APPLICATION OF CATHODOLUMINESCENCE IMAGING TO THE STUDY OF SEDIMENTARY ROCKS

Minerals in sedimentary rocks, such as quartz, feldspar, and carbonate minerals, emit characteristic visible luminescence called cathodoluminescence (CL) when bombarded by high-energy electrons in a suitable instrument. CL emissions can be captured and displayed as color images in a cathodoluminescence microscope or as high-resolution monochromatic images in a scanning electron microscope. CL imaging is particularly useful for studying sedimentary rocks because it provides information, not readily available by other techniques, about the provenance of the mineral grains that constitute sedimentary rocks. CL images also provide insights, not available by other research techniques, into diagenetic changes, such as cementation and porosity loss, which take place in sandstones, shales, and carbonate rocks during burial.

The book begins with an easily understood presentation of the fundamental principles of CL imaging. This presentation is followed by a description and discussion of the instruments used to obtain CL images. Finally, the principal applications of CL imaging to study of sedimentary rocks are described in detail. This short guide provides the first comprehensive, focused, easily understood description of the various applications of cathodoluminescence imaging to study of sedimentary rocks. It will be an important resource for academic researchers, industry professionals and advanced graduate students in sedimentary geology.

SAM BOGGS received his Ph.D. degree from the University of Colorado and worked in the petroleum industry for a number of years before beginning an academic career. After joining the University of Oregon he taught courses and carried out research in sedimentary petrology, stratigraphy, field geology, petroleum geology, and geological oceanography. He continues to do research as a professor emeritus at the University of Oregon and is a senior fellow of the Geological Association of America.

DAVID KRINSLEY is a courtesy professor at the University of Oregon, and a professor emeritus at Arizona State University. His current research interests include the study of both coarse- and fine-grained sediments using scanning and transmission electron microscopy. His particular interests are the examination of sandstones and shales with scanning electron microscopy combined with time-of-flight scanning mass spectrometry. Professor Krinsley is a fellow of the American Association for the Advancement of Science and a senior fellow of the Geological Association of America.

Sam Boggs and David Krinsley have published numerous other books including *Backscattered Scanning Electron Microscopy and Image Analysis of Sediments and Sedimentary Rocks* with co-authors Kenneth Pye and Keith Tovey (Cambridge, 1998).

APPLICATION OF CATHODOLUMINESCENCE IMAGING TO THE STUDY OF SEDIMENTARY ROCKS

SAM BOGGS, JR. AND DAVID KRINSLEY
University of Oregon

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/9780521858786

First published 2006

Printed in the United Kingdom at the University Press, Cambridge

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

ISBN-13 978-0-521-85878-6 hardback
ISBN-10 0-521-85878-X hardback

Contents

Preface

Although the phenomenon of luminescence was recognized as early as the seventeenth century, systematic observation and discussion of cathodoluminescence (commonly referred to as CL) and its application to geological problems did not take place until the middle 1960s. Interest in geological applications of cathodoluminescence expanded rapidly following introduction of the concept, resulting in publication of nearly a dozen English-language CL books. Although some of these books focus on commercial applications of CL (e.g., in the semi-conductor industry), many of them deal with geological applications. These books discuss the theoretical principles of cathodoluminescence and describe practical uses of CL to solution of a variety of geological problems; however, none focuses exclusively on applications in the field of sedimentology. Hundreds of research papers that discuss theoretical and applied aspects of cathodoluminescence were also published during this period. A significant number of these research contributions have focused on the practical uses of CL as a tool for studying sedimentary rocks, particularly with regard to analysis of provenance of siliciclastic sedimentary rocks and diagenesis of both siliciclastic and carbonate sedimentary rocks.

We have attempted in this book to bring together in one volume the principal applications of cathodoluminescence imaging to study and interpretation of sedimentary rocks. The book draws heavily on information available in the published literature, as well as on our own research into cathodoluminescence applications in sedimentology. The book is divided into two parts. Part I includes an introductory chapter followed by discussion of the theoretical basis for cathodoluminescence (Chapter 2) and description of the instruments and techniques used in cathodoluminescence imaging and related analytical procedures such as trace-element analysis (Chapter 3). Part II focuses on applications of CL

in the field of sedimentology, the principal concern of this book. Chapter 4 discusses the use of CL as a tool for interpreting the provenance of siliciclastic sedimentary rocks. Chapter 5 evaluates the effectiveness of CL imaging for identifying and interpreting diagenetic minerals and fabrics in siliciclastic sedimentary rocks. Chapter 6 explores the CL characteristics of carbonate minerals and the usefulness of CL for description and interpretation of the diagenetic features of carbonate sedimentary rocks. Finally, Chapter 7 explores applications of CL imaging to a variety of miscellaneous topics: skeletal petrology, apatite, sedimentary ore deposits, petroleum geology, archeology, and Precambrian rocks.

Cathodoluminescence microscopes and scanning electron microscopes and electron probe microanalyzers equipped with CL detectors are commonly available instruments in many university and commercial laboratories. Therefore, many graduate and undergraduate students, as well as academic and industry professionals, have access to CL facilities. We hope that this book will be of use to students and professionals alike who may be interested in exploring the many exciting applications of cathodoluminescence imaging to sedimentological problems.

Acknowledgments

Examples and illustrations used in this book have been drawn from a variety of published sources as well as from our own work. We wish to thank Abbas Seyedolali and Young-In Kwon for assistance with the scanning electron microscope in acquisition of cathodoluminescence images and for stimulating discussions of cathodoluminescence applications. Gordon Goles (deceased) shared his insight into the theoretical aspects of cathodoluminescence; his incisive grasp of pertinent principles has been an inspiration. Kari Bassett read some early chapters and provided critical feedback. Finally, we thank Patricia Corcoran for reviewing the entire manuscript and providing expert editorial assistance.