THE CO_2 CHALLENGE – A CALL TO ACTION

Susan L. S. Stipp

Since we first walked upright and contemplated our destiny, humankind has recognised its struggle with Nature. Humans were fragile, at the mercy of wind, sun, water, hunger and disease. Our ancestors soon began to engineer their world, to build, to cut forests and plough, to rearrange water and rock, and to make ever more dramatic changes to the face of the Earth. Civilisation developed, but people were still at the mercy of the elements. Even as late as the mid-eighteenth century, when Rousseau, Voltaire and other philosophers were debating Man and Nature, human existence was fragile. Now, our engineering has improved the quality of life, but has also triggered unexpected consequences that put humankind and the biosphere at risk. Nature has become fragile.

We learned to make fire and our thirst for energy began, but it was only when fossil fuels came into widespread use that the carbon cycle became unbalanced. Extra CO_2 in the Earth's atmosphere holds in heat, thus warming permafrost, promoting the release of more carbon dioxide and methane, increasing the heat-holding capacity of our global greenhouse. Global warming and climate change are one risk. In the air and in the sea, CO_2 reacts with water, forming carbonic acid, H_2CO_3, driving pH down. More acidic seawater is a second risk.

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Concern about the effects of increased CO_2 is not a sudden development. I remember people talking about "heat pollution" more than 30 years ago. I remember my children having less snow to roll in than I had as a child. Many of us remember Bob and Betty Berner's book on the carbon cycle. Scientists have been publishing clear results for years, but society, government and industry did not hear the message. In the 1990s, models developed by John Edmonds and many others were predicting serious consequences if CO_2 emissions were not cut. I heard a talk by Fred Mackenzie at a conference in Granada in December, 2000, when he presented modelling results that showed that even if we stopped burning fossil fuel that day, global temperature increase would not be stemmed for many years. The message was clear that it was already too late to prevent global warming, but it took several more years before the message began to be heard. This is not a question of belief. One cannot ask if one "believes" in global warming the way one might ask another if he believes in Santa. Now, abundant evidence leaves little room for doubt that climate is changing. Eleven of the last twelve winters have been the warmest since record taking began. Ice over the Arctic Ocean and Antarctica is thinning. Continued warming will have dramatic and devastating consequences for populations living near sea level – for humans as well as biota.

One wonders what made society begin to hear the wake-up call. Was it more frequent and more violent storms and droughts than we remember? A documentary by a prominent American politician? The alarming number of threatened species? Polar bears drowning from exhaustion? It has become an emotional and controversial topic. In society, in the press and at scientific meetings, new ideas are being discussed, new technologies developed. Now, in some countries, there is a strong desire in industry and government to respond. There is talk of stronger global agreements. But there is also complacency – or worse, an attitude that it is "too expensive" to change our energy-greedy lifestyle. We are beginning to hear about models that promote a business-as-usual scenario, that optimise on the best adaptation strategies. People *are* adaptable – at least those who have resources. For those who do not, drought, flooding and changes in disease patterns will bring suffering.

In August, at a conference in London, I heard Fred Mackenzie speak again, this time on changes in seawater acidity. The pH of the world's oceans has already dropped by 0.1 pH unit as a direct result of CO_2 uptake. Corals are already threatened, and other calcium carbonate–producing organisms will soon follow because $CaCO_3$ stability depends on pH. Fred talked about a "tipping point", when the buffer capacity of seawater is exhausted. The resulting pH drop would have dramatic consequences for marine organisms. An example is *Emiliania huxleyi*, a species of algae that blooms during the North Atlantic summer. It is characterised by elaborate, microscopic coccolithospheres of calcite. The algae produce oxygen and fix carbon dioxide in mineral form. Species death caused by ocean water pH below that of calcite stability could alter global O_2 and CO_2 balances and remove a link in the food chain. There are many other examples. Ocean acidification puts biodiversity at risk.

The geological record might offer some comfort. It tells us that conditions on the Earth have never been constant. Climate has changed and species have evolved in response. Slow change has promoted diversity. However, the rock history book also warns us that catastrophic changes in conditions are accompanied by mass extinctions. The concern about warmer climate and more acidic oceans is that change is occurring very fast – too fast for species to adapt.

Of course we must stop burning fossil fuels and develop sustainable alternatives, such as wind, solar, wave and geothermal power. We should not be burning hydrocarbons; they are too valuable a resource for petrochemical production. But even if we stop burning oil, gas and coal tomorrow, it would take years for CO_2 concentration to return to early-twentieth-century levels. And we cannot stop using fossil fuels tomorrow. In this issue of

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PRINCIPAL EDITORS
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tremblpi@ete.inrs.ca

EDITORIAL OFFICE
Université du Québec
Institut national de la recherche scientifique
Eau, Terre et Environnement
Natural Resources Canada / Ressources naturelles Canada
Geological Survey of Canada / Commission géologique du Canada
PARTNERS OF THE QUÉBEC GEOSCIENCE CENTRE
490, rue de la Couronne
Québec (Québec) G1K 9A9 Canada
Tel.: 418-654-2606
Fax: 418-654-2525

Layout: POULIOT GUAY GRAPHISTES
Copy editor: THOMAS CLARK
Proofreaders: THOMAS CLARK, DOLORES DURANT
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THIS ISSUE

This issue presents the current state of science on the topic of CO_2 sequestration. Five thematic articles discuss the technical aspects and the logistical pros and cons of the various CO_2-storage options now being evaluated. This issue required extraordinary care and attention to detail because of its relevance to the ongoing debate about climate change, and Principal Editor Susan Stipp worked very hard with the guest editors and authors to ensure a timely and balanced coverage. We thank them all for their commitment and patience.

