The Canadian Mineralogist
Vol. 32, pp. 469-474 (1994)

BOOK REVIEWS

Applied Mössbauer Spectroscopy – Theory and Practice for Geochemists and Archaeologists. By S. Mitra, Physics and Chemistry of the Earth, vol. 18, Parts III – VI. Pergamon Press Ltd., Headington Hill Hall, Oxford 0X3 0BW, U.K. 1992, 381 pages, CAN $395 (ISBN 0-08-0421997HC) hardbound.

There are dozens of books and review chapters and articles on "applied Mössbauer spectroscopy". This one attempts to distinguish itself by being "for Geochemists and Archeologists" but distinguishes itself more by the low level of its presentation and by its superficial description of the relevant literature up to about 1990.

This book is not the place to learn Mössbauer spectroscopy. It is divided into "Theory" and "Practice"; both halves read like lists of keywords, to which incomplete explanations and out-of-context descriptions are appended. It might be moderately useful as a collection of references (with comments and figures) organized by topic but, as such, it is clearly overpriced, especially if one considers that a complete and up-to-date Mössbauer reference database and search program pertaining to the earth sciences can be purchased for less from the Mössbauer Effect Data Center.

The author makes a valiant attempt to show the importance of Mössbauer spectroscopy in mineralogy, petrology, environmental studies and archeology. In all areas, the usefulness of the technique derives mostly from the ease and accuracy with which it can deliver quantitative $Fe^{3+}/\Sigma Fe$ analyses. Site occupancies of Fe^{2+} and Fe^{3+} in coordination polyhedra can also commonly be measured, and magnetic species such as the iron oxides and oxyhydrites can usually be identified and distinguished from the paramagnetic iron-bearing mineral species.

Anything more, however (such as resolving and quantifying *cis* and *trans* octahedral sites in micas), usually requires tenuous leaps of faith that are made by many researchers and simply reported without critical comment in this book. The author does not give a discussion of the limits of Mössbauer spectroscopy, but rather tends to overstate its achievements. The room-temperature Mössbauer spectrum of a mineral contains much information and is very sensitive to small structural and compositional changes but, overall, it is also not understood and usually misinterpreted or overinterpreted.

Denis G. Rancourt
University of Ottawa

Marine Hydrothermal Systems and the Origin of Life. Edited by N.G. Holm. Kluwer Academic Publishers, P.O. Box 989, 3300 AZ Dordrecht, The Netherlands, 1992, 242 pages. US $133.00 (ISBN 0-7923-2018-2).

This book, which is reprinted from *Origins of Life and Evolution of the Biosphere*, Volume 22, Nos. 1-4, 1992, presents a critical assessment of the possible role of hydrothermal systems in the origin of life. The authors' challenge is daunting and no less fundamental than the origin of life on this planet (and possibly the entire universe). The work adopts a multidisciplinary approach whereby processes relating to the origin of life are reviewed with respect to the inorganic and organic geochemistry of hydrothermal systems. The authors make passing reference to terrestrial systems and ancient seafloor sulfide deposits, but emphasize high-temperature "black smoker" vents at modern sediment-bare and sediment-covered oceanic spreading centers. Although it is recognized that lower-temperature off-axis hydrothermal systems have a higher flux of fluid, the paucity of data for these systems has prevented a rigorous evaluation of their suitability for the generation of life.

The book's greatest achievement is the distillation of a multidisciplinary literature into a concise and well-written review of the current understanding of the role (if any) of hydrothermal processes in the origin of life. Although the hydrothermal model for the origin of life is far from being proved, it is shown that hydrothermal systems do provide conditions that, on the basis of available data, are suitable for the generation of prebiotic organic compounds and, therefore, possibly life itself. Of equal importance is the critical review of measured and experimental data, and the identification of areas that require a great deal of research if fundamental questions on the origin of life are to be fully addressed.

There are ten chapters in all, with an extensive bibliography at the end of the book, and the chapters are logically organized from natural hydrothermal systems to the synthesis of organic compounds. Other than the introductory and concluding chapters, the book is divided into three major areas, presenting reviews of the inorganic and organic geochemistry of modern hydrothermal systems (mostly "black smoker" environments) (chapters 2 to 5), the prebiotic chemical markers that may be important in hydrothermal systems (chapter 6), and the synthesis of organic compounds under hydrothermal conditions (chapters 7 to 9).

