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Geochemistry of Sediments and Sedimentary Rocks: Evolutionary Considerations to Mineral Deposit-Forming Environments

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Geochemistry of Sediments and Sedimentary Rocks: Evolutionary Considerations to Mineral Deposit-Forming Environments

Edited by Dave Lentz
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Judging from the title of this book, I was expecting to find between its covers everything that a mineral deposit geologist should know about the effects of global evolution on ore-forming environments. After all, it is only sedimentary rocks that continuously encrypt in their records (notwithstanding that individual pages of the chronicle may be scattered over the different continents or even lost) the nature and architecture of the contemporaneous lithosphere, hydrosphere, atmosphere and biosphere, that along with tectonic and magmatic events, control ore-forming processes. Unfortunately for me as a mineral deposit geologist, this is not the case. The book concentrates on current research directions and methodologies that use the geochemistry of sedimentary rocks, especially their radiogenic isotope and whole rock chemical composition. Of the eleven chapters, only a review on the isotopic composition of seawater addresses evolutionary considerations and of the remainder, only three chapters focus on discussion of mineral deposit-forming environments.

Despite the initial disappointment, I found the book very educational and well worth reading. Each chapter covers a selected topic from its basic principles through to the current state of knowledge, with illustration by case examples. Both this structure to individual chapters and my impression of disconnect between the title and the content of the book have their explanation in the origins of the book. The original manuscripts were intended as notes for a short course aimed at encouraging the integration of advances in sedimentary geochemistry, particularly aspects of global evolution, into mineral deposit studies – hence the structure of the individual chapters to educate the non-specialist in the current state of knowledge, technology and techniques of the selected specialty. Unfortunately the short course did not proceed, and delinquency in the submission of final manuscripts produced the title versus content gap. Nevertheless, the reader is treated to authorative reviews by leading experts on a spectrum of topics pertaining to sedimentary geochemistry.

If it were not for weathering, sorting during transportation, and diagenesis, there would be few challenges to the geochemistry of sedimentary rocks. The composition of terrigenous sedimentary rocks would merely reflect the compositional aggregate of their source areas. However, it is the physical and chemical interaction of the lithosphere with the hydrosphere, atmosphere and biosphere during weathering, sorting and diagenesis that encrypts the information on the evolution of these Earth systems, and therefore the challenge is to understand the processes involved in order to decipher the encryptation. As editor Dave Lentz observes in his introductory chapter "Geochemistry of sediments and sedimentary rock: historical to research perspectives" the developments in mass spectrometer and microanalytical technology have seen an explosion of compositional data over the last decade at levels of precision and detection hitherto unattainable, and this has allowed more stringent constraints to be placed on sedimentary processes, particularly via the use of isotope geochemistry. This book brings the reader up to date on these advances.

Although not organized as such in the layout, I found that individual chapters in the book can be divided into four categories: i) those that concentrate on isotope geochemistry, ii) those that concentrate on isotope technology/methodology, iii) those that concentrate on major/trace element geochemistry, and iv) those that review a mineral deposit type.

i) Those that concentrate on isotope geochemistry

The chapter by Scott McLennan and co-workers entitled "The roles of provenance and sedimentary processes in the geochemistry of sedimentary rocks" is an overview of the current status of sedimentary geochemistry with emphasis on the uses and limitations of radiogenic isotopes, especially in provenance studies. A beginning summary of the chemical and mineralogical effects of weathering, sedimentary sorting and diagenesis is particularly useful for its extensive bibliography. The following section, under the sub-title "Provenance", reviews the use of whole rock and mineral component isotope analyses for geochronology and chemical tracers. A third and final section, subtitled "Some Case Studies", first discusses the mobility of REE, Th and U during diagenesis and then illustrates the use of isotopes to evaluate provenance and sedimentary processes and how sedimentary geochemistry can be used to constrain models for tectonic environments, paleoclimates and crustal evolution. The chapter is intense reading but is packed with information that when digested certainly satiates the appetite for knowledge of the current status of sedimentary geochemistry. The chapter on "Provenance and crust-mantle evolution studies based on radiogenic isotopes in sedimentary rocks" by Jonathan Patchett concentrates on the use of Sm-Nd, Lu-Hf and Rb-Sr isotopic approaches to problems of sedimentary provenance, tectonic environments and crust-mantle evolution. The chapter gives a lucid description of the fundamentals of the Rb-Sr, Sm-Nd and Lu-Hf systems and then discusses the uses of these systems to resolve problems of global evolution, particularly the growth and destruction of crust. Case examples discussed cover weathering and rivers, orogenic sedimentation, and cratonic sedimentation, and in doing so highlight some of the major problems of global budgets and global evolution that need to be investigated. A point that caught my eye was the superiority of the Sm-Nd system for a majority of problems because of the complexities introduced by the Rb-Sr decoupling by weathering and the zircon effect on the Lu-Hf system. Jan Veizer's chapter on "isotopic evolution of seawater on geological time scales: sedimentological perspective" is an excellent review of the variation of strontium, carbon, sulphur and oxygen isotopes of seawater throughout geological time. The background to the topic is clearly explained by an overview of the isotopic fractionation patterns between seawater and the host minerals, and the possible modifications to seawater isotopic signatures by various diagenetic processes. The evolutionary curves of the different isotopes are well illustrated at different levels of detail and are compared to theoretical curves of different models of global evolution. Veizer points out that on geological time scales the broad covariance of the different seawater isotopes points to an inter-related lithospere-hydrosphere-atmosphere-biosphere system that is driven by tectonics, and that the major use of seawater isotope trends is as tracers of large-scale features of global evolution and the correlation of sedimentary sequences that have poor biostratigraphic control.

