

# Micro- and Mesoporous Mineral Phases<sup>1</sup>

For those working in a lab, one of the “petits plaisirs” enlightening everyday life is when the librarian proclaims “I have just received and shelved a new white book.” You realize immediately that a brand new volume of the prestigious book series *Reviews in Mineralogy and Geochemistry* (RiMG) has arrived from the States. Needless to say, you break off what you are doing, you open it, and you go through it rapidly, even if the title is far from your current topic of interest. A quick flip through the pages usually suffices to give you a good idea of what and who is in the forefront of the subject. If you are in the field, or eagerly want to learn about it, the white brick immediately becomes a reference book for your ongoing work or training. After some months or years of use, the book may eventually turn to grey and lose more and more bundles of pages—that is, it may show evidence of how much it has been useful!

*Micro- and Mesoporous Mineral Phases* is volume 57 in the RiMG series. It was launched in 2005 and edited by Giovanni Ferraris and Stefano Merlino for the Mineralogical Society of America (MSA) and the Geochemical Society, in partnership with the Italian Accademia Nazionale dei Lincei. The 448 pages of text and figures are organized into 12 chapters, themselves corresponding to the 12 invited lectures delivered at the 2004 meeting on micro- and mesoporous mineral phases, held on December 6 and 7, in Rome, Italy.

The book starts with two chapters dealing with the definition of micro- and mesoporous phases (chapter 1, by L.B. McCusker) and the topology of their framework host (chapter 2, by S. Krivovichev). Then, the polysomatic aspects of microporous minerals related mostly to layer silicates are developed (chapter 3, by G. Ferraris and A. Gula), as are heterosilicates involving coordination polyhedra other than tetrahedra in the framework (chapter 4, by N.V. Chukanov and I.V. Pekov; chapter 5, by I.V. Pekov and N.V. Chukanov; chapter 6, by J. Rocha and Z. Lin). Treatment of the structural and crystal chemical features of sodalite-type structures (chapter 7, by W. Depmeier) precedes the presentations of the modular aspect of the cancrinite-davyne group and C-S-H phases (chapter 8, by E. Bonaccorsi and S. Merlino). More casual examples encompass the versatility of the tunnel structures of manganese oxides (chapter 9, by M. Pasero) and that of apatite (chapter 10, by T. White, C. Ferraris, J. Kim and S. Madhavi). Porous

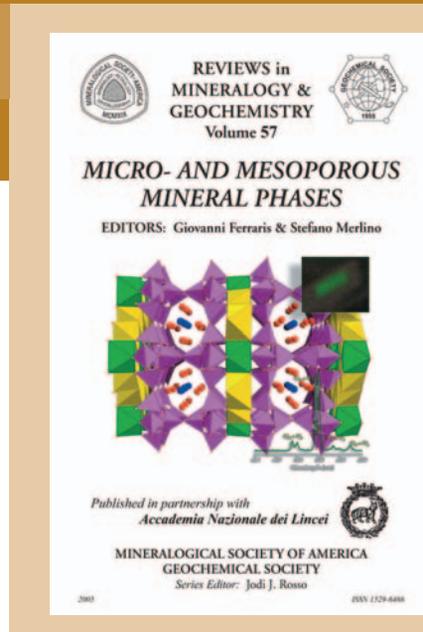
sulfide and selenide structures are then discussed (chapter 11, by E. Makovicky). Finally, mesopores arising from microstructures based on non-porous, crystalline or not, atomic structures of carbon, serpentine, and clathrates are addressed (chapter 12, by M. Mellini) and placed in an Earth science and materials science context. Zeolites are not covered in this volume because they were the subject of the RiMG volume number 45, published in 2001.

This book is a most valuable hymn to the crystallography and crystal chemistry of more or less open mineral structures. A neophyte going through the book may have the strange feeling that many structures seemingly violate the usual rule of thumb: that crystals should have a compact atomic structure. Well, we have long known, from the description of silicate structures based on progressive polymerization of silicate tetrahedra, that channel-bearing frameworks are present among ring silicates and among some chain and layer silicates, i.e. well before the well-known framework silicates including zeolites are mentioned. But to realize that so many other structure types and even sulfides or selenides may display open structure is amazing and quite informative.

