and Moalem discuss the connection between aluminium and Alzheimer's disease. Like many of you, I had heard mention of this in the popular media, but the facts as they present them are far different from what the limited knowledge I had before reading this chapter. The next chapter deals with prion diseases and their residence in soils. Just in case you don't know now what prion diseases are - think mad cow and chronic wasting diseases. To me these chapters were the farthest afield from my background, and I found them fascinating; and I think every geoscientist would also find them worth reading. It was so interesting to learn some of the science behind what is discussed in the popular media.

The next chapter by Huang et al. deals with a subject close to my research; coal workers pneumoconiosis, as well as my childhood. In my home area in the Midwest we called this disease "black lung" and it was caused from working in the pre-regulated coal mines. One very interesting aspect of this article deals with the relationship of the differing minerals present in the coal dust and how their presence or absences affects the disease.

The last three chapters all deal more directly with the "connections" between the inorganic and organic world. The first in this group is my Glimcher and discusses the structure of bone. The chapter gives an excellent overview of our current understanding of bone and the methods used to determine them. The next chapter by Cerruti and Sahai discusses bone and dental implants; and (pun intended) really is the connection between inorganic and organic materials.The last chapter by Livage and Coradin discusses living cells and oxides glasses. Again an incredibly interesting chapter that directly shows how what we have learned in the physical world can be applied to improving our human health.

In summary, often the purpose of a book review is help individuals decide if they wish to purchase the book being reviewed. However, in the case of this volume, as well as all past, and hopefully future, RIM and RiMG volumes, the cost is so low that anyone with even a slight interest in the subject area should purchase the volume. Also, and this volume is no exception, volume 64 continues the high quality of this series. As usual, all the chapters contain a wealth of references that all researchers interested in this area will find very useful.

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Nick's Picks (#133)

Making Geochemistry Green

With the recent announcement that former U.S. Vice President Al Gore was awarded the Nobel Peace Prize for his efforts on combating climate change, global warming has undoubtedly reached its highest point of social awareness to date. Most geochemists are perhaps encouraged by all of the recent public attention regardless of political slant. Increased interest around the world will likely translate into increased funding in the Earth sciences, particularly those involved with climate research. But we are not new to the concept of global warming; many geochemists have been fighting this battle for a long time. Other efforts to help curb global warming are almost strictly geochemistry problems, including carbon sequestration.

An additional research front in which geochemists are becoming more involved is energy-related research (see the June 2007 issue of Elements). Clearly, the future of our world's energy demand will rely on the expertise of geoscientists, but these technologies are still far away from contributing to a large portion of the global energy demand. For example, the U.S., which vies with China for the world's most greenhouse gas emissions, only gets 2% of its energy from renewable sources. While we strive towards increasing the efficiency and affordability of renewable technologies, many of us outside the heart of such research may be wondering what other tactics we can employ to advance these efforts. As you will see, we have a great deal to do, but perhaps none would be as significant as changing a few of our outdated practices in the laboratory. Here are a few links that will get you on your way to making your lab a little greener and a few more that will introduce geochemists to the concept of "Green Chemistry."

Improving The Laboratory

Close Your Hood! (C&EN, October 8, 2007, 44-45) "The average fume hood consumes as much energy as three houses!" This is an amazing statistic. Think about all the fume hoods in your lab/department. Are they properly maintained? Are they just used for storage? Do you have a system in place to make sure they are turned off at night?

Need Advice on Making Your Lab Green? Interactive Q&A from *The Scientist*. Experts from National Laboratories in the U.S., governmental agencies, and industry chime in to answer questions submitted online by readers. For more information, see the related article: Can Labs Go Green?

This Man Wants to Green Your Lab: Excellent interview in *Science* with soil ecologist Allen Doyle, the founder of the LabRATS program at the University of California, Santa Barbara. The LabRATS programs assesses deficiencies in standard laboratory operations on their campus. "The typical lab consumes four to five times as much energy as an equivalent-sized office or classroom, to say nothing of the huge amount of plastic, paper, and hazardous chemicals researchers go through." I doubt this information is new to everyone reading this, but it is striking to see it in print. Seven tips for making your lab a little bit greener according to Doyle are presented at the right, but you should definitely check out the entire article.

Seven tips for making your lab more energy efficient ***(From Science 318, 39-40; Oct 5, 2007)***
1. Close hood sashes and disable unused hoods
2. Defrost freezers regularly
3. Turn off equipment at night
4. Borrow and lend used equipment
5. Share surplus chemicals and use environmentally friendly reagents
6. Request removal of unused light bulbs from ceiling fixtures
7. Print on both sides

Green (Geo)Chemistry?

The U.S. EPA defines Green Chemistry as "the use of chemistry for pollution prevention. More specifically, green chemistry is the design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances." As evident from the links below, Green Chemistry is a major scientific initiative right now. As further evidence, many universities are offering undergraduate and graduate courses in Green Chemistry, hoping to train a new breed of environmentally-responsible chemists. But what about *geo*chemists? Nothing came up on Google when I searched "Green Geochemistry." If it is ever to catch on, we need to be cognizant of ways to reduce waste, increase energy efficiency, and increase safety in chemical synthesis. Although geochemists do not typically synthesize many chemicals, most of the principals of Green Chemistry are still applicable.

The Twelve Principles of Green Chemstry ***(from The U.S. EPA)***
1. Prevent waste
2. Design safer chemicals and products
3. Design less hazardous chemical syntheses
4. Use renewable feedstocks
5. Use catalysts, not stoichiometric reagents
6. Avoid chemical derivatives
7. Maximize atom economy
8. Use safer solvents and reaction conditions
9. Increase energy efficiency
10. Design chemicals andproducts to degrade after use
11. Analyze in real time to prevent pollution
12. Minimize the potential for accidents

Green Chemistry resources on the web:

Green Chemistry Joins College Curriculum: AP article from Oct 9, 2007

U.S. EPA's Green Chemistry Program: The largest resource for Green Chemistry on the web. See table at right.

Green Chemistry (Journal):Published by the Royal Society of Chemistry (RSC), Green Chem. is a monthly publication devoted to sustainable practices in the laboratory.

The Green Chemistry Network (RSC): Tons of resources for the green chemist including PowerPoint slides for the classroom, a message board, and tons of great links.

The Green Chemistry Institute (ACS): A

GN133 Content

President's Letter | October 2007
by Susan L. Brantley

Il Vulcano From Hephaistos to Helgeson
by Jan P. Amend

Book Review: RiMG v. 64, Medical Mineralogy and Geochemistry
by Mickey E. Gunter

Nick's Picks (#133) Making Geochemistry Green
by Nicholas Wigginton

Who's Nick?

Nick is Nicholas Wigginton.

He is a Ph.D Candidate in the Department of Geosciences at Virginia Tech. If you have a pick or a suggestion for Nick please contact him at wigginto@vt.edu.

partnership between the American
Chemical Society and the U.S. EPA.Great
source for Green Chemistry in the news, as well as information about Green Chemistry at conferences.

Green Chemistry Takes Root: Article in U.S.A. Today on Green Chemistry (Nov. 22, 2004)

Green Chemistry Assistant: A web-based program for chemistry students published by St. Olaf College (Minnesota, USA).