BOUNTIES FROM THE EARTH

Gordon Brown

Most of us, including me, use the products of modern technology without fully appreciating what raw Earth materials are required to make a cell phone, a modern internal combustion engine, an aluminum beer can, or the concrete used in buildings. Moreover, many of us don't know much about the processes by which these common products and materials are made, such as the electrolytic production of aluminum from bauxite (discovered by Hall and Héroult in 1886), or the production of electronic-grade, single-crystal silicon needed to make silicon semiconductors. In a more general sense, many of us don't fully appreciate the role played by geochemical and mineralogical processes in concentrating Nature's bounty of raw materials into the form of metal, mineral, and hydrocarbon deposits that are increasingly needed by the 7.4 billion humans currently inhabiting Earth.

My interest in the raw materials needed to build the structures and products of ancient and modern civilization began when I taught my first mineralogy course at Princeton University in 1971. I realized I could make the study of minerals more interesting by discussing some of their ancient uses. For example, did you know that Roman soldiers were paid salt rations and that this led to the saying "a person is not worth his salt," as well as to the word "salary" (Hurlbut 1970)? Did you know that lead (symbol Pb, from the word "plumbum") smelted from galena was used by Romans to make water pipes—hence the origin of the word "plumbing"—as well as to make lead containers for storing their wine and for preparing sapa, which was a sweet syrup made by boiling acidic wine in lead containers? The sapa, consisting mainly of lead acetate, was added to wine to sweeten it (Lessler 1988). Did you know that the Romans made primitive cement by burning limestone to produce quicklime and that a controversy still exists about whether the Great Pyramids of Giza were made either by molding limestone blocks in place from a geopolymeric concrete or by quarrying limestone blocks and moving them into place (Folk and Campbell 1992; Barsoum et al. 2006)?

My interest in the modern uses of minerals was further piqued in 1984 when I visited the British Museum of Science in London (UK) and saw a fascinating exhibit showing the minerals that are needed to fabricate the components of an internal combustion engine. That well-designed exhibit underscored the fact that modern society is profoundly impacted by the minerals and rocks that we extract and then process into the various raw materials needed to make cement, window and flat-panel glass, glass ceramics, aluminum and steel, and modern electronic devices such as cell phones and the MacBook Pro I used to write this editorial.

Internal combustion engines are complicated, but not nearly as complicated as the iPhone in my pocket. When one "googles" the raw materials needed to build an iPhone, a list of components is usually found, but little information is given about the minerals or elements that go into building the circuit board, SIM card, batteries, and other iPhone components. So, we tend not to think about the raw materials necessary to manufacture such devices. After some digging, however, I found the figure below (Fig. 1) showing the rare earth elements (REEs) needed to make key components of an iPhone. These and other REEs are concentrated by geochemical processes in economic deposits of REE-containing minerals, notably bastnaesite, monazite, xenotime, and lateritic ores in which REEs are adsorbed onto clay minerals. This is but one example of how geochemistry and mineralogy have had a profound impact on modern civilization. Can you imagine living in the modern world without a cell phone?

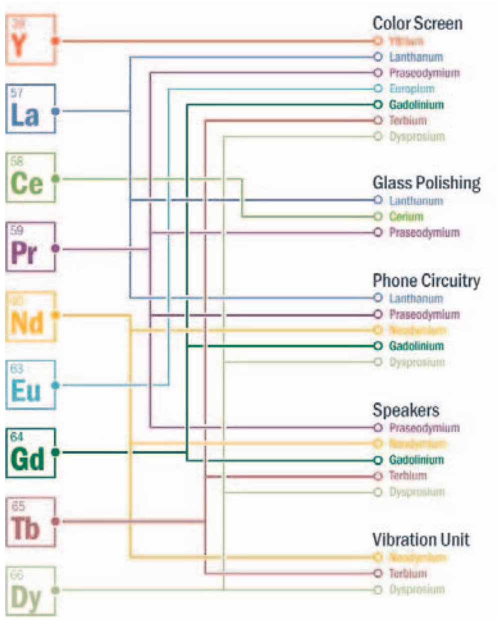

FIGURE 1 The nine rare earth elements used in the components of an iPhone. IMAGE REPRODUCED WITH PERMISSION FROM GREENE (2012).

This issue of *Elements* provides examples of the impacts of geochemistry and mineralogy on modern civilization, including the discovery and environmentally sustainable development of metal and mineral deposits, the importance of minerals and mineral–microbe interactions to environmental problems, the symbiotic relationship between mineralogy and materials science, in addition to the importance of geochemistry in understanding anthropogenic impacts on chemical contamination of groundwater, surface waters, soils, and air at major urban centers. Also included are thought-provoking articles describing the use of stable isotopes to detect adulterated foods, to conduct forensic investigations of criminal activities, and to detect and

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THIS ISSUE

Geoscientists impact society. They find new mineral resources, mitigate environmental problems, create designer materials for industrial applications, advance medical testing methods, track food industry products, aid in law enforcement activities, and so much more. One can't say that "the sky is the limit" for geoscientists, for they are also studying the worlds beyond our planet and applying that knowledge to benefit society. The authors in this issue present several exciting facets of the seemingly limitless potential of our science. Ludden et al. (pp 253–258) also remind us that a geoscientist's job involves more than expanding the scientific knowledge base. It is our responsability to effectively communicate our knowledge and, ultimately, to translate it into answers and solutions that can be used by industry, society, and policymakers. It is a difficult job but, if done well, the outcome will surely be beneficial to the future of our science and society.

