KAOLINS: NANOMINERALS WITH A PROUD HERITAGE

Gordon Brown

Imagine that you were one of the early *Homo sapiens* agriculturalists living during the Upper Paleolithic period near what is now called Kauling (or Gaoling) in Jiangxi province of China. Roughly 25,000 years later, Chinese geologists would discover that the local kaolin deposit was derived from the alteration of a granite stock of Middle Jurassic age (Chen et al. 1997). Further imagine that your small band of agriculturalists had established a village near a stream. While playing along the stream's bank, your children noticed a soft, malleable material they could form when wet into small objects resembling some of the local wildlife. To their delight, these small objects hardened into a brittle material when exposed to sunlight, preserving the shapes of the model squirrels and foxes they made.

Stimulated by your children's discovery, you also gathered some of this soft plastic material and molded it into different shapes, including several small pots. During the day, your pots hardened in the sunlight, and on your next visit to the stream, you scooped up water in the pots, drank from one of them, and carried the pots filled with water back to your nearby campsite. When you checked on the pots early the next day, you discovered that the dried material had become wet again, the pots had slumped, and the water had leaked out. You crafted a new pot and later carelessly dropped it into a bed of red-hot coals in your campfire, where it baked overnight. The next time you filled this "fired," rock-hard pot with water, it did not dissolve, and you found that water could be stored in it for weeks with little or no damage to the pot.

This primitive technology was likely discovered in many other parts of Eurasia and Africa by other early *Homo sapiens* agriculturalists and was exported to Southeast Asia, Australia, and North and South America by early humans. The accidental discovery that this soft, plastic material, now known as kaolin and often containing fine-grained quartz, mica, and other minerals, could be formed and fired into useful objects, such as pots for storing water and grains, was an important one. However, these early *Homo sapiens* had no idea what changes the firing process caused to the clay pot. We now know that firing a kaolinite pot to ~1000 °C causes the kaolinite to dehydrate and transform into a harder, less porous, waterproof form known as stoneware. Firing such a pot to ~1650 °C causes the kaolinite to partially melt and form a glassy material, which when formed into thin pieces is known as porcelain or "fire china," after the country where this process originated (Hurlbut 1970).

Early potters learned how to glaze their pots with a paint or slip of watery clay before firing, which made them even more durable and impervious to water. The durability of fired clay objects is well known to archaeologists, who have traced human activities throughout prehistory based in part on pieces of broken pottery, or potsherds, from different periods (see photo). Another early use of kaolin was consumption by humans and animals for gastrointestinal ailments—a practice known as geophagy (Laufer 1930). This practice is thought to date back 2 million years to *Homo habilis*, based on evidence found in what is now Zambia (Young 2011) and it continues today in many parts of the world.

A stoneware shard from one of the earliest pots, dated at 20,000 BP and discovered in the Xianren cave, Jiangxi province, China. From Wu et al. (2012), reprinted with permission from AAAS

Since these early uses, kaolin-group minerals have found many modern technological uses in materials science (ceramics, papers, pigments, plastics, nanocomposites, and bionanocomposites), as well as in modern medicine (antibacterial applications, drug delivery in cancer treatments, and targeted gene therapy using tubular halloysites). In hindsight, clay minerals such as kaolinite have played a prominent role in the development of civilization, and pottery and art objects made from clay have helped modern humans understand these developments. In addition, Earth and soil scientists now understand the layered, atomic-level structure and unique properties of clay minerals, which are among the most abundant natural nanomaterials. They also understand the chemical weathering processes responsible for clay deposits such as the Kauling kaolin deposit in China, as well as the important role that fine-grained clay minerals play in a variety of geochemical and pedogenic processes, such as the sorption and release of contaminant and nutrient elements and molecules in aquatic systems and soils.

This issue of *Elements* focuses on kaolin-group minerals and emphasizes their special place in the early cultural history of China, which is well known for developing porcelain-making techniques. It also discusses the atomic-level structure and polytypism (different layer stacking sequences) of kaolin-group minerals, high-pressure kaolinite polytypes, the importance of defects and impurities in kaolinite, and the ability of kaolinite to reveal its environmental history through defects induced by radiation damage. Another important process discussed in this issue is the interaction of kaolin-group minerals with the environment, especially with ions in aqueous solutions and bacteria. Particularly fascinating are the articles on the history of mining and processing of

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THIS ISSUE

This issue illustrates admirably how materials known and used since the dawn of humanity may still have many surprises in store for us in terms of new uses and applications. Guest Editors Paul Schroeder and David Bish chose to present the whole spectrum of uses of kaolin, from ancient porcelains to nanocomposites.