Chapter 1 (Why are Hydrothermal Systems Proposed as Plausible Environments for the Origin of Life? by N.G. Holm) is a brief review of the evolution of ideas on the possible role of seafloor hydrothermal systems in the origin of life, including a response to criticism of the hydrothermal model. Chapter 2 (Hydrothermal Systems: their Varieties, Dynamics, and Suitability for Prebiotic Chemistry, by N. G. Holm and R. J.-C. Hennet) offers a general review of modern hydrothermal systems and their geological and tectonic settings, *e.g.*, sedimented and unsedimented oceanic rifts, hot spots, back-arc rifts, subduction zones and continental rifts. The authors' treatment of ancient hydrothermal systems is cursory and ignores many of the reports of vent fauna associated with seafloor massive sulfide deposits. Processes considered include conditions of the fluid, particularly temperature, pressure, pH, oxidation state, chemical composition, with an emphasis on CO_2, N, P, CH_4 and other organic compounds. Continental hydrothermal systems involving meteoric water are largely ignored, although the database for active continental systems is limited. Chapter 3 (Modern Life at High Temperatures, by R.M. Daniel) is an up-to-date, extremely relevant but rather brief review of the evolution of thermophilic bacteria, their metabolic pathways and the temperatures at which they live. Almost all the information in this chapter comes from laboratory experiments and thermochemical calculations. Chapter 4 (Aqueous Organic Geochemistry at High Temperature/High Pressure, by B.R.T. Simoneit) reviews the organic geochemistry of sedimented and unsedimented seafloor hydrothermal systems, with an emphasis on the Guaymas Basin, Gulf of California. This chapter provides a thorough documentation of organic compounds as a function of the thermal regime where they were generated or where they now reside, *i.e.*, within zones of hydrothermal reaction or upflow, in vent fluids, seafloor sulfide mounds and chimneys. Processes of alteration of organic matter by hydrothermal fluids are also considered here. Chapter 5 (Chemical Environments of Submarine Hydrothermal Systems, by E.L. Shock) is an excellent review of modern hydrothermal systems, including the geological setting, composition of vent fluids, constraints on fluid temperature, pH, $f(O_2)$ and composition, and fluid–rock reactions. Experimental data on the synthesis of organic compounds under hydrothermal conditions also are discussed. Although most of the observations on hydrothermal fluids come from modern axial vents, experimental data indicate that the off-axis, lower-temperature systems are better suited to generate organic compounds. For a neutral atmosphere, hydrothermal synthesis of organic compounds is only a factor or two less than the sum of organic contribution and production from all nonhydrothermal sources. Chapter 6 (Chemical Markers of Prebiotic Chemistry in Hydrothermal Systems, by J.P. Ferris) reviews possible precursor molecules in hydrothermal systems or laboratory simulations of them. Covered in this chapter are the types of molecules that may have formed on primitive Earth and that have been observed in the interstellar medium, comets and meteorites, the stability of organic molecules in supercritical hydrothermal fluids, and Fischer–Tropsch-type experimental reactions that are potentially important in the formation of biological molecules under hydrothermal conditions. Experiments on organic synthesis are reviewed in Chapter 7 (Hydrothermal Organic Synthesis Experiments, by E.L. Shock). There is ample heat in hydrothermal systems to drive abiotic synthesis reactions, and experimental results are consistent with metastable synthesis of organic compounds. Unfortunately, most of the experiments that simulate natural hydrothermal conditions are poorly constrained (*e.g.*, temperature, pressure, pH, oxidation state, fluid compositions). Experiments using high contents of transition metals in the abiotic synthesis of organic compounds under seafloor hydrothermal conditions are summarized in Chapter 8 (An Experimental Approach to Chemical Evolution in Submarine Hydrothermal Systems, by H. Yanagawa). The transition metals buffer the $f(O_2)$ at fairly low levels, thereby preventing the destruction of amino acids. Chapter 9 (Mineral Theories of the Origin of Life and an Iron Sulphide Example, by A.G. Cairns-Smith, A.J. Hall and M.J. Russell) considers the role of minerals in the origin of life, based partly on an example of ancient hydrothermal sulfides in Ireland. The model, which is not supported by experimental or observational data, proposes that iron sulfides played an important role in the reduction of CO_2 and, therefore, the formation of organic compounds such as methane. The final chapter (Chapter 10, Future Research, by all contributors) emphasizes the need for careful monitoring and on-site experimentation of active hydrothermal systems, the chemical modeling of hydrothermal systems, and continued but better-constrained laboratory simulation of organic compounds under hydrothermal conditions.

