Elements

PRINCIPAL EDITORS
PATRICIA M. DOVE, Virginia Tech, USA (dove@vt.edu)
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@gfx-potsdam.de)

ADVISORY BOARD
JOHN BRODHOLT, University College London, UK
NORBERT CLAUER, CNRS/UdS, Université de Strasbourg, France
WILL P. GATES, SmecTech Research Consulting, Australia
GEORGE E. HARLOW, American Museum of Natural History, USA
JANUSZ JANECZEK, University of Silesia, Poland
HANS KEPPLER, Bayerisches Geoinstitut, Germany
DAVID R. LENTZ, University of New Brunswick, Canada
ANHUAI LU, Peking University, China
ROBERT W. LUTH, University of Alberta, Canada
DAVID W. MOGK, Montana State University, USA
TAKASHI MURAKAMI, University of Tokyo, Japan
TERRY PLANK, Lamont-Doherty Earth Observatory, USA
XAVIER QUEROL, Spanish Research Council, Spain
MAURO ROSI, University of Pisa, Italy
BARBARA SHERWOOD LOLLAR, University of Toronto, Canada
TORSTEN VENNEMANN, Université de Lausanne, Switzerland
OLIVIER VIDAL, Université J. Fourier, France
MEENAKSHI WADHWA, Arizona State University, USA
JON WOODHEAD, University of Melbourne, Australia

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 EISENHAUER, 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
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
YASUHITO OSANAI, Japan Association of Mineralogical Sciences
CLIFFORD R. STANLEY, Association of Applied Geochemists
MICHAEL WIEDENBECK, International Association of Geoanalysts

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

EDITORIAL OFFICE
WASHINGTON STATE UNIVERSITY TRI-CITIES
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

THE PYRAMIDS OF GIZA AND ARCHIMEDES' PALIMPSEST: WHAT WOULD INDIANA JONES THINK OF MODERN APPROACHES TO ARCHAEOLOGY?

1811-5209/16/0012-$0.00 DOI: 10.2113/gselements.12.1.3

Gordon E. Brown Jr.

My first exposure to cultural heritage occurred in 1974 when I was asked by a group of physicists from the Stanford Research Institute (now SRI International based in California, USA) to serve as a mineralogical consultant for their project on the pyramids of Giza (Egypt). Their objective was to perform radio frequency (rf) sounder experiments in search of archaeologically significant hidden chambers. I carried out powder X-ray diffraction and optical emission spectrographic analyses of limestone chips from the Giza pyramids. The high water content of the analyzed limestones, the high relative humidity (80%) inside the pyramids, and the hydrous clay minerals found in the limestone helped explain the high attenuation of the rf signal, which prevented any new chambers from being located (Dolphin et al. 1975). About 10 years later a major controversy erupted when Frenchman Joseph Davidovits suggested that the blocks comprising the Giza pyramids were cast in place using limestone aggregate and a wet alkali aluminosilicate binder (i.e. geopolymeric limestone concrete blocks) rather than having been quarried (Davidovits 1987; Davidovits and Morris 1988). This opinion was challenged a few years later by Robert Folk, the well-known sedimentary petrologist at the University of Texas Austin (USA), who conducted field and laboratory studies of the Giza pyramids and of the limestone from the local Tura quarries, which are thought to be the source of the limestone blocks for the Khufu pyramid (the Great Pyramid) at Giza (Campbell and Folk 1991). More recently, material scientists from Drexel University (Philadelphia, USA) carried out microstructural analyses of nine samples of the stones comprising the Giza pyramids using scanning and transmission electron microscopies (SEM and TEM), coupled with energy dispersive X-ray analyses (EDXA) (Barsoum et al. 2006). Barsoum and colleagues concluded that while most of the blocks, especially those in the core, were indeed quarried and carved, some blocks at or near the surface (casing stones) appear to have been cast in place using a primitive limestone-based cement. However, in reviewing this more recent study, I am not convinced that the mineralogical work is definitive, due to the authors' reliance on SEM–EDXA for identifying phases and their lack of any X-ray or electron diffraction data on the samples, which would have provided more definitive results on the identity of the crystalline phases.

