

PRINCIPAL EDITORS

GORDON E. BROWN JR., Stanford University, USA (gordon.brown@stanford.edu)
 BERNARD J. WOOD, University of Oxford, UK (Bernie.Wood@earth.ox.ac.uk)
 FRIEDHELM VON BLANCKENBURG, GFZ Potsdam, Germany (fvb@gfz-potsdam.de)

EXECUTIVE COMMITTEE

COSTANZA BONADIMAN, Società Italiana di Mineralogia e Petrologia
 THOMAS D. BULLEN, International Association of GeoChemistry
 CATHERINE CORRIGAN, Meteoritical Society
 KATERINA M. DONTSOVA, The Clay Minerals Society
 BARBARA L. DUTROW, Mineralogical Society of America
 ANTON EISENHAEUER, Geochemical Society
 DANIEL J. FROST, European Association of Geochemistry, Chair
 BERNARD GROBÉTY, Swiss Society of Mineralogy and Petrology
 MARK E. HODSON, Mineralogical Society of Great Britain and Ireland
 HEATHER JAMIESON, Mineralogical Society of Canada
 MATTHEW I. LEYBOURNE, Association of Applied Geochemists
 GUY LIBOUREL, Société Française de Minéralogie et de Cristallographie
 KLAUS MEZGER, Deutsche Mineralogische Gesellschaft
 MAREK MICHALIK, Mineralogical Society of Poland
 JUAN J. MILLAN, Sociedad Española di Mineralogía
 YASUHIITO OSANAI, Japan Association of Mineralogical Sciences
 MICHAEL WIEDENBECK, International Association of Geonanalysts

EXECUTIVE EDITOR

JODI J. ROSSO (jrosso.elements@gmail.com)

EDITORIAL OFFICE



2710 Crimson Way, TWST 263
 Richland, WA 99354-1671, USA
 Tel/Fax: (509) 420-5331 (UTC-8)

Layout: POULIOT GUAY GRAPHISTES
 Copy editor: PATRICK ROYCROFT
 Proofreader: PATRICK ROYCROFT
 Printer: ALLEN PRESS

The publishers assume no responsibility for any statement of fact or opinion expressed in the published material. The appearance of advertising in this magazine does not constitute endorsement or approval of the quality or value of the products or of claims made for them.

www.elementsmagazine.org



DON'T MISS AN ISSUE OF ELEMENTS. Join a participating society today!

NUCLEAR WASTE DISPOSAL, CLIMATE CHANGE, AND BREXIT: THE IMPORTANCE OF AN EDUCATED PUBLIC

1811-5209/16/0227-\$0.00 DOI: 10.2113/gselements.12.4.227



Gordon E. Brown, Jr.

Modern society faces a variety of major challenges that will impact the quality of our lives. Of these, 15 have been singled out as “Global Challenges” by the Millennium Project (2014) (SEE FIGURE BELOW). One of the greatest of these challenges is the availability of sufficient clean water. Another is sustainable development and climate change. Much of the US public now accepts that the rapidly increasing levels of CO₂ in the atmosphere are caused by human activity, including the burning of fossil fuels. However, there is little consensus among US scientists, engineers, politicians, and the public about how to reduce atmospheric CO₂ levels, especially at a time when developing countries are seeking the same standard of living enjoyed by the world’s most industrialized countries. Yet another challenge, which is related both to the burning of fossil fuels and to climate change, is adequate energy to power our global society. As the World Nuclear Association (WNA) has shown, nuclear energy is an attractive option: for example, France derives over 75% of its electricity from nuclear fission (WNA 2015). One of the major societal concerns limiting the widespread use of nuclear power, however, is safe disposal of nuclear waste, which is the topic of this issue of *Elements*. Other societal concerns about nuclear energy include the possibility of releasing into the environment radioactive material from a nuclear power plant. Such an event happened in March 2011 during the partial meltdown of the cores of three reactors at the Fukushima Daiichi nuclear power plant in Japan, the effects of which continue to this day through the interaction of groundwater with the melted cores (see the June 2012 issue of *Elements*). The Fukushima Daiichi event resulted in shifts in public opinion about

