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David Morrow

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Reviews

Backscattered scanning electron microscopy and image analysis of sediments and sedimentary rocks

By David H. Krinsley, Kenneth Pye, Sam Boggs, Jr. and N. Keith Tovey
Cambridge University Press
40 West 20th Street
New York, NY 10011-4211 USA
1998, 193 p., US$80.00

Reviewed by David Morrow
Geological Survey of Canada
3303 33 Street N.W.
Calgary, Alberta T2L 2A7

This is a hard-covered, approximately quarto-sized, nine-chapter volume published by Cambridge University Press and authored by four widely published researchers who are well known in the fields of sedimentary petrography and diagenesis. The volume is not unduly thick at about two centimetres from cover to cover. The cover design is attractive and evocative of its subject material without being garishly colourful. It is sturdily bound and should stand up well to everyday use.

A brief preface mentions that much of the early development of the scanning electron microscope (SEM) occurred in the engineering department of the University of Cambridge after 1948. This is followed by a short introductory chapter outlining the history of development of the backscattered electron mode (BSE) and the closely related secondary electron (SE) mode of the SEM and their applications to geological problems. The authors state here that their purpose is to show the types of geological information that can be obtained using BSE microscopy in comparison to techniques of optical microscopy. Most differences between these techniques are related to the order of magnitude greater resolution of BSE images.

The second chapter outlines the theory behind BSE and SE imagery. The dependence of BSE intensity on mineral mean atomic number is described along with the usefulness of SE imagery to enhance edge definition of minerals in BSE images. The use of grey-scale variations in BSE images to identify many different minerals and pore space is illustrated as well as problems in the differentiation of minerals with similar mean atomic numbers, such as dolomite, quartz and orthoclase. For these problem minerals, energy dispersive X ray analysis (EDX) or wavelength dispersive X ray analysis may be used to identify characteristic elements in order to discriminate between problem minerals. The problem of signal-to-noise ratio in the wide variety of types of backscattered electron detectors and issues concerning sample preparation are discussed.

The following chapters, with the exception of the final chapter, are essentially an attempt to demonstrate the usefulness of BSE microscopy for a wide range of petrographic and diagenetic problems, or, in other words, to fulfil the purpose stated by the authors in the introduction. This demonstration begins with chapter three dealing with sediment grains, weathering and early, near-surface, diagenetic phenomena. Examples include grain etching and grain overgrowths in dune sands, weathering-related dissolution of quartzites and granites, and the effects of marine salt spray weathering of sandstone blocks that cap seawalls. An interesting study concerns the degradation of concrete under the influence of sulphate-bearing groundwater solutions derived from a buried "industrial ash" horizon. Formation of the mineral ettringite, undetectable optically, has caused expansion and disintegration of the concrete because of the large molar volume of this mineral. Many examples of early diagenetic siderite formation and replacement in intertidal and marsh settings are shown.

Chapters four and five deal with sandstones and shales. The power of BSE analysis is well illustrated in image after image of sandstones showing details of intergranular clay, carbonate and anhydrite cements. Element zonations in carbonate cements, such as in ferroan dolomite, are clearly shown. BSE imagery shows fine details of processes such as albitization, silicification and kaolinitization of feldspars. BSE imagery is particularly well suited to the study of fine-grained rocks such as silts and shales and can reveal diagenetic details such as micrometre-sized authigenic pyrite and siderite in shales. Exotic mineral cements such as barite, which are difficult to identify optically, stand out clearly in BSE images because of their high atomic number. Microfabrics in shales are particularly clearly shown in BSE images.

Porosity in epoxy-impregnated samples shows in BSE images as nearly black regions and can be rendered more visible by contrast inversion to white. Excellent BSE images show details of porosity distribution in sandstones and shales. Very fine networks of sub-micrometre-sized pores can be seen in shales, as well as secondary dissolution porosity in feldspars and quartz. It is probably fair to say that BSE and SE imagery have been underused in studies devoted to documentation of porosity types and distribution for petroleum reservoir characterization. However, caution must be exercised in the discrimination of organic materials from porosity. Heavy metals can be used to "spike" organic materials for greater BSE visibility and differentiation from pore space.

The application of BSE imagery to the study of carbonate components is obvious and well shown in chapter six. The authors rightly argue that the study of dolomite and calcite cement stratigraphy should be studied using BSE imagery, and present many fine photographs to prove their point. Chapters seven and eight deal with the more specific topics of desert varnish and glauconite formation.

