directly attributed to seafloor hydrothermal activity as opposed to the laterally extensive Superior type iron formation attributable to more global evolutionary events. As the title indicates, most example of the use of various element ratios, including REE patterns, as vectors to the site of hydrothermal deposits (where sulphide ore deposits occur) are from the Bathurst mining camp of New Brunswick, but examples from other ancient deposits and the modern seafloor are also given. The data from these different areas are summarized in six tables and 40 diagrams, making the chapter a valuable reference for the chemistry and chemical architecture of this type of deposit.

The book has been well edited and laid out. There is an index, and the Table of Contents lists the three levels of sub-headings for each chapter, so that the reader can quickly find the pages dealing with a particular topic. Few typographical and other technical errors remain, and not too much flipping of pages is needed to consult diagrams referred to in the text. The two-column, 8.5 x 11 inch pages are clear and crisp, but their readability would have been improved by the use of a font size larger than the 9 pt that has been used. The book is bound in an attractive hard cover, and at just 5/8th inch thick, it will not consume too much space on a bookshelf. However, priced at between \$55 and \$80, depending upon professional society affiliation, it cannot be considered to be cheap, and its relatively high price for such a slim volume will be a deterrent to some.

Who should buy the book? I don't think it can be recommended as a primer to introduce the reader to modern sedimentary chemistry because of two main shortfalls: 1) It is not self-contained in the sense that to fully follow many of the discussions and diagrams, it is necessary to consult other literature, even though this literature is very well cited. For example, in reading the chapter by McLennan et al., I found that I had to reach for other texts to remind myself of the fundamental systematics and conventions of the U-Th-Pb and Sm-Nd systems to follow the full significances of comments and discussions.
2) Individual chapters could have been better integrated with one another where appropriate, so that the student is brought to awareness of the inter-connections that do exist between the different specialties dealt with in the book. For example, even though weathering and diagenesis is an integral part of the ore-forming process described in the chapter by Brown, there is no connection made to the weathering and diagenetic trends described in the chapter by Nesbitt. I also don't think it can be recommended as a reference book because, apart from the tables given by Lentz and Peter and the evolutionary charts of Veizer, it lacks a sufficient number of tables of raw data for different types of sedimentary rocks from different geological environments that would give the book a long shelf life as a source for standard information on sedimentary geochemistry.

Having said that, the volume is a good review of the status of under-standing in sedimentary geochemistry and is a comprehensive statement of current research methodologies and research directions in this specialty. The reader will come away with a general idea of where sedimentary geochemistry is at, and perhaps a thirst for the more detailed information cited in the bibliographies. I therefore think it would be most useful for those who already have a grasp of the fundamentals of sedimentology and lithogeochemistry, and who want to be quickly brought up to speed on current thoughts and research directions in the field of sedimentary geochemistry. In other words, as was its original intent, it is a short course manual.

Snowball Earth: the Story of the Global Catastrophe that Spawned Life as We Know it

by Gabrielle Walker
Crown Publishers. N.Y., 2003
CDN\$37.95, hardcover. ISBN 0-609-60973-4
Reviewed by E.R. Ward Neale
5108 Carney Road N.W.
Calgary, Alberta T2L 1G2

This book recounts the development of the Snowball Earth theory from its beginnings up to press time and even beyond (several articles in print or progress are cited!). It is pitched at the layperson's level and close to half of the text is devoted to the lives and motivations of the scientists involved. Most readers of this review will know the main Snowball protagonist - the GSC's former Precambrian virtuoso, Paul Hoffman. Many will have heard him in his present role of Harvard professor as he has expounded on the theory at national meetings and in university settings across the continent and around the world. The progress of the theory, its adherents and challengers, flashbacks to other scientists with theories ahead of their times (e.g. Wegener's continental drift) are cleverly interspersed and told in an exciting, suspenseful way by a skilled, informed and experienced narrator. Author Gabrielle Walker, a Cambridge Ph.D. and well-known science editor, has visited key Snowball field sites around the world and has had lengthy interviews with the main players over the past several years. Her book will appeal to scientists and non-scientists alike.

Evidence for a world-wide Late Proterozoic glacial event (or events) originated with the late Brian Harland of Cambridge University. His fieldwork, beginning over 60 years ago in the Svalbard Archipelago, Norway, and Greenland, recognized obvious glacial marine deposits bounded above and below by oolitic limestones that suggested tropical deposition. When he presented a paper in 1963 on a "Great Infra-Cambrian Glaciation" he was shot down by critics who interpreted his glacial dropstones as products of marine mudslides. Paleomagnetism was not advanced enough to prove that his "ice rocks" had originated near the equator so he reached a dead end.

