

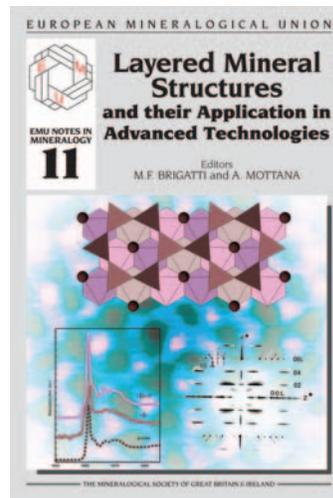
LAYERED MINERAL STRUCTURES AND THEIR APPLICATION IN ADVANCED TECHNOLOGIES*

The current information about the existence of clay minerals on extra-terrestrial bodies leads many to conclude that layered mineral structures facilitated the advent of self-replicating organic compounds on Earth (i.e. life as we know it, here or elsewhere). Coupling this notion with Akihiko Yamagishi's pioneering work on stereoselective molecular recognition of organics on clay surfaces further supports the long-standing hypothesis of mineral natural selection in biochemistry (see Cairns-Smith, *Elements*, volume 1, 2005) and the fact that we have much to learn from nature's world of clay nanocomposites. Also, a quick literature search using "clay nanocomposite" reveals hundreds of citations in seemingly disparate engineering, medicine, geoscience, and materials science journals. All of this collectively suggests that layered mineral structures harbor enormous potential for applications in advanced technologies. The recent publication on this very subject by the European Mineralogical Union, *Notes in Mineralogy*, volume 11 (EMU 11), edited by M. F. Brigatti and A. Mottana, arrives in a timely fashion to give us the latest insights. The importance of this book is derived from the coverage of the fundamental, yet complex, layered structures that are possible from combining one or more layer types. Such combinations help make new-aged technological materials or enable ways to interpret old-aged geologic materials.

I first digress by noting a slight misunderstanding hampering the explosion of experimental work driven by hopes of discovering poly-functional layered mineral structures. The incentive for finding new materials is to expand thermal, rheological, time-release, and redox inhibitory/promoting material boundaries for biomedical, engineering, and environmental enterprises. The problem I see is that researchers outside the field of mineralogy view natural layered mineral structures as some sort of reagent-grade compound, like those purchased from a chemical supply store. Natural clays have novel properties, but they are not all alike and are quite variable. A prime example is seen in the kaolin-group minerals, which are used in ceramics, paper coatings, pharmaceuticals, inks, and plastics. Kaolin occurs with a wide range of crystallite order/disorder, crystal sizes and aspect ratios, and degrees of isomorphous iron substitution. Committing a career of research to creating new materials without prior knowledge of the mineral structures will not only frustrate those who endeavor but also delay the potential benefits to society.

EMU 11 provides an ideal starting resource for those wanting to learn more about natural layered materials. Chapters 1, 2, 3, and 7, with first authors Brigatti, Guggenheim, Li, and Bergaya, respectively, give overviews of layered silicates, order/disorder schemes, titanosilicates, and intercalation, which collectively serve as a condensed resource for those needing a refresher in systematic clay mineralogy. Lanson's chapter eloquently nurtures the notion of using X-ray diffraction (XRD) to characterize anisotropic lamellar compounds (including layered double hydroxides) and the need to experimentally do this before, during, and after testing. Following up XRD studies with calculated XRD models assures the confidence needed to extract thermodynamic data, formulate reaction mechanisms, and anticipate kinetic effects needed to give new clay composites functionality. Speaking of models, Sainz-Díaz's delightfully readable chapter on computational mineralogy helps to see how using both classical and quantum mechanical methods specific to layered structures can be applied to interpreting spectroscopic properties, reactivity, and surface interactions with organic and water molecules. This *in silico* work is supported by discussions of published experimental vibrational and nuclear spectroscopic studies, which keep this book from being an isolated theoretical exercise.

* Brigatti MF, Mottana A (eds) Layered Mineral Structures and Their Application in Advanced Technologies. EMU Notes in Mineralogy Volume 11, XVI + 396 pp, ISBN 978-0-903056-29-8



The remaining chapters tackle more uncertain questions, such as "exactly how does water interact with layer charges of common smectite group minerals?" This question has long been of interest to industry. Christidis emphasizes a new, more insightful approach that promotes treating smectitic samples using a variety of saturations, like alkylammonium and potassium, to assess key properties of thixotropy (i.e. the ability to form a gel upon standing and become fluid under stress—an essential process employed every time you brush your teeth). Clay minerals and double hydroxides are not the only layered structures in nature worthy of exploitation.

Mottana and Aldega's chapter broadens the theatrical stage of layered materials to include graphene and addresses the pesky problem of how to define quasi-ordered nanosized intercalated structures. Traditional bulk methods, such as bulk powder XRD, often make hamburger out of the materials we are trying to define by averaging both bulk and surface properties. The closer we want to look at an intercalated structure, the less bulk XRD techniques can tell us (perhaps a new variant of Heisenberg to haunt us). The good news is that methods such as grazing incidence XRD and X-ray absorption spectroscopies are reviewed with practical examples to guide us in studying configurations.