This book allows ample space for the presentation of crystallographic data on these chemically and structurally diverse crystalline compounds. Many unit-cell data and structural formulae are available, and anyone who wants to figure out those 3-D crystal structures on his computer may import fractional co-ordinates from current mineralogical data banks. It is also a gold mine for anyone interested in testing new materials for the countless, present and future applications of porous mineral phases. Among the possible applications, such structures may act as molecular sieves, catalysts or catalyst supports, gas absorbers and sources, glue for hardening of cement, biocompatible materials, battery elements, traps for remediation of nuclear wastes, and fuel cell electrolytes, to mention a few.

Thus, this book reinforces existing bridges between materials science and crystallography. It is also rewarding to see how classical structure resolution of minerals by X-ray diffraction can feed the present needs of industrial and environmental applications.

But as you close this RiMG volume, you may wonder if all these mineral structures are really porous structures. A reader not aware of the wide definition of porous minerals may wonder about the very existence of pores in many of the structures presented here. Thus, the “polyhedral” representation or the “small ball and stick” diagrams used everywhere in the figures overemphasize holes and tunnels that a “space filling” diagram might not have



shown so clearly. Also the systematic separation of a “guest” atom or group of atoms from a “host” framework reinforces this feeling. Discussing only the host may lead to the wrong conclusion that pores do exist in the structure. Intuitively, pores are related to open spaces in the structure, which may or may not be interconnected. In practice, such open spaces may be either empty or loosely occupied by molecules or low-charge ions. This means that you can remove such guests without disturbing too much the charge balance and the rigidity of the host framework. Many structures in the book depart from this intuitive view.

This book may also be inspiring for the mineralogist or materials physicist interested in working out the types of defects involved in those averaged, supposed-to-be-perfect structures (polysomes, twins, stacking faults, intergrowths, etc.). The editorial quality of the text is quite good, while the computer-assisted drawings are clear and informative.

In conclusion, I recommend this volume not only to libraries in Earth sciences but also to libraries specializing in solid-state chemistry. An annual subscription to *American Mineralogist* provides you with free RiMGs published during the current year. Additional copies may be ordered at moderate cost from the MSA business office.

Oh! I guess that another new “petit plaisir” experienced in many labs right now is when the colorful *Elements* magazine appears in the mail box. Again, our ongoing activities come to a halt, as we cannot resist going through it greedily!

**Alain Baronnet**

Université Paul Cézanne and Centre de Recherche en Matière Condensée et Nanosciences (CRMCN-CNRS)  
Campus Luminy, 13288-Marseilles cedex 9, France

<sup>1</sup> Giovanni Ferraris and Stefano Merlino, editors (2005) *Reviews in Mineralogy and Geochemistry* 57, Mineralogical Society of America, 3635 Concorde Pkwy Ste 500, Chantilly, VA 20151-1125, United States. US\$40; 25% discount for MSA members

# Mineral Deposits and Earth Evolution<sup>1</sup>

This book contains papers that were part of the Geological Society of London's 2003 Fermor flagship meeting "World-Class Mineral Deposits and Earth Evolution." The objective of the meeting was to investigate how mineral deposits have changed during Earth's evolution over the last 3.8 Ga and what they can tell us about this evolution.

With these objectives in mind, Groves et al. point to the change in the nature of the sub-continental lithospheric mantle (SCLM) with time. In the Archean, the high degree of plume-related partial melting led to the formation of thick, highly depleted, buoyant SCLM, while the lower degrees of melting characteristic of the Phanerozoic gave rise to thinner and denser, easily delaminated and subducted mantle. They argue that it is only Ni-Cu deposits that show a variation directly attributable to a cooling Earth. The style of deposition of U, Fe and Mn is related to the development of an oxygenated marine environment in the interval 2.6 to 2.0 Ga. Porphyry Cu, orogenic Au, and VHMS deposits likely accumulated throughout time, and their existence is rather a question of preservation than of deposition or non-deposition.

Harcouet et al. report on their thermal evolution model during the period of structural deformation in the Ashanti gold belt of Ghana between 2.130 and 2.095 Ga (just prior to Au mineralization in the belt at 2.063 Ga). They suggest that the thermal perturbations shown by their modelling could be related to periodic "mantle overturning," but stress that the increase in heat flow indicated by their model is not of catastrophic proportions. An interesting aspect of the model is that it indicates significant lateral heat flow, which is caused by differences in thermal conductivity of different rock units and is concentrated close to the boundaries between these units. This may have been important in promoting local circulation of mineralizing fluids.

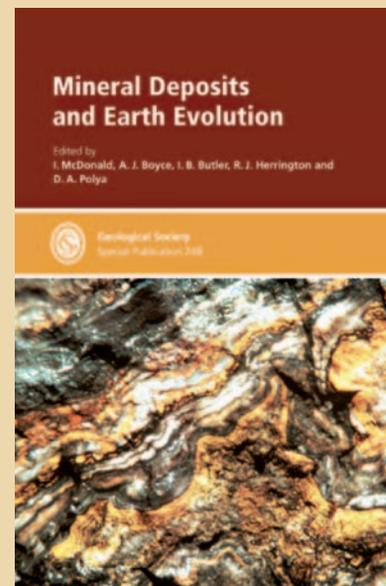
A very different, global approach to the origin of gold mineralization is taken by Leahy et al. They argue that an essential requirement is the presence of gold-enriched source rocks occurring in a tectonic environment and at a metamorphic grade that would have permitted the existence of fluids to dissolve and transport the gold. They recognize seven distinctive tectonic settings and analyze the 181 currently active, large (>100 t Au) gold mines in terms of these settings. They find that 46% of the deposits fall within large

ocean closure orogens, 32% within continental arcs and 10% within large accretionary arc complexes. They conclude by relating Au mineralization strictly to tectonism and decay theories that have postulated "golden epochs" as either spurious or coincident with periods of enhanced crustal growth.

Hayward et al. show how the chemical and morphological heterogeneity of Witwatersrand gold can be used to approach the question of whether the gold is the result of hydrothermal modifications of early placer deposits or was initially introduced hydrothermally. While most of the observed gold grains had morphologies indicative of hydrothermal deposition, wide variations in the Ag and Hg content in gold throughout the Witwatersrand are likely related to variations in the provenance of the detrital gold in the various "reefs." They attribute the morphologies of the gold grains to very localized (mm- to cm-scale) remobilization by low volumes of fluid.

De Wit and Theart present a statistical analysis of the number of different types of deposits related to different Archean cratons, and also of differences between deposits in Archean cratons and in younger crust. There is a wide variation in the frequency of occurrence of many deposit types among different Archean cratons, with the Zimbabwean craton being particularly rich in many of the groups of elements that they consider. Archean cratons are much better mineralized than areas underlain by younger rocks except for the element group U-Th-REE. Their analysis suffers in that they are unable to factor in the effectiveness of the exploration that has been applied in different areas (which they acknowledge) and that they use number of deposits per unit area rather than the integrated amount of metal contained within all of the deposits per unit area as the yardstick for comparison. Nevertheless their analysis points to certain areas that contain less than the expected number of discoveries. After reflection on possible reasons for this, the explorationist might be able to use this fact as an indication of where the chances of grass-roots success would be the greatest.

A number of papers depart from the strict discussion of ore deposits and tackle the question of how the Earth's atmosphere may have evolved with time. Traditionally, it has always been maintained that biogenic fractionation of sulfur isotopes started after the close of the Archean, although some data obtained over the last 15–20 years have cast doubt on this hypothesis. In order to provide a better understanding of the development of isotopic fractionation processes during the Archean, Grassineau et al. chose to study the



isotopic composition of S and C in the 3.8 Ga Isua and 2.7 Ga Belingwe greenstone belts, and compare their results with their own and literature data on the 3.24 Ga Barberton belt. Their overall conclusions are that a biological sulfur cycle may have been operational at 3.8 Ga and 3.2 Ga but was flourishing by 2.7 Ga, and that the biological carbon cycle was operational by 3.2 Ga and may have operated at 3.8 Ga.

Farquhar and Wang start with a very coherent explanation of mass-independent sulfur isotope fractionation that will be welcomed by anyone (this writer included!) who wants an accessible summary of the field. Such fractionation is strong in rocks older than 2.45 Ga, minor but present in rocks with ages between 2.45 and 2.0 Ga and apparently rare to absent in rocks younger than this. They point out that when oxygen in the atmosphere is  $10^{-5}$  PAL and less (PAL = present atmospheric oxygen), photolysis of  $\text{SO}_2$  and the mass-independent production of  $^{33}\text{S}$  is most efficient, with transfer to the surface occurring as both  $\text{H}_2\text{SO}_4$  and  $\text{S}_8$  aerosols. Photolysis can still occur at  $>10^{-5}$  PAL with less efficiency and is likely to cease at  $>10^{-1.5}$  PAL. This may be the reason for the variation in mass-independent  $^{33}\text{S}$  in rocks of different ages, and thus may place constraints on the change in the oxygen content of the atmosphere with time. They stress, however, that the lack of mass-independent  $^{33}\text{S}$  in younger rocks could have causes other than the oxygen content of the atmosphere, including changes in the ozone content of the atmosphere which could have screened out the radiation causing S photolysis.

Lowry et al. show that there is a relationship between the isotopic composition of sulfur in sulfides related to granitoid intrusions in different terranes of Scotland and northern England and the sulfur that occurs in the surrounding sediments or underlying basement. They observed that in the Lakesman-Leinster and Grampian terranes, intrusions contain sulfur whose isotopic values vary from typical

<sup>1</sup> McDonald I et al., editors (2006) Mineral Deposits and Earth Evolution, Geological Society Special Publication 248, 280 pp, ISBN 1862391823

mantle values to mantle values enriched in heavy sulfur, but in the Southern Uplands, intrusions are enriched in light sulfur. These variations suggest that contamination by local sediments has been important in controlling the sulfur isotope composition of the intrusions and their related mineralization. The isotopic composition of sulfur in intrusions of the Northern Highlands is more varied and is thought to reflect the thick cratonic basement underlying this area.

Raiswell and Anderson have developed a model to account for at least part of the iron enrichment observed in deep-basin sediments. Anoxic environments that develop on oceanic shelves containing a high proportion of organic matter serve as traps for Fe, taking it into solution as sulfide or causing it to precipitate as pyrite. In either case it remains trapped within the pores of sediments on the shelves. Once the supply of iron oxide ceases, the Fe content of pore waters builds up, and dissolved Fe can escape into the overlying more oxidized water, where part is re-precipitated as Fe oxide, but part escapes and is transported into deeper water where it precipitates as iron sulfide and becomes concentrated in the deep basinal sediments.

Grieve provides a useful summary of the characteristics of impact structures and associated metamorphism. He divides impact-related deposits into three classes. Progenetic deposits are pre-existing deposits that have been brought to accessible depths by the impact; major examples include the Witwatersrand and uranium in the Carswell structure of the Athabaska district of Canada. Syngenetic deposits form as a direct result of shock pressure or heat (including subsequent

hydrothermal activity) related to the impact; Sudbury is the prime example, although Witwatersrand gold has been affected by impact-related hydrothermal activity. Epigenetic deposits occur in and are younger than the structures produced by impact; oil and gas accumulations are the prime examples.

Other papers focus on specific tectonic settings or specific ore deposit types. Herrington et al. present a reinterpretation of the structure of the Urals, simplifying this into two magmatic arcs: a western, immature, Late Ordovician volcanic arc (the Tagil-Magnetogorsk arc) that developed as a result of eastward subduction and a continental arc (the Valerianovka arc) located at the leading edge of the Kazakh plate. These collided in the late Paleozoic and at the same time were thrust westward over the East European craton. The arcs were welded by syn-collisional granitoids and subsequently offset along a series of post-collisional, sinistral strike-slip faults, which accounts for the lens-like distribution of the terranes.

Heinrich et al. summarize the implications of their results from laser-ablation-ICPMS analysis of fluid inclusions for the genesis of porphyry copper systems. They comment that the fluid/rock ratios required to produce a deposit need not be much greater than 1, that the size of a deposit depends more on the efficiency of the transfer of Cu from magma to fluid phase (they suggest that immiscible Cu-rich sulfides may play a role in this transfer) than on the overall size of the magma system, and that the grade of the deposit depends on how much fluid is cooled over the required temperature range within a restricted body of rock before the ambient temperature rises too high. They suggest that circulating meteoric

water may play a role in cooling the environment of ore deposition, although they have found no evidence that the mixing of meteoric and magmatic water has played a role in sulfide deposition.

Far more attention has been paid in the geologic literature to diamonds found in kimberlites and lamproites than to alluvial diamonds. Bluck et al. seek to redress the imbalance by discussing factors that are important in the formation of placer deposits along the coast of Southwestern Africa. They conclude that the development of mega-placer deposits ( $>50 \times 10^6$  carats at  $>95\%$  gem quality) depends on the craton size and its diamond fertility; the efficiency of the drainage (not preceded by earlier systems and focussed on a limited terminal area); and the energy prevailing in the terminal area, which should be sufficient to remove the less dense components transported by the drainage system.

While this book could be criticized in that not all papers relate to the theme of Earth evolution, many of the papers relate directly to the topic and provide a useful update to explanations for the change of styles of mineralization with time and to isotopic constraints on the nature of the early atmosphere. The other papers are most certainly not to be decried in that they also provide good summaries of the state of our understanding of the formation of major ore deposit types. This book belongs on the shelf of any student of ore deposits. Preparing this review has certainly taught me a lot!

**Tony Naldrett**  
University of Toronto

## UNIVERSITY OF NEW BRUNSWICK - TENURE TRACK POSITION

The Department of Geology at the University of New Brunswick (Fredericton) invites applications for a **tenure track position as Assistant Professor** in fields related to **Metamorphic Petrology and/or Earth and Planetary Materials**, effective January 1, 2007.

This new position will complement expanding research and teaching activities in Petrology and Earth/Planetary Science and build upon the recent appointment of a Tier 1 Canada Research Chair in Planetary Materials, and allied Research Scientist and Research Engineer appointments in the Planetary and Space Science Centre housed in the Geology Department. The Department of Geology maintains undergraduate programs in Geology, Environmental Geochemistry and Geological Engineering to which the successful candidate is expected to contribute. The teaching responsibilities of the successful candidate will include undergraduate courses in metamorphic petrology and mineralogy, as well as contributing to the overall undergraduate program. Department research facilities include cathodoluminescence and

fluid inclusion microscopes, high-T controlled-atmosphere furnace, hydrothermal apparatus, piston-cylinder apparatus for high-P/high-T phase equilibrium studies, rocking autoclaves and an excellent thin sectioning workshop. Analytical equipment includes ICP-OES, XRD and a micro-Raman spectrometer. Excellent analytical electron microscopy capabilities at UNB's Microscopy and Microanalysis Facility, including EPMA, analytical SEM and analytical STEM, provide fundamental research support. Further details can be obtained from [www.unb.ca/fredericton/science/geology](http://www.unb.ca/fredericton/science/geology).

The successful candidate will be expected to develop and manage an externally funded program of independent research. Candidates must have a Ph.D. in research areas that should include one or more of the following: metamorphic petrology, mineralogy, mineral physics, planetary materials/planetary evolution. Experience in the field study of metamorphic rocks will be considered an asset.

Interested persons should submit a letter of application, current curriculum vitae with a list

of publications and the names, addresses (including email) and telephone numbers of three (3) references to:

**Chair**  
**Department of Geology**  
**University of New Brunswick**  
**2 Bailey Drive**  
**Fredericton, NB E3B 5A3**  
**Canada**

Email submissions to the Chair in care of Christine Lodge <[lodg@unb.ca](mailto:lodg@unb.ca)> are encouraged, and must be followed by hard copies of the required information.

Review of applications will begin September 1, 2006 and continue until a suitable candidate is found.

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. Applicants must indicate current citizenship status.

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IS COMMITTED TO THE PRINCIPLE OF  
EMPLOYMENT EQUITY