The volume ends with chapter nine dealing with image analysis, almost to the extent of being an image analysis short course. Issues such as the advantages of direct digital capture versus conventional photography are discussed. It is clear that digital capture is preferable overall, although conventional photography is still generally better for publication. For image analysis, digital BSE files give far truer renderings of the grey-scale gradations necessary to characterize mineral assemblages, amorphous materials, and porosity than do scanned conventional BSE image photographs. One great advantage of digital BSE files is that they may be "stacked" with corresponding digital EDX element concentration files in multilayer files acquired during the same SEM operating session to provide more comprehensive and accurate assessments of what is shown in the BSE images.

There are a few zingers. On page 7 the electron backscatter coefficient "0" is said to be proportional to beam strength for atomic numbers less than 47 and *vice-versa* for higher atomic numbers, but the graph on this page clearly shows the opposite. A little more serious is a statement on page 88 where the dissolution of carbonate minerals is related to "an increase in pore water pH" owing to an episode of decarboxylation. Most readers will recognize that increases in pore water pH will tend to favour precipitation, rather than dissolution, of carbonates. There are few, if any other, mistakes of this type.

An overall deficiency of the volume is the absence of case studies where BSE images have been used as one of many components in geological problem solving. It would have also been helpful to see more complementary SEM images, such as EDX images, accompanying the many illustrated BSE images, as well as optical microscope views of some lower resolution images. The authors come dangerously close to providing a simple atlas of BSE images, contrary to their stated purpose, but they do succeed in the end in demonstrating the wide range of data types that can be obtained by use of BSE images.

Many workers will recognize the great potential of BSE images as adjuncts to their own work. This book succeeds admirably in demonstrating how BSE imagery might be applied in new ways. This handsome book is priced at US$80.00. Not everyone will find it necessary to have this book, but, alternatively, no one will regret adding it to their overstuffed bookshelves.

Past global changes and their significance for the future

Edited by K.D. Alverson, F. Oldfied and R.S. Bradley
Quaternary Science Reviews, v. 19, n. 1-5
January 2000, 479 p.
US$57 journal issue
US$64 hardcover

Reviewed by James M. White
Geological Survey of Canada
3303 33 Street N.W.
Calgary, Alberta T2L 2A7

> When the logic of history hungers for bread and we hand out a stone, we are at pains to explain how much the stone resembles bread.
>
> *Aldo Leopold*

History certainly hungers for bread in the field of climatic change. Earth sciences are challenged to integrate disciplines of paleoecology, paleoceanography, isotopic geochemistry, modern climatology and atmospheric modelling to shed light on natural variability and possible future climatic states. This volume has an ambitious title. Is it a loaf, or a stone?

Papers derive from a meeting of the IGBP (International Geosphere–Biosphere Programme) PAGES (Past Global Changes) project, University of London, 1998. The PAGES project is to,"provide a quantitative understanding of the Earth's environment in the geologically recent past and to define the envelope of natural environmental variability, against and alongside which anthropogenic impacts in the Earth System may be assessed" (Alverson and Oldfield, 2000, p. 3). These authors outline the components of the volume, and also introduce the reader to the many acronyms, nested under the grand acronym, PANASH (Paleoclimates of the Northern and Southern Hemispheres).

The volume's contributions are weighted to the Holocene (the last 10,000 years) and historic record, but there are eight papers spanning the last 100,000 years and up to 420,000 years. Thus the volume considers primarily the proxy records of high-frequency climatic events of the late Pleistocene and Holocene, and instrumental records of historic times. Tectonics and climatic change are considered only by An, in his discussion of the East Asian monsoon system. "Paleoenvironmental archives and methods" and "Pole-equator-pole" transects may be some of the most valuable sections to the geologically oriented reader. Raynaud *et al.* review high-latitude ice core records of atmospheric trace gas concentrations and isotopes, and their interplay with temperature changes on a time scale of up to 400 Ka. Raynaud *et al.* (2000, p. 10) state that, "The longer record indicates that the industrial increases of CO_2 and CH_4 are most likely unique in terms of growth rate and lead to present-day atmospheric concentrations which have been unprecedented over the last 420,000 yr." Regarding the effect of greenhouse gases and glacial-interglacial cycles, they observe that, "...changing the orbital parameters initiated the glacial-interglacal climatic changes, then the greenhouse gases amplified the weak orbital signal, accompanied several thousand years later by the effect of decreasing albedo during the retreat of the northern hemisphere ice sheets." (2000, p. 16).