Next on the scene was brilliant ("nutty" he says) Joe Kirschvink from Cal Tech. A paper contending that Precambrian glacial deposits in South Australia showed the flat magnetic fields indicative of equatorial origin intrigued him. Tests for magnetic overprinting had not been applied, so Joe sent a graduate student to study and sample the site. The flat magnetic fields proved to be original and, hence, equatorial. All he wrote was a two page article in an obscure monograph. In it, he indicated that volcanism would continue throughout global glaciation and so CO-2 would build up to enormous levels as there was no mechanism to remove it from the atmosphere. The Greenhouse affect would kick in, the atmosphere would become like a furnace, the global ice would melt and the scorching climate would set the stage for the emergence of a whole new kind of life. He christened the event "Snowball Earth". Before dropping its advocacy and moving to other "nutty projects", Joe sat with Paul Hoffman at a dinner and told him about the Snowball theory.

Enter the book's hero, our Paul. Leaving the Geological Survey of Canada after an altercation with its director and spending a couple of years at University of Victoria, he accepted a professorship at Harvard. Then, where to find a field project? Namibia, in southwest Africa, with vast, unstudied, desert exposures of 600–700 Ma rocks was a natural. His initial purpose in 1993 was to measure timing of continental shifts, but he became more and more intrigued with exposures of glacial marine deposits bounded below and above with tropical carbonates. A literature search found similar phenomena reported on all continents and unearthed Brian Harland's and Joe Kirschchvink's ponderings on global glaciation. The carbonates above and below fascinated Paul with their anomalous C_{13}:C_{12} ratios, and those above with their rose-coloured crystal fans and mysterious vertical tubes. All was explained when he teamed up with an insightful young Harvard colleague, Dan Schrag, a carbonate and paleoclimate specialist. This produced the theory many readers of this review have heard from Paul's own lips or read in Science or Scientific American a few years ago. In short: 1) the C_{13}:C_{12} ratios showed greatly diminished life immediately before and after global glaciation; 2) volcanic CO_2 wrapped Earth in a blanket of warmth causing rapid melting; 3) scorched air sucked up moisture and hyper-hurricanes spread sheets of acid rain on glacial rock dust and swept it into the oceans; 4) saturated oceans deposited cap carbonates all around our planet. Their crystal fans resemble those found near acid hot springs, the vertical tubes were produced by gas bubbles. A good story but science has doubters!

"The Present is the Key to the Past" is an anchor of our science and a catastrophic Snowball Earth was not welcomed by many practitioners. Two chapters are devoted solely to the challenges and the challengers. There were many, e.g. sand wedges in the "ice rocks" of Australia suggest freezing and thawing and hence seasonal variations. Another was the question of how life could survive global glaciation. Paul and his colleague, Dan, either found answers to the queries or modified their theory to accommodate them. Sometimes an attempt to disprove the theory backfired - a student working on the Precambrian "ice rocks" in Australia found evidence of seven polar reversals, providing welcome proof of the long duration of the glacial event. She was a student of Columbia University's Nick Christie-Blick, who seems obsessed with melting the Snowball theory. He even presented a seminar at M.I.T. entitled "The Snowball Earth: A Neoproterozoic Snow Job"! Paul now has evidence that at least two, and possibly as many as five successive global glaciations occurred between 750 and 590 Ma. This is now widely (but not universally) accepted. So, what effect did it have on development of multicellular life?

A chapter entitled "Creation" takes the reader on field trips to Ediacara, Australia, the White Sea, and finally to Mistaken Point, Newfoundland to learn details of the multicellular life forms that appeared before the "Cambrian Explosion". The Newfoundland fossils are well-dated by their overlying volcanic ash at 575 Ma, just 15 Ma after the end of global glaciation. Coincidence, or did climatic extremes trigger the beginning of complexity in life forms? Biologists, just as geologists, are conditioned to thinking of evolution progressing slowly, and catastrophic causes arouse suspicion. There have been many challenges; for example, reports of complex life in pre-Snowball times, and "DNA Clock" experiments that initially suggested a more ancient origin of complexity. However, recent DNA experiments carried out by a doubter at Dartmouth University seem to tie the beginning of complex life to the Snowball era.

A final chapter reviews recent speculations on the causes of global glaciation. The current favourite involves congregation of the continents around the equator causing sunlight to be reflected and resulting in multiple global glaciations until dispersal approximately 590 Ma ago.

Most readers of this review know from first hand or geo-gossip something of Paul Hoffman. They will learn much more about this famed Boston Marathon runner, jazz enthusiast, hot-tempered genius and his continual quest for recognition and fame. In contrast, his closest colleague, Dan Schrag, is pleasant, easy going and adept at smoothing out "snowbrawls". The person who got it all going, Brian Harland, is "a slight man with pinched features and a nervous disposition" who worries over details and plans to excess. He has survived many dangerous mishaps in his Arctic explorations. Good- humoured Joe Kirschvink picks topics that others shun, continually makes discoveries that bring him into the spotlight and then moves on to something else. His students love him! Then there is Nick Christie-Blick, soft-spoken Brit, who devotes himself to "picking away at the threads of theories until he finds a detail that unravels the whole thing". Many more participants are described. All are sufficiently different to shatter any stereotypes as Gabrielle Walker tells the story of the most hotly contested theory in Earth science today and the scientists, pro and con.