In this issue, our thematic coverage is preceded by three short pieces providing perspectives from industry, science, and the political domain. They set the stage for the articles that follow. We plan to use this format from time to time, when the subject matter would benefit from such a presentation.

ELEMENTS' 2007 IMPACT FACTOR AT 2.23

Since its first issue was published, in 2005, *Elements* has seen its impact factor climb from 0 to 2.23 in 2007. Considering the rate of increase, it is likely to continue its upward trend. Here is a list of the 10 most cited articles as of mid-September, 2008:

- Charlet L, Polya DA (2006) Arsenic in shallow, reducing groundwaters in southern Asia: An environmental health disaster. Elements 2: 91-96 (*16 citations*)
- Self S, Thordarson T, Widdowson M (2005) Gas fluxes from flood basalt eruptions. Elements 1: 283-287 (*14*)
- Harley SL, Kelly NM, Moller A (2007) Zircon behaviour and the thermal histories of mountain chains. Elements 3: 25-30 (*13*)
- Ohtani E (2005) Water in the mantle. Elements 1: 25-30 (*13*)
- Vaughan DJ (2006) Arsenic. Elements 2: 71-75 (*12*)
- Ferris JP (2005) Mineral catalysis and prebiotic synthesis: Montmorillonite-catalyzed formation of RNA. Elements 1: 145-149 (*11*)
- Morin G, Calas G (2006) Arsenic in soils, mine tailings, and former industrial sites. Elements 2: 97-101 (*10*)
- Campbell IH (2005) Large igneous provinces and the mantle plume hypothesis. Elements 1: 265-269 (*10*)
- Wignall P (2005) The link between large igneous province eruptions and mass extinctions. Elements 1: 293-297 (*10*)

SOCIETY NEWS HIGHLIGHTS

As managing editor, I get to read the society news pages several times, and I always find lots of interesting items. Here are some I found particularly interesting in this issue. The International Association of Geoanalysts reports that a new osmium isotope reference material is now available for distribution (page 346). The Mineralogical Society of Great Britain and Ireland announces that it will cease publication of *MinAbs Online* at the end of 2008. On page 343 you can read a succinct history of *Mineralogical Abstracts*, which has been published since 1920. The Mineralogical Society of America reports on its plan for moving *American Mineralogist* to a paperless world (page 340). As most of the societies publishing a journal will eventually have to face this situation, we can take inspiration from their conclusions. I was also interested to read in the SFMC news (page 344) about the virtual gallery of mineralogy launched by the Museum National d'Histoire Naturelle. Relive or get a taste of the 2008 Goldschmidt Conference by checking the two-page spread provided by the Geochemical Society and the European Association for Geochemistry on pages 352 and 353.

MULTI-SOCIETY CATALOGUE

Our 2009 multi-society mineralogy/geochemistry catalogue is being mailed with this issue of *Elements*. This is the fourth catalogue we have published, and it is a collaborative effort among the participating societies. Please keep it as a reference for the coming year or give it to a colleague or student as an encouragement to join one of the participating societies. If each of us did this, the mineralogy-geochemistry-petrology community could double instantly. Imagine our impact! Membership in any of the participating societies includes a subscription to *Elements*.

Pierrette Tremblay, Managing Editor

We thank the Chemical Sciences, Geosciences and Biosciences Division, Office of Basic Energy Sciences, Office of Science, U.S. Department of Energy (DOE) for financial support of this issue.

EDITORIAL *(Cont'd from page 291)*

Elements, we present ways to remove CO_2 from the atmosphere and sequester it in a way that minimises risk to life at the Earth's surface. Also in this issue, we introduce a new feature called "Perspectives". The short articles, written by well-respected leaders from industry, academia and government, are intended to provide a platform that will stimulate constructive and cooperative discussion and development of solutions.

Humankind has engineered its way out of its vulnerability in the hands of Nature. Now, we stand with fragile Nature under our feet. Global warming is a serious concern. Increased acidity in the oceans is changing biological habitats.

It will take a concerted effort, and there will be tough choices for society, science, government and industry, in both the developed and the developing worlds. We need to reduce personal consumption of goods and energy. Society needs to accept responsibility and bear the costs of a lower-CO_2 world. We need serious commitment, now, from government and industry, at a global scale, but particularly from the developed countries. Hard decisions will require political and industrial leaders with courage, who are steadfast, especially in the shadow of a financial crisis.

The best way to meet the CO_2 challenge is through fundamental understanding of how our world works, in order to (1) provide the fastest and most direct way to develop sustainable energy-production methods and more efficient manufacturing, heating/cooling and transport, and (2) capture CO_2 from fixed-source contributors such as power plants and industry and convert it back to rock form, stable for geological time. A key is basic understanding of how rocks weather in the biosphere and how new minerals are formed. Our scientific community is the only one with the necessary set of skills to tell the world how to transfer carbon from the atmosphere into a stable environment. This is THE geochemical/mineralogical/petrological theme of the decade! How can we focus more of our creativity, training and academic positions on solving this problem? We have the opportunity – and a heavy responsibility – to pass to our children a world that they will be able to live in.

Western society has been dozing for 30 years, choosing to ignore the warnings, or believing they were wrong. They are not wrong. It's time to wake up, get our heads out of the sand, and do something.

Susan L. S. Stipp
University of Copenhagen
stipp@nano.ku.dk