The book is generally well produced, with few typographical or grammatical errors. Most of the figures are legible and carefully annotated, with

the exception of a few computer plots where the type is rather faint. Running headings of each article are presented at the top of each page. Although the style of writing reflects that of individual authors, the material is generally up-to-date, logically organized and clearly presented. Unfortunately, the authors make little use of the extensive literature of ancient hydrothermal systems and their associated biota. After all, modern hydrothermal systems are a rather new phenomenon (since 1977), whereas ancient systems have been studied for more than a century. Furthermore, ancient deposits offer the added advantage of providing a window into the earliest hydrothermal environments in which life may have originated, and of presenting a three-dimensional view of a hydrothermal systems, from the reaction zone to the seafloor. The book is appropriate in the library of geochemists and biologists studying the origin and evolution of life at hydrothermal centers. The cost is comparable to other books in the field.

Wayne D. Goodfellow
Geological Survey of Canada

BRAZIL GOLD '91 – The Economics, Geology, Geochemistry and Genesis of Gold Deposits. Edited by E.A. Ladeira. A.A. Balkema Uitgevers B.V., Postbus 1675, 3000 BR Rotterdam, The Netherlands. 823 + xxvii pages. Dfl. 165 (US $87) (ISBN 0-949106-53-4).

Brazil Gold '91 was the major conference in the world in 1991 on this commodity for geologists. It was held in Belo Horizonte (State of Minas Gerais) and very well attended, considering that 117 papers and abstracts were submitted by participants from 23 different countries. This book contains the proceedings of this conference as a collection of articles ranging from extended abstracts (4–6 pages) to short papers (8–10 pages), all of them refereed by a board composed of five Brazilian geoscientists, one of them a mineral economist.

The book consists of five thematic sections preceded by the papers written by the invited lecturers. All of the material was submitted in camera-ready format. Thus the individual authors were responsible for the correct editing of their work. Although a variety of fonts were used, the papers have a consistent overall format. This typographical inhomogeneity does not detract from the presentation, which is clear and easy to read.

In the section on the invited lectures, three full papers and four extended abstracts appear: two papers review the regional geology and ore deposits of important mining districts in Brazil (the Quadrilatero Ferrifero and the Rio Itapicuru). In the third paper, F. Robert gives a terse presentation of the two most common styles of Au mineralization in the Abitibi Greenstone Belt.

The section on regional studies covers gold districts from every continent except Oceania, and will probably be of great interest to explorationists in search of "new frontiers". Cathelineau *et al.* present one of the most original contributions by "revisiting the shear zone" model for the formation of gold deposits.

About half of the papers in the section on petrology and geochemistry of gold deposits deal with Archean mineralization. Some of them (*e.g.*, Groves *et al.*, and Spooner) indicate a new trend in the interpretation of field data, *i.e.*, the recognition that magmatic, rather than metamorphic fluids, probably played an important role in the genesis of Archean gold deposits. The other articles of this section present data on younger gold deposits and on analytical studies. Amongst the latter is an intriguing contribution by Knipe *et al.*, who investigated the site-specific occurrence of Au in sulfide separates. From this work, it is clear that further advances in the study of ore textures will be strictly related to the understanding of processes involving surface chemistry.

The sections on the geology and case studies of gold deposits and on their structural controls are dominated by field descriptions of mineralization from all over the world. Most of the deposits are pre-Phanerozoic in age, with typical Mesozoic and Tertiary epithermal Au systems unfortunately conspicuous by their absence.

I have always found that papers on mineral exploration techniques and strategies present only very general information, since a successful explorationist would tend to avoid publishing "the tricks of his trade". The relevant section in Brazil '91 is no exception to the rule. However, those papers tackling basic concepts in exploration geochemistry are the most useful.

In conclusion, the main strength of the Proceedings of Brazil Gold '91 lies in the broad variety of districts, styles of mineralization and individual deposits. The weak points center on the variable quality of the individual papers and the poor command of the English language by some of the authors. However, for most of the subject matter covered by this book, the original documentation is in many cases scarce, written in a local language, or hardly accessible to the geological community at large, *e.g.*, deposits in Brazil, India, Italy, *etc.* Thus, this publication becomes an essential addition to any professional, academic and governmental library. For an 823-page hard-cover book, the price of US$87 is quite reasonable.

Alfonso G. Trudu
Monash University, Clayton, Victoria, Australia

Analysis of Geological Materials. Edited by Chris Riddle. Marcel Dekker, Inc., 270 Madison Avenue, New York, N.Y. 10016, U.S.A., 1993, 480 pages. CAN $150.00 hardbound (ISBN 0-8247-9132-0).

I was interested in reviewing this book because of the need to find under one cover a comprehensive up-to-date account of the very large array of methods currently available for analysis of geological materials, some of which are very sophisticated, and many of which are still in the development stage. I also expected that such a book would clearly document the strengths and weaknesses of methods of bulk- and micro-analysis, in such a manner that would be helpful, both to users of analytical services, as well as to analysts themselves. Though some of these requirements are found in the book, I was generally disappointed, possibly because my initial expectations were too high.

The book consists of nine chapters and an index, and purports "to bridge the gap between geology and analytical chemistry, and between geologists and analytical chemists." According to the editor, the "one particular reader in mind ... is the new graduate student whose work involves geochemical research but who has only a superficial knowledge of analytical techniques."

The small (15 × 23 cm) format is a handicap because it results in small print in some tables and figures; also, some tables and figures may not be sufficiently near to their discussion in the text. Two different styles of reference are used by the authors, and some authors provide their own separate glossary (which is not always internally consistent), suggesting limited editorial direction. Another such example is indicated by the bulk of the content of Chapter 1 (An overview of geochemical research: implications for the geoanalyst, by R.H. Sutcliffe), dealing with examples of geochemical research problems that could easily have been integrated into Chapter 9 (The interpretation of geochemical data, by P.C. Lightfoot), which is a review of several examples of geochemical studies.

What I found particularly frustrating was the lack of a detailed table of contents for each chapter, leaving the reader with little inkling as to what will be covered and making speed reading very difficult, because of unexpected headings and subheadings, as well as unconventional labelling for each heading. In addition, the choice of headings and subheadings is sometimes difficult to follow. Consider this aspect for Chapter 9, where it is difficult for the reader to guess what will be developed next, and where the reader can get lost by trying to use the heading format to locate oneself within the chapter. For example, there are the five following "B." sub-sub headings: **Qualitative Modelling** (p. 383), **An Example: Exploration for Magmatic Sulfides at Insizwa** (p. 398), **Presentation of Trace Element Data** (p. 403), **The Sm-Nd Scheme** (p. 426), and **Partial Melting** (p. 435). How is the reader to guess that the first "B." refers to sub-head **II. MAJOR ELEMENT OXIDE DATA**, the second, to **III. MODAL MINERALOGY AND MINERAL CHEMICAL DATA**, the third, to **IV. TRACE ELEMENT DATA**, the fourth, to **V. RADIOGENIC ISOTOPE VARIATIONS**, and the fifth, to **VI. QUANTITATIVE MODELLING OF COMBINED ELEMENTAL AND ISOTOPIC VARIATIONS**? This is another example where editorial work could have made a contribution to the effectiveness of the contents.