THE IMPACT OF *ELEMENTS*

This issue is focused on the impacts of geochemisty, so it is a good occasion to update our readers on the "impact" of *Elements*. *Elements* was designed to impact our community by delivering a high-quality scientific magazine that delivers thematic review articles, opinion pieces, society news articles, advertisements for products and services related to our community, job postings, book reviews, and topical features (see below).

The standard yardstick by which to measure "impact" is Thomas Reuters' Impact Factor and article citation rates. The 2015 Journal Citation Reports®, released in June, indicated that *Elements*' 2014 impact factor is 4.463, which makes it rank 3rd among mineralogy journals and 7th among geochemistry and geophysics journals. In 2014, our 379 citable articles had 1866 citations, giving an average of 4.9 per article. *Elements* has had over 8600 citations since its inaugural issue in 2005.

As of August 2015, the most highly cited issues since the time of publication are:

- v3n1 – "Zircon, Tiny but Timely" (754)
- v2n2 – "Arsenic" (451)
- v4n5 – "CO_2 Sequestration" (403)
- v1n5 – "Large Igneous Provinces" (356)
- v3n4 – "Frontiers in Textural and Microgeochemical Analysis" (340)

These numbers, along with the continued commitment of the 17 participating societies to produce this magazine, the high-quality products and services advertised in our issues, and the over 15,000 members who continue to receive each issue are just a few indicators that *Elements* magazine is making a positive impact on our scientific community.

ELEMENTS FEATURES

Elements is your magazine, and you can contribute to the many features—some published regularly, others from time to time. Unless otherwise indicated, send your ideas and contributions to Jodi Rosso (jrosso.elements@gmail.com).

People in the News highlights the accomplishments of members of our community: awards they have received, especially outside our community, or exciting new projects in which they are engaged.

Triple Point raises issues of broad interest to the readers of *Elements* and explores different aspects of our science (teaching, publishing, historical aspects, etc.), our societies, funding, policy, and political issues.

The ***Elements*' Toolbox** presents new technological developments of interest to our readers. You can send your ideas and suggestions for coverage to Michael Wiedenbeck (michawi@gfz-postdam.de).

Cosmo*Elements* keeps us in touch with exciting discoveries in cosmochemistry, provides short articles that can be used in the classroom, and offers reports on space missions that carry geochemical and mineralogical instruments. Contact Cari Corrigan (corrigan@si.edu).

A Life in Science is dedicated to supporting the career aspirations and progress of geoscientists, from students to retired professionals. It focuses on ways to make your life easier and to help you establish a satisfying career in the geosciences. Contact Penny King (penny.king@anu.edu.au).

Travelogue: Have you done fieldwork in, or traveled to, an exotic location? Consider writing an account of your experiences.

Parting Shots fills one of the back pages, and its job is to entertain, to provide something lighter than all the serious stuff in the earlier pages. Intriguing, beautiful, or baffling photographs take the reader on a relaxing voyage into the web of connections that makes the realm of *Elements* so enthralling. Contact Ian Parsons (ian.parsons@ed.ac.uk).

Mineralogy Matters is dedicated to promoting the importance of the subject of mineralogy. Contact David Vaughan (david.vaughan@manchester.ac.uk).

Jodi Rosso, Executive Editor

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follow the progress of human diseases such as cancer. An overriding message in these articles is the importance of analytical methods that can detect low concentrations of elements and isotopes and map their distribution in solids, soils, water, air, food, and human tissue. These articles illustrate very well the impact that geochemistry is having on modern society through well-chosen examples and case studies.

In closing, let's consider cement, one of the most important commodities derived from natural raw materials. Portland cement, the most common variety, is made by heating impure limestone (i.e. containing aluminosilicates) with additives such as shale, sand, slag, fly ash, bauxite, and iron ore, all of which then produces a material called klinker. A small amount of gypsum or anhydrite (typically 5% of the total) is added to the klinker, and the mixture is finely ground and mixed with water. Complex chemical reactions occurring in the klinker–water mixture result in new phases, including needle-shaped crystals of ettringite, a sulfate that adds great strength to Portland cement (Cotterill 2008). It's somewhat mind-boggling to find out that 4,180,000,000 metric tonnes of cement (mostly Portland cement) was used by humans in 2014 (USGS 2015), with the three largest producers—China, India, USA—responsible for consuming 59.8%, 6.7%, and 2.0%, respectively. Earth's bounty of natural resources will continue to be utilized by humans to build our infrastructure and transportation systems, to power our society, and to develop even more useful personal devices than the cell phone. However, we must continue developing and practicing environmentally sounds methods of extracting this bounty.

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