ii) Those that concentrate on isotope technology/methodology

The chapter by Richard Cox on "Morphological, chemical, and geochronological techniques for characterizing detrital zircon" discusses almost everything that the reader would like to know about zircon in sedimentary rocks for geochronological purposes. This includes descriptions of its abundances, morphologies and chemistry and methods for its characterization by optical, etching, cathodoluminescence, and scanning electron microscope imaging techniques. The pros and cons of the different methods of analysis for U-Th-Pb zircon geochronology are discussed, as are zircon fission track and other potential techniques such as U-Th-He, Rb-Sr, Nd-Sm and Lu-Hf. The chapter by Robert A. Creaser titled "A review of the Rhenium-Osmium (Re-Os) isotope system with application to organic-rich sedimentary rocks" emphasizes the importance of the Re-Os isotope system to the direct dating of sedimentary rocks, particularly black shales in which these broadly chalcophile and siderophile elements are concentrated by reductive extraction from seawater. The use of this method is likely to become more widespread as a result of the development of the Negative Thermal Ionization Mass Spectrometry developed in the 1990s.

iii) Those that concentrate on major/trace element geochemistry

The chapter on "Petrogenesis of siliciclastic sediments and sedimentary rocks" by Wayne Nesbitt is a clear and concise review of the effects of weathering, sorting and diagenesis on the major element compositions of terrigenous sediments. It starts from basic principles and leads the reader step by step via liberal and effective use of Al_2O_3- (CaO + Na_2O)- K_2O (feldspar diagram) and Al_2O_3- (CaO+Na_2O+ K_2O)-(FeO_T+MgO) (mafics diagram) ternary diagrams to an understanding of the processes and trends of chemical/ mineralogical change during weathering, sorting and diagenesis.The chapter by Peter Fralick on "Geochemistry of clastic sedimentary rocks: ratio techniques" deals with the tailoring of ratios to prove immobility using immobile elements from minerals that have similar hydrodynamic behavior, the use of spider diagrams with MORB or mantle normalization to deduce provenance and the tectonic control of elemental abundances, and the use of ratios to determine hydraulic sorting relationships in paleoplacer deposits. The chapter explains the rationale for identifying immobile elements and whether trends reflect gain-loss of other elements or mobility. Although Fralick points out ratio plots are only one of a variety of methods, his guidelines are a valuable starting point to anyone wanting to decipher the variance in their geochemical data sets.

iv) Those that review a mineral deposit type

Raymond Coveney in his chapter "Metalliferous Paleozoic black shales and associated strata" gives a general overview of the European Kupferschiefer, Pennsylvanian black shales of central U.S.A. and the Cambrian Niutitang shale of China, areas in which he has personally carried out research. The overviews concentrate on the metal chemistry and metallic mineralogy of the shales and are illustrated by maps showing the aerial extent of the shales and the locations of mines or high metal contents. The origins of these metal concentrations are controversial, but epigenetic models involving reduction of source fluids prevail for the Kupferschiefer and Niutitang shales and the possibility of an association with MVT brines in the Pennsylvanian shales of central U.S.A. Alex Brown in his chapter "Redbeds: source of metals for sediment-hosted stratiform copper sandstone copper, sandstone lead, and sandstone uranium-vanadium deposits" reviews conventional genetic models for the deposit types listed in the title, illustrated by some case examples. For all deposit types, the ore-forming process involves the early oxidative diagenesis of first-cycle continental clastic sediments; the leaching of metals from labile minerals by saline groundwaters; and the transport of the metals by groundwater flow to a reductive subsurface environment, such as beds containing organic detritus or digenetic pyrite, where the metals are precipitated. Jan Peter in his chapter "Ancient iron formations: their genesis and use in the exploration for stratiform base metal sulphide deposits, with examples from the Bathurst Mining Camp" reviews the chemistry and mineralogy of Algoma type iron formations – that is iron formations of restricted lateral extent that can be 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

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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