Backscattered Scanning Electron Microscopy and Image Analysis of Sediments and Sedimentary Rocks

Backscattered scanning electron microscopy (BSE) reveals the minerals, textures, and fabrics of sediments and rocks in much greater detail than is possible with conventional optical microscopy. *Backscattered Scanning Electron Microscopy* provides a concise summary of the BSE technique. This comprehensive guide uses abundant images to illustrate the type of information BSE yields and the application of the technique to the study of sediments and sedimentary rocks.

The authors review the use of this petrographic technique on all the major sedimentary rock types, including sediment grains, sandstones, shales, carbonate rocks, rock varnish, and glauconite. They also describe image analysis techniques that allow quantification of backscattered scanning electron microscope images and illustrate the potential applications of these methods.

Heavily illustrated and lucidly written, this book provides researchers and graduate students with the most current research on this important geological tool.

Backscattered Scanning Electron Microscopy and Image Analysis of Sediments and Sedimentary Rocks

DAVID H. KRINSLEY
KENNETH PYE
SAM BOGGS, JR.
N. KEITH TOVEY

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 2RU, UK

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9780521453462

First published 1998
This digitally printed first paperback version 2005

A catalogue record for this publication is available from the British Library

Library of Congress Cataloguing in Publication data
Backscattered scanning electron microscopy and image analysis of
sediments and sedimentary rocks / David H. Krinsley . . . [et al.].
p. cm.
Includes bibliographical references (p. –) and index.
ISBN 0-521-45346-1
1. Rocks, Sedimentary – Analysis. 2. Sediments (Geology) –
Analysis. 3. Scanning electron microscopy. I. Krinsley, David
H. (David Henry), 1927– .
QE471.B26 1998 97-18011
552′.5′028 – dc21 CIP

ISBN-13 978-0-521-45346-2 hardback
ISBN-10 0-521-45346-1 hardback

ISBN-13 978-0-521-01974-3 paperback
ISBN-10 0-521-01974-5 paperback

Contents

Preface

This book focuses on the study of sedimentary rock thin sections using images obtained from the scanning electron microscope (SEM) in the backscattered electron mode (BSE). About half the text consists of description and analysis, and the rest SEM micrographs. Until now, there has not been a book available that provides BSE information on the various sediments and sedimentary rock types. We hope the book will provide an analytical tool for sedimentologists and others who may profit from a reference volume for use in their studies.

The earliest known work concerning the construction of an SEM was published in 1938. Much of the subsequent development was done in the engineering department of the University of Cambridge between 1948 and 1965. The first BSE pictures with good resolution were produced in the 1970s. Today, BSE photographs of sediments and sedimentary rocks appear regularly in the major sedimentological journals.

The basic components of an SEM are the lens system, electron gun, electron collector, visual and recording cathode ray tubes (CRTs), and the electronics associated with them. BSE is simply one of the operational modes. Electrons from the primary beam of an SEM strike the atoms of a sample and are reflected or scattered (backscattered) out of the material at high angles. These electrons are collected and

used to produce a gray-level photograph that contains both compositional (atomic number) and topographic information.

Because an image in the BSE mode has a much greater resolution than can be produced with the ordinary light microscope (in addition to atomic number information), BSE has been used in sedimentology and associated fields to provide textural data that are somewhat similar to those obtained with the light petrographic microscope. For instance, when a thin section is viewed using this technique, size, shape, distribution, and composition of sedimentary grains can be observed at magnifications of from 25 to 20,000 times, with resolutions at least 10 times those of the light microscope. The mineralogy and porosity of very fine particles can be obtained; additionally, information about diagenetic alteration of very fine particles, including cementation and replacement, are routinely acquired. Thus the fine-grained fraction of sediments and sedimentary rocks can be examined in great detail, and new insights made available to the microscopist.

The book is divided into four parts. Chapters 1, 2, and 3 are introductory; they discuss the nature of BSE images, and BSE's general application to weathering and early diagenesis of sedimentary grains. Chapters 4, 5, and 6 are concerned with sandstones, shales, and carbonates. Chapters 7 and 8 involve specific examples taken from our work on desert varnish and glauconite. Chapter 9 discusses image analysis of BSE photographs.

SEM/BSE instruments are commonly available to researchers in academia and industry. As these microscopes become smaller and less expensive, the SEM in its various modes will become widely used by undergraduates, graduates, and researchers wishing to obtain submicroscopic information on rocks and minerals. The value of BSE is limited only by the imagination of the researcher.

Acknowledgments

Numerous individuals and organizations have assisted the research from which the examples used in this book have been drawn. Financial support was provided by NATO, the Royal Society, the U.K. Natural Environment Research Council, the Petroleum Research Fund of the American Chemical Society, the U.S. Department of Energy, ARCO, British Petroleum, Schlumberger Cambridge Research, and the Ocean Drilling Program, Texas A&M University. We particularly wish to thank J. Burton, A. Cross, R. Dorn, H. Dypvik, P. Isles, J. Jack, A. Kearsley, D. Newling, W. Porter, I. Pryde, A. Seyedolali, M. B. Shaffer, K. Smith, P. Trusty, and J. Watkins for assistance with specimen preparation, maintenance of scanning electron microscope equipment, and production of illustrations.