This ongoing controversy about how the pyramids of Giza were built illustrates the important role of modern analytical methods in cultural heritage, which is the subject of this special issue of *Elements*.

Another example of the use of modern analytical methods in archaeology involves Archimedes of Syracuse (Sicily, now Italy but formerly a part of Greece), the famous Greek mathematician and scientist who lived from ~287 BC to ~212 BC. His well-known contributions to mathematics and science are wide-ranging, particularly his discovery—according to legend while taking a bath—of how to measure the volume (and density) of an irregularly shaped object by the amount of water it displaces. In 1906, Danish scholar Johan Heiberg discovered a battered manuscript at the Church of the Holy Sepulchre in Constantinople (Turkey) written on recycled parchment and containing strange Greek writings, mysterious drawings, and mathematical symbols, most of which were covered by more modern paintings. He recognized that the faint material was from Archimedes, including the only surviving copy of *On Floating Bodies* in the original Greek. However, Archimedes ideas had been recorded by the monk Johannes Myronas in 1229 rather than by Archimedes himself. Let's fast forward to 2003 when my SLAC National Accelerator Laboratory colleague Dr. Uwe Bergmann decided to try to decode Archimedes writings in the famous palimpsest using the X-ray fluorescence signal from the iron-based pigment employed by Myronas to record seven of Archimedes' treatises. As shown in Figure 1, using extremely intense synchrotron light, Uwe was successful in "seeing" through the overlying paint on ancient parchment and uncovering the hidden writings in what is now termed the Archimedes' Palimpsest. Uwe's

Figure 1 (**Left**) A leaf from the Archimedes Palimpsest covered by a forged painting from the twentieth century as viewed in normal light. (**Right**) Image of the same page (reversed) and illuminated using synchrotron X-rays to stimulate X-ray fluorescence from the iron in the ink, which now shows the vertical Greek text written by the monk Myronas in 1229. Photo credit Uwe Bergmann

Cont'd on page 4

THIS ISSUE

Cultural heritage often brings to mind valuable artifacts, artwork, ancient manuscripts, and historic monuments and buildings. But, cultural heritage involves more than just the material objects: it also consists of the more tangible elements such as the values, oral history, traditional craftsmanship, and the knowledge and skills that are transmitted across generations. Cultural heritage provides a window through which we can learn about our past and which ultimately prepares us for the future. As George Santayana wrote more than a century ago, "Those who cannot remember the past are condemned to repeat it." (*The Life of Reason*, 1905)

There is all too often a race to study and/or preserve this heritage as these treasures can be so easily lost to urbanization, wanton destruction during conflicts, natural disasters, or even climate change. A recent article by Eli Kintisch in *Hakia Magazine* (26 January 2016; http://www.hakaimagazine.com/article-long/history-melting) provides a timely illustration of what we face. With the onset of global warming, Arctic coastlines are rapidly being eroded due to loss of ice. In one such area, the cultural heritage of the Iñupiat, a semi-nomadic people who have lived in Alaska for at least 4,000 years, is being lost to this erosion. The race is on as our climate continues to warm whilst saving these historical remains would require "months of encampment, dedicated freezers, and soil engineers."

As the articles in this issue of *Elements* attest, geoscientists are well-positioned to aid in the study, interpretation, and preservation of cultural heritage. So, join the race!

INTRODUCING FRIEDHELM VON BLANCKENBURG: PRINCIPAL EDITOR 2016–2018

After some arm-twisting and promises of free champagne at future principal editors' annual meetings, we are happy to report that Friedhelm von Blanckenburg has joined the *Elements* team as a principal editor. Friedhelm is currently professor and head of the Geochemistry of the Earth Surface Section at the GFZ German Research Centre for Geosciences at Helmholtz Centre Potsdam (Germany), and he is also professor of geochemistry at Freie Universität Berlin (Germany).

Friedhelm also coordinates two large international research networks: the European training network "Isonose" (Isotopic tools as novel sensors of Earth surface resources) and the German-Chilean program "Earthshape" (Earth surface shaping by biota).