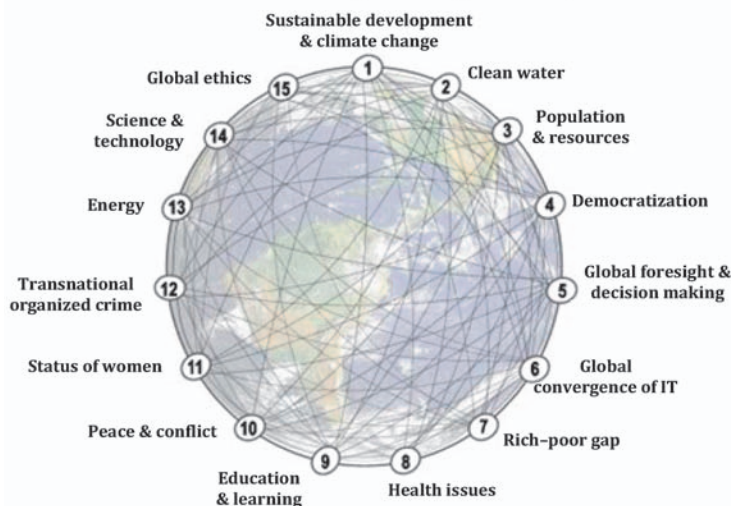
the safety of nuclear energy and contributed to Germany’s decision to eliminate nuclear power by 2022 (Appunn 2015). One result of this decision is the continued reliance by Germany on coal-fired power plants and by an increased reliance on wind and solar for electricity generation.

After reading the six articles in this issue, I am reminded of the complexity of the nuclear waste disposal problem, a complexity that has delayed final choices of waste disposal sites in most countries that have nuclear waste inventories. As pointed out in the introductory article of this issue “... there are, at present, no operating nuclear waste repositories for spent nuclear fuel from commercial nuclear power plants or for the high-level waste from the reprocessing of spent fuel” (Ewing et al. 2016).

I remember well a lecture I gave on radioactive waste on March 3, 2010 in an environmental geochemistry course I teach at Stanford University (California, USA). Earlier that morning, the US Department of Energy Secretary Steven Chu had announced the creation of a Blue Ribbon Commission on America’s Nuclear Future. This effectively marked the cessation of the Yucca Mountain Project. I modified my lecture and told my class that Yucca Mountain was no longer the choice for nuclear waste disposal in the US. The final report from the Blue Ribbon Commission (BRC 2012) recommended a process whereby an alternative site might be selected. One of the main conclusions of this report was that “no state, tribe, or community should be forced to store spent nuclear fuel or high level waste without its consent.”

The challenge of nuclear waste disposal has interesting parallels with other major societal challenges such as climate change as well as with political issues such as Brexit (“British Exit”—the 2016 UK referendum to leave the European Union). In all three cases, an educated public is essential for casting informed votes on major political issues and influencing government policy makers to legislate national and international policies that benefit humankind in the long-term while minimizing negative impacts. I happened to be in London (England) and Cardiff (Wales) three days after the exit decision by UK voters and had a chance to talk about this decision with a number of Brits, ranging from taxi drivers, bar tenders, and hotel employees to the academic elite of the EU. Some who voted for exit felt they didn’t have sufficient information to make an informed decision and would like another referendum, which is unlikely to happen. Others who voted in favor of

15 Global Challenges Facing Humanity



FROM THE MILLENNIUM PROJECT (2014).

THIS ISSUE: GLOBAL NUCLEAR LEGACY

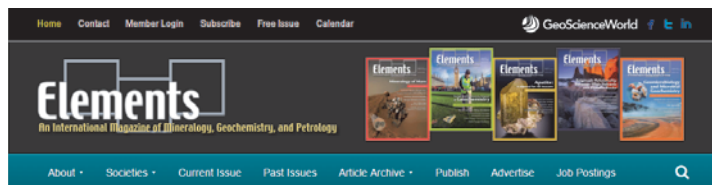
For over 70 years, in the local community where the *Elements* editorial office is located, the residents have been living in the shadow of the Hanford nuclear production complex (eastern Washington, USA). During its heyday (1943–1987), this US government facility was responsible for producing 67.4 metric tons of plutonium for nuclear weapons from its 9 nuclear reactors and 5 processing plants. This was an inefficient process that generated ~53 million gallons of solid and liquid radioactive waste, which is stored in 177 large underground tanks, and ~450 billion gallons of liquids from the nuclear reactors which was discharged to soil disposal sites. This nuclear legacy remains today at the Hanford site. For the past 35 years, the US government has spent billions of dollars to monitor, characterize, contain, and clean up the waste at Hanford. Not only is this a complex and difficult process, but exactly where that waste will be permanently stored has yet to be decided as pointed out in this issue of *Elements*. Moreover, since 1984, the region has also been home to a commercial nuclear energy facility (Columbia Generating Station) that generates about 10% of all the electricity in the state of Washington—enough to power the city of Seattle. The spent nuclear fuel from this facility also needs a final, permanent resting place. While federal and regional governments tussle with the how and where to store hazardous nuclear waste, the local residents live with a nuclear legacy. We are all fortunate to have scientists, such as those who contributed to this issue of *Elements*, helping to advance the waste removal and repository processes.