The interaction of organic molecules with layered structures and surface properties of clay minerals represents the current frontier for advancement of new materials in technology. The ability to control crystal surfaces for the binding of molecules such as DNA is fundamental for biosensing, environmental science, and catalysis. Valdré and coauthors explore recent advances in surface imaging techniques with atomic force microscopy (AFM) and review some practical advances in understanding decontamination of biological warfare agents, biofilm formation, and prebiotic chemistry. They clearly demonstrate the nucleotide selectivity, using powerful AFM images of DNA ordering with linear confirmations on brucite-like edges of a chlorite sheet, while by comparison the siloxane region topography indicates a very different agglomeration of the same DNA. Being able to control adsorption of nucleic acid bases at different pHs and solution compositions on clay minerals raises the possibility of a genetic code based on purines and a mechanism for protecting biomolecules from degradation.

Next to zeolites, clay minerals and their cousin layered structures (e.g. graphene) provide maximal amount and diversity of surface reactivity sites, coming from outer surfaces, edge surfaces, and interlayer surfaces. Schnoonheydt and Johnston bring closure to EMU 11 by linking water-ion interactions with clay surfaces (most examples being smectites) and the amazing chiral discrimination that occurs when the organic complexes interact on these surfaces. Once these complex interactions are fully understood, the advances in electrochemistry, photochemistry, and catalysis should open the path for novel ways to selectively react enantiomeric (right- and left-handed) compounds. Some day we may realize a device, based on a clay-dye with extreme thermal, mechanical, and chemical stability, small in size, low in energy demand, and high in light-scattering efficiency, that will enable us to biosense medical problems well in advance of what we can do today.

The bottom line is that EMU 11 is a very nice review volume for state-of-the-art layered mineral characterization methods. The references cited within it and peer-reviewed journals give the ultimate resource. The lesson learned from this book is "get to know your layered mineral structure well," particularly if it is a natural material, and you will be well suited to discover the next nanocomposite to advance technology.

Paul Schroeder, University of Georgia

where performance

Whether guaranteeing tighter process specs or accelerating product development, the new Thermo Scientific ARL PERFORM'X spectrometer provides speed, reliability, stability, analytical precision for elemental analysis of liquids, solids, powders. Ideal for labs in geochemical, petrochemical and advanced materials analysis. Fastest, digitally mastered goniometer. Focused X-ray small spot and mapping options. Low maintenance cost. If you haven't yet exploited the performance of X-ray analysis, we invite you to challenge the versatility of the new ARL PERFORM'X spectrometer.

meets versatility

• analyze@thermofisher.com • www.thermoscientific.com/performx

New Thermo Scientific
ARL PERFORM'X WDXRF Spectrometer



© 2012 Thermo Fisher Scientific Inc. All rights reserved.

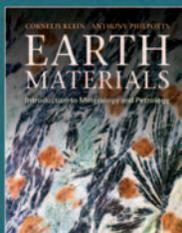
CAMBRIDGE

FEATURED TITLES *from* CAMBRIDGE UNIVERSITY PRESS!

TEXTBOOKS

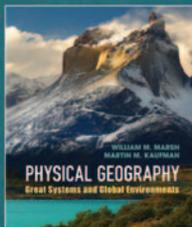
Earth Materials
Introduction to
Mineralogy and Petrology
Cornelis Klein
and Tony Philpotts

\$200.00; Hb: 978-0-521-76115-4
\$99.00; Pb: 978-0-521-14521-3;
552 pp.



Physical Geography
Great Systems and
Global Environments
William M. Marsh
and Martin M. Kaufman

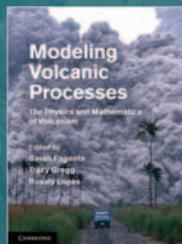
\$99.00; Hb: 978-0-521-76428-5;
720 pp.



Coming Soon!
Modeling Volcanic Processes

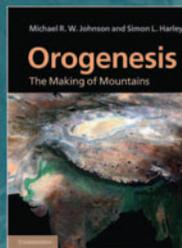
The Physics and
Mathematics of Volcanism

Edited by
Sarah A. Fagents,
Tracy K. P. Gregg,
and Rosaly M. C. Lopes
\$80.00; Hb: 978-0-521-89543-9;
416 pp.



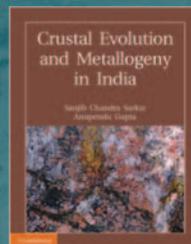
**Orogenesis:
The Making of
Mountains**

Michael R. W. Johnson
and Simon L. Harley
\$75.00; Hb: 978-0-521-76556-5;
398 pp.



**Crustal Evolution
and Metallogeny
in India**

Sanjib Chandra Sarkar
and Anupendu Gupta
\$140.00; Hb:
978-1-107-00715-4; 912 pp.



New Edition!

**The Earth
Its Birth and Growth
2nd Edition**

Minoru Ozima,
Jun Korenaga,
and Qing-Zhu Yin
\$95.00; Hb: 978-0-521-76025-6
\$42.99; Pb: 978-1-107-60076-8;
164 pp.



View our full Earth and environmental sciences catalog at
www.cambridge.org/earth

www.cambridge.org/us/earth
@CambUP_earthsci



CAMBRIDGE
UNIVERSITY PRESS