In her article about mining kaolin, Jessica Elzea Kogel provides an excellent snapshot of mining today, and I encourage all to read it. She stresses the importance of mining responsibly, with a plan for returning the land to a postmining use that will have value to the local community. Gaining acceptance by the local community ("social license") by involving all stakeholders is just as important as drilling to delimit the ore resources.

Why does mining get such bad press then? In a recent issue of *Canadian Geographic*, the possibility of mineral exploration, let alone exploitation, in an isolated area of Jordan was seen as a catastrophe. This is a paradox, because we consume greater and greater amounts of resources per capita. These resources need to be dug up from the ground somewhere—as long as it is not in our own back yard. Sadly none of the mining companies approached by the guest editors chose to advertise in this issue to let us know how they have embraced the challenge of gaining acceptance from local communities. And perhaps this is part of the mining industry's problem.

I am very fond of this issue's Parting Shot. The idea germinated at the last GSA meeting in Denver. Over a glass of wine, Rod Ewing was telling a few of us how he enjoyed reading Ian Parsons' Parting Shots. "He could write about a brick and make it interesting," said Rod. Ian rose to the challenge—read his Parting Shot about the Friendly Brick (by the way, the lovely little girl in the picture is my granddaughter, Ellie Rose). And kaolin was the perfect issue in which to publish this Parting Shot.

TRANSITION

I am thrilled that Jodi Rosso has been chosen to succeed me at the end of this year (see accompanying text). I did not know Jodi personally but thought she had the perfect profile for the job. So I was delighted that after an international search, the search committee came to the same conclusion. For the last month Jodi and I have conversed during weekly Skype calls, and it has been inspiring to share ideas and make plans. At the Goldschmidt Conference in Sacramento, we intend to map out the next few months to ensure that the transition is complete by the end of the year.

FROM A READER

"Thought you might like this… Served up while on a KLM flight, and I really was reading the latest issue!! Not that I would recommend the wine especially."— John Ludden

FREE TO STUDENTS

Students take note: In this issue, two of our regular advertisers are offering for the first time free student editions of their software.

The Geochemist Workbench student edition is offered to students currently registered as full-time undergraduates or graduates at an accredited university offering degrees in geoscience. Students can apply on the website http://student.gwb.com.

As part of its 20th-birthday celebrations, CrystalMaker has launched a free "CrystalViewer" program. This is designed for use by individual students, to empower and inspire them to explore our microscopic world. CrystalViewer includes a library of over 120 structures, including a range of minerals, advanced materials (many derived from mineral prototypes), plus a teaching library of crystal chemical compounds.

Pierrette Tremblay, Executive Editor

DR. JODI ROSSO APPOINTED NEW EXECUTIVE EDITOR OF *ELEMENTS* STARTING JANUARY 1, 2015

After an extensive international search over the past year and with 35 applicants from 10 countries, Jodi Rosso was selected as the next Executive Editor for *Elements*. She will replace current Executive Editor Pierrette Tremblay, who will step down at the end of 2014 after 10 years.

Jodi brings her extensive and diverse experience in mineralogy, petrology, and geochemistry (MPG) to *Elements*. She received her PhD from Stanford University (USA) with an emphasis in geochemistry. Since 2000, she has been the series editor of Reviews in Mineralogy and Geochemistry, a joint publication of the Mineralogical Society of America (MSA) and the Geochemical Society, overseeing the publication of 29 volumes on a wide range of MPG subjects. She also serves as editor of the Monographs series, published by MSA.

Jodi is a devoted reader of *Elements* and, being particularly fond of Parting Shots, she likes to start reading each issue from its last page. Her considerable publication experience with RIMG volumes, her research training in MGP, and her enthusiasm and creativity were compelling qualities for her being selected for the position.

She and the retiring executive editor will work closely over the next several months to ensure a smooth transition of leadership at the magazine. Please welcome Jodi Rosso to the *Elements* family.

Executive Editor Search Committee (appointed by *Elements*' Executive Committee): Barb Dutrow, chair; Liane G. Benning, Bernardo Cesare, Rod Ewing, John Valley, J. Alex Speer (ex officio)

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kaolin-group minerals, the development of environmentally sensitive modern mining practices, and the many uses of kaolin-group minerals in modern technology and medicine. After reading these articles, it should be clear that kaolin-group minerals had a major impact on early humans and that they continue to impact modern humans through their many and varied uses.

Gordon E. Brown Jr.
Principal Editor in charge of this issue

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