Elements has now published three issues related to our shared global nuclear legacy. The December 2006 (v2n6) issue is a primer on the environmental aspects of the nuclear fuel cycle, and our June 2012 (v8n3) issue focuses on the Fukushima Daiichi nuclear accident following the catastrophic earthquake and tsunami that hit Japan in March 2011. With the addition of this third issue on geological repositories for nuclear waste, *Elements* readers now have an excellent set of resources on nuclear waste at their disposal (no pun intended!). We encourage you to read all three of these issues to increase your awareness of this global nuclear legacy. Also, use them in your classrooms to educate your students about this important subject ... it is one that will have an impact on future generations. Members can access all three of these issues at the *Elements* website.

Jodi Rosso

ELEMENTS WEBSITE, FACEBOOK, TWITTER

The new *Elements* website will be launched the first week of August 2016. Be sure to add a bookmark in your web browser to our homepage (www.elementsmagazine.org) to access the latest content, find past issues, read about our 17 member societies, learn about *Elements* and how to publish in the magazine, see our new meetings calendar, submit job postings, and so much more. Check it out!



Elements is also increasing its social media footprint. We are now on **Facebook** (www.facebook.com/elementsmagazine/) and also on **Twitter** (@Elements_Mag)! Stay connected. “Like” and “Follow” us.

IMPACT FACTOR 2015

Elements continues to be a widely read and cited magazine according to the recent 2016 Journal Citation Reports® that were released in June by Thomas Reuters. In 2015, *Elements* content received almost 2,100 citations and had an impact factor of 4.585, which is our highest ranking yet. *Elements* now ranks 2nd among all mineralogy journals and 5th among geochemistry and geophysics journals. Thank you to our participating societies, editorial team, guest editors, authors, and advertisers for making *Elements* such a well-respected magazine.

Gordon Brown, Bernard Wood, Friedhelm von Blanckenburg, and Jodi Rosso



EDITORIAL *Cont'd from page 227*

exit did so because they felt marginalized by their government and by the power structure of their country. The EU academics I spoke with were stunned by the exit decision. One thing that became clear to me after my limited exposure to UK public opinion was that the UK policy makers on both sides of the Brexit issue did not adequately educate the public, and some distorted the facts. The ultimate impact of this decision on UK and EU citizens is very difficult to predict.

Returning to the nuclear-waste disposal challenge, one issue that has become abundantly clear after 50 years of investigating potential nuclear-waste disposal schemes is that the site(s) selected must be both technically and socially acceptable (Metlay 2016). However, in order to convince the public that a proposed site (and its disposal technique) is acceptable, the public—as well as their representatives in local, state, and federal governments—must be educated. An excellent example of a successful public education campaign is the one that preceded the environmental cleanup of Rocky Flats (Colorado, USA), a US Environmental

Protection Agency (EPA) Superfund site located 16 miles from downtown Denver where, from 1952 to 1989, plutonium (Pu) pits for US nuclear weapons were manufactured. The buildings and soil at the Rocky Flats site became contaminated by Pu after a number of fires and leaks. A group of scientists from Los Alamos National Laboratory (New Mexico, USA) held public forums that incorporated scientific debate and stakeholder education about the best cleanup solutions. Extensive scientific studies showed that physical mechanisms, particularly colloid transport, dominated the transport of Pu at the site, and it was this knowledge that allowed the most extensive cleanup in the history of EPA Superfund legislation, with billions of dollars in taxpayer savings (Clark et al. 2006).

In closing, I recommend that those interested in some of the early thinking about geological disposal of nuclear waste read the book by Konrad Krauskopf (1988), my late Stanford colleague who was one of the clearest thinkers on this complex topic.

Gordon E. Brown, Jr., Principal Editor

REFERENCES

- Appunn K (2015) The history behind Germany's nuclear phase out. Clean Energy Wire Factsheet. 24 July 2015 <https://www.cleanenergywire.org/factsheets/history-behind-germanys-nuclear-phase-out>. Accessed July 9, 2016
- BRC (2012) Report to the Secretary of Energy, January 2012. Blue Ribbon Commission on America's Nuclear Future. 180 pp
- Clark DL, Janecky DR, Lane LJ (2006) Science-based cleanup of Rocky Flats. *Physics Today* 59(9): 34-40
- Ewing RC, Whittleston RA, Yardley BWD (2016) Geological disposal of nuclear waste: a primer. *Elements* 12: 234-239
- Krauskopf KB (1988) *Radioactive Waste Disposal and Geology*. Chapman and Hall, London, 145 pp
- Metlay DS (2016) Selecting a site for a radioactive waste repository: a historical analysis. *Elements* 12: 269-275
- The Millennium Project (2014) Global Challenges for Humanity. www.millennium-project.org/millennium/challenges.html. Accessed July 10, 2016
- WNA [World Nuclear Association] (2015) Nuclear share figures, 2004-2014. World Nuclear Association. www.world-nuclear.org/information-library/facts-and-figures/nuclear-generation-by-country.aspx#UkrawYakrOM. Accessed July 10, 2016