Chapter 2 (A practical guide to field sampling for geological programs, by J.M. Richardson) covers the different types of field samples that may be collected, including a discussion of Quality Assurance/Quality Control (QA/QC). The following chapter (Sample preparation, by J.-P.G. Saheurs, W.P. Wilson and W.G. Sherwood) discusses laboratory preparation of different field samples necessary to produce pulps for bulk analyses. The contents include some flow-sheets and details or references to specific sample types (*e.g.*, Au, the PGE, Mo, U, and base metals), as well as a very useful listing of selected suppliers of equipment, and a comprehensive bibliography, including full titles of articles and books. There is some duplication between the text on pages 69-70 and Table 1.

Chapter 4 (Laboratory methods of analysis, by P.J. Potts) is the longest and also the most ambitious chapter in the book. Indeed, this chapter represents the *raison d'être* of the book and is an attempt to review and assess "a confusing armoury of geoanalytical techniques now available, each technique having its own analytical characteristics, many having overlapping capabilities." Unfortunately, the coverage is uneven owing to the little likelihood of one person having sufficient in-depth knowledge of all the bulk and micro-analytical techniques covered. The weakest sections concern the micro-analytical techniques. For example, the discussion of SIMS is incomplete and misleading because there is no mention of the success achieved with Au and Ag determinations, by using combinations of high mass-resolution, with or without voltage offsets, but with implanted standards, to produce highly valuable quantitative results at the sub-ppm level (Chryssoulis *et al.* 1986, 1987, 1989, Chryssoulis 1990, Chryssoulis & Cabri 1990). Likewise, the discussion of PIXE, or what should be properly described as μ-PIXE, is also misleading. For example, it is stated that "...PIXE facilities are only available at a restricted number of sites..." whereas in reality there are over 40 proton microprobes currently in existence, though they vary significantly in their analytical mission (Czamanske *et al.* 1993). Thus PIXE facilities are far more abundant than SHRIMP laboratories, for example. In addition, it is well known to users of proton microprobes that there are PIXE

laboratories that will perform analyses on samples sent by mail, thus overcoming the perceived lack of facilities due to geographic location. The discussion is in places unclear, *e.g.*, why single out and state that As, Mn, and Ta may be determined by PIGE with a Ge(Li) detector (p. 211), when these elements are routinely determined by conventional PIXE? In fact, PIGE is usually used to augment PIXE because of the ability to analyze for the light elements Li, Be, B, F, and Na, which are of geological interest and also difficult (or impossible) to determine by electron microprobe. On the other hand, the author seems to favour the X-ray microprobe, which is said to "...offer several advantages as a microanalysis technique." In this case, no mention is made of the scarcity of such facilities, the spatial resolution of the beam, or the interpretation of satellite reflections. A valuable addition to a chapter such as this, where an attempt is made to review current methods of bulk- and micro-analysis, would have been to include a tabulation of the advantages and disadvantage of *all* the methods (including items such as speed of analysis, cost, detection limits, *etc.*), as well as spatial resolution in three dimensions for each microanalytical technique. The reference list in this chapter is very limited in quantity and in breadth of coverage. At the end of the reference listing is appended a "Bibliography" of references not quoted in the text, but which is likewise distinguished by its lack of sufficient breadth. It is particularly unfortunate that an excellent 1992 Special Issue of the *Journal of Geochemical Exploration* (Geoanalysis, G.E.M. Hall, ed., **44**, Nos. 1-3, 1-321) is simply listed under "General" in the Bibliography. Few readers will guess its contents from this minimal referencing! This important special issue contains comprehensive separate chapters, for example, on techniques that are described more briefly in Chapter 4 (AAS, ICPES, ICPMS, XRF, INAA, radiochemical NAA) and, in addition, it contains excellent chapters on quality of data, precision, reference samples, and decomposition techniques, all of which deserve far more credit for their relevant contributions, but do not appear to be quoted in the other chapters of the book under review.

Chapter 5 (Analytical methods: field and remote locations, by R.R. Barefoot, J.C. Van Loon and G.E.M. Hall) reviews current methods of analyses that can be done under field conditions. Chapter 6 (Ores and concentrates by J. Bozic and F.E. Smith) is a useful account of factors that are specific to bulk analyses of sulfide-bearing metallic ores and concentrates, ranging from on-stream analyses to giving an example of a contractual agreement between a mill and a smelter. This chapter also includes a discussion of Certified Reference Materials for ores and concentrates, a subject which properly should have been included (with more details) in the following Chapter 7 (Geostandards: preparation, sources, and evaluation, by K. Govindaraju). The latter chapter makes brief reference to Chapter 6 for "...special consideration of ore-grade reference materials...". In Chapter 7, the tabulation given of abbreviations of geostandards organizations, products, and terms used appears to be inconsistent and incomplete: a project is listed instead of an organization (which is not listed), some "organizations" are identified by a city, others by a country, and for some no location is given. The list under "Products" contains two geostandards, one database, and two newsletters, a skimpy listing indeed! The rest of this chapter is likewise uneven in its treatment, *e.g.*, descriptions for the preparation of reference standards in some organizations are detailed, whereas others are very brief, consisting only of references to the literature. I also found the small section on trace elements difficult to understand. A tabulation that purports to classify "recommended values according to the number assigned per element" suggests that there are zero reliable values for Ir, Pd, Pt, and Ru, and few for Au, which is difficult to believe. In contrast, a comprehensive and up-to-date listing of geochemical reference materials by Potts *et al.* (1992) lists a very large number of standards for each element, indicating varying degrees of confidence. Listed under the highest degrees of confidence, *viz.* certified and recommended values, are 15 for Au, 5 for Pt, 4 for Pd, and 1 each for Ir and Ru. Could it be that Govindaraju's listing is too limited owing to a narrow interpretation of what constitutes a standard useful for geochemical studies?

Finally, Chapter 8 (Quality control and quality assurance, by W.M. Johnson) is a review and discussion of QA/QC procedures for bulk analyses, including use of reference standards, concluding with an example for the documentation of Zn determinations in a Zn concentrate.

In spite of many shortcomings, there is useful information to be found in this book. The problem is that the reader may find it difficult to find this information quickly and efficiently; certainly the "bare-bones" index will not help very much. The final deterrent for "the new graduate student" to purchase a personal copy may be the rather exorbitant price.

Louis J. Cabri
Canada Centre for Mineral and Energy Technology

References

Chryssoulis, S.L. (1990): Quantitative trace precious metal analysis of sulfide and sulfarsenide minerals by SIMS. *In* Secondary Mass Spectrometry, SIMS VII (A. Benninghoven, C.A. Evans, K.D. McKeegan, H.A. Storms & H.W. Werner, eds.). J. Wiley & Sons, Ltd., Chichester, U.K. (405-408).

———— & CABRI, L.J. (1990): The significance of gold mineralogical balances in mineral processing. *Inst. Min. Metall. Trans.* **99**, C1-C10.

————, ———— & LENNARD, W. (1989): Calibration of the ion microprobe for quantitative trace precious metal analyses of ore minerals. *Econ. Geol.* **84**, 1684-1689.

————, ———— & SALTER, R.S. (1987): Direct determination of invisible gold in refractory sulphide ores. Proc. Int. Symp. on Gold Metallurgy – Refractory Gold (R.S. Salter, D.M. Wyslouzil & G.W. McDonald, eds.). Pergamon Press, New York, N.Y. (235-244).

————, CHAUVIN, W.J. & SURGES, L.J. (1986): Trace element analysis by secondary ion mass spectrometry with particular reference to silver in the Brunswick sphalerite. *Can. Metall. Quart.* **25**, 233-239.

CZAMANSKE, G.K., SISSON, T.W., CAMPBELL, J.L. & TEESDALE, W.J. (1993): Micro-PIXE analysis of silicate reference standards. *Am. Mineral.* **78**, 893-903.

POTTS, P.J., TINDLE, A.G. & WEBB, P.C. (1992): *Geochemical Reference Material Compositions*. CRC Press, Boca Raton, Florida.

ERRATUM

In the contribution by E. Marcoux, J.-P. Milési, S. Sohearto and R. Rinawan, entitled "Noteworthy mineralogy of the Au–Ag–Sn–W(Bi) epithermal ore deposit of Cirotan, West Java, Indonesia" (*Can. Mineral.* **31**, 727-744, 1993), an error exists in the symbols used in Figure 9, on page 736. Open circles should have been used to represent gustavite, and full circles should have been used to represent lillianite, instead of *vice versa*.