Friedhelm is well known for his work in the use of cosmogenic nuclides, particularly ^{10}Be, to quantify Earth surface processes, such as the rates of erosion and uplift, glaciation, and sediment recycling. His steady stream of seminal publications in this area have had a significant impact on our thinking about the rates of these surface processes. His recent development work of the ^{10}Be(meteoric)/^{9}Be tracer in ocean sediments has led to entirely unexpected insights on the tectonic and climatic stability of the Earth's surface during the Quaternary. In addition to his work on cosmogenic isotopes, Friedhelm is also well known for his work on stable iron isotopes in a variety of applications, including iron isotope fractionation at planetary scales, in higher plants, in human blood, during hydrothermal ore deposition and alteration, during diagenesis and metamorphism of banded iron formations, between dissolved and suspended particles in sea water, and in microbial carbonates.

Another important area to which Friedhelm has made major contributions is the development of new stable isotope methods and experimental protocols, including an assessment of the accuracy of stable iron-isotope ratio measurements on samples with organic and inorganic matrices, and the use of UV-femtosecond laser ablation in multiple collector ICP-MS measurements. And, early in his career, he developed the "slab breakoff" model for syn-collisional magmatism. His research accomplishments have been recognized by his election to the German Academy of Sciences Leopoldina and the Berlin-Brandenburg Academy of Sciences and Humanities, and his receipt of the Ralph Alger Bagnold Medal from the European Geosciences Union. He currently serves on the Editorial Board of *Chemical Geology* and the *American Journal of Science*.

Friedhelm is no stranger to *Elements*. He was the German Mineralogical Society (DMG) representative to the *Elements* Executive Committee (2007–2015) and was a guest editor for our October 2014 issue on "Cosmogenic Nuclides" issue (October 2014, v10n5). His past experience with *Elements* will be put to good use as a principal editor. He is already hard at work on our June 2016 issue ("Cosmic Dust").

The editorial team of *Elements* is delighted that Friedhelm has accepted our invitation to become a principal editor and we look forward to working with him.

Patricia Dove, **Gordon Brown**, **Bernie Wood**, **Friedhelm von Blanckenburg**, and **Jodi Rosso**

EDITORIAL *Cont'd from page 3*

conclusion in his 2007 *Physics World* article is particularly appropriate for this issue of *Elements:* "In a fascinating cycle spanning more than two millennia, it is fitting that one of the most advanced tools of modern physics – the particle accelerator – should make such a big contribution to our understanding of this genius from ancient Greece who had so significant an impact on modern science."

These two examples of the application of modern analytical methods to archaeology and cultural heritage stand in stark contrast to the approaches employed by archaeologists prior to World War II, as popularized by the fictional character Indiana Jones in movies such as *Indiana Jones and the Last Crusade*, set from 1912 to 1938, and *Raiders of the Lost Ark*, set in 1936. "Indy's" adventuresome spirit and keen eye could not have resolved the controversy about how the pyramids of Giza were built and could not have detected the hidden writings of Archimedes beneath layers of more modern pigment on recycled parchment. Real archaeologists of that era would have been astounded by what today's analytical methods, especially those using synchrotron light, can detect and see.

The six articles in this issue of *Elements* show the power of modern analytical and geophysical methods that are commonly used in the geosciences but now applied to characterizing, interpreting, and conserving cultural heritage. Hopefully, this issue will stimulate a greater involvement of geoscientists in future studies of our cultural heritage.

Gordon E. Brown, Jr.
Principal Editor

REFERENCES

Barsoum MW, Ganguly A, Hug G (2006) Microstructural evidence of reconstituted limestone blocks in the Great Pyramids of Egypt. Journal of the American Ceramic Society 89: 3788-3796

Bergmann U (2007) Archimedes brought to light. Physics World 20: 39-42

Campbell DH, Folk RL (1991) The ancient Egyptian pyramids – concrete or rock? Concrete International 13: 28, 30-39

Davidovits J (1987) Ancient and modern concrete: what is the real difference? Concrete International: Design and Construction 9: 23-35

Davidovits J, Morris M (1988) The Pyramids: An Enigma Solved. Hippocrene Books, New York, 280 pp

Dolphin LT and 11 coauthors (1975) Electromagnetic Sounder Experiments at the Pyramids of Giza. Stanford Research Institute Report to the Office of International Programs, National Science Foundation, Washington, D.C. Accessed at http://www.ldolphin.org/egypt/egypt1/.