Her final lines: "Theories like the Snowball often languish for decades without being properly probed. They need champions to drag them into the scientific limelight and expose them to scrutiny. They need people like Paul."

Biomineralization

Edited by P. M. Dove, J. J. De Yoreo and S. Weiner
Reviews in Mineralogy & Geochemistry v. 54, 381 p., 2003; Mineralogical Society of America; ISBN 093995066-9
US$36.00 (US$27.00 for members of Mineralogical Society of America, Geochemical Society or Clay Minerals Society)

Reviewed by Brian R. Pratt
Department of Geological Sciences
University of Saskatchewan
Saskatoon, Saskatchewan S7N 5E2
brian.pratt@usask.ca

I am glad that the U.S. Library of Congress, which normally treats earth sciences poorly, saw fit to catalogue the Reviews in Mineralogy & Geochemistry under one number, because not only is that distinctive row of small, white dog-eared paperbacks a point of visual geographic reference, but also a rich source of easy-to-find information on a sweeping array of mineralogical topics. Each volume is crystallized around a short course, and that on biomineralization was delivered prior to the fall 2003 meeting of the American Geophysical Union. This is a series of review papers covering a range of recent developments in the field. It adds to an extensive literature on biomineralization, summarized in a number of fairly recent books, such as those written or edited by B.S.C. Leadbeater and R. Riding (1986), H.A. Lowenstam and S. Weiner (1989), R.E. Crick (1989), S. Mann et al. (1989), K. Simkiss and K. Wilbur (1989), J.G. Carter (1990), E. Bäuerlein (2000) and S. Mann (2001), each of which takes a somewhat different tack. In this book, biomineralization means biologically mediated mineral precipitation, that is, both biologically controlled as well as biologically induced, the latter sometimes referred to as organomineralization. (Organomineralization has also been used to denote early diagenetic precipitation triggered by residual organic compounds such as fulvic acids, an area not treated here.) The whole subject is understandably vast and complex.

The introductions of the papers collectively sum up the importance of biomineralization and why geologists should care: organisms—prokaryotic starting nearly 4 billion years ago, eukaryotic barging in for the past half a billion or so—shouldered their way into virtually all geochemical cycles on Earth's surface to the point that most geochemical reactions are really biogeochemical. Organisms are in charge, you better believe it! The grandness and the range of scale, from gross patterns in the rock record to global geochemical cycles to cell metabolism, are captivating. Furthermore, the activities of organisms in bygone eras sequestered minerals that are part of the reservoir re-entering the system via weathering. It is all so simple. The devil is in the details—if you thought chemistry and thermodynamics hurt, try adding organisms to the brew!

This book consists of 12 chapters by an assortment of leading authorities. They are well written and well illustrated and the book is well produced, a tribute to the sponsoring societies. It is ordered, not unnaturally, from the minute to the mega in terms of scale. But if we seek the narrative dimension, the hallmark of geology, we can peek at the final chapters first. A.H. Knoll gives a masterful summary of the evolutionary history of biomineralization, outlining the origins, the phylogeny and fossil record of shells, spicules, endo- and exoskeletons, and so on. He deals with the Neoproterozoic appearances, the "Cambrian explosion", the Ordovician radiations of heavily calcified skeletons, the Permo-Triassic extinction, subsequent recovery as part of the "Mesozoic marine revolution" (the arms race between predators and prey), and the late Mesozoic rise of calcite-secreting coccolithophorids and silica-secreting diatoms. The importance of these events is amplified by P. Van Cappellen who provides an instructive overview of global biogeochemical cycling, the time scale at which its components operate, the size of the reservoirs, their fluxes and their turnover times, and the basic theory behind numerical models. He then delves a little more deeply into the carbon and silica cycles. Both these papers bring the vital perspectives of Deep Time and Whole Earth to the world of biomineralization, showing that biogeochemical pathways have evolved since organisms began to participate, with the backdrop of changing global tectonics. Knoll also touches on the future by reporting the suggestion that the oceans are not well buffered against rapidly rising atmospheric CO_2 levels, meaning that the physiological cost of calcification might become too high for many invertebrate groups to sustain, thereby duplicating past extinction scenarios.

Turning to the more biological, the introductory chapter by the book editors gives us a list of biominerals—much longer than you might imagine—and shows that many groups have evolved the extraordinary feat of being able to extract ions from highly undersaturated environments. The authors outline the mechanisms whereby secretion, active pumping, passive diffusion or gradient diffusion at the cellular level cause nucleation on particulates, on cell surfaces, or genetically programmed precipitation in organic matrices either on or within cells. This introduction is followed by a succinct summary by J.S. Evans of the principles of molecular biology and biochemistry as they pertain to the three categories of macromolecules that are involved in mineral precipitation: proteins, polysaccharides and membrane assemblies. The more thermodynamic background to crystal nucleation and growth is then laid out by J.J. De Yoreo and P.G. Vekilov.