The application of electron backscatter diffraction and orientation contrast imaging in the SEM to textural problems in rocks

DAVID J. PRIOR,1,* ALAN P. BOYLE,1 FRANK BRENKER,2 MICHAEL C. CHEADLE,1 AUSTIN DAY,3 GLORIA LOPEZ,4 LUCA PERUZZO,6 GRAHAM J. POTTS,1 STEVE REDDY,2 RICHARD SPIESS,6 NICK E. TIMMS,7 PAT TRIMBY,8 JOHN WHEELER,1 AND LENA ZETTERSTRÖM9

1Department of Earth Sciences, Liverpool University, L69 3BX, U.K.
2Institut für Mineralogie und Geochemie, Universität zu Köln, Zülpicher Strasse 49b, 50674 Köln, Germany
3HKL technology, Bläkildevej 17k, 9500 Hobro, Denmark
4Departamento de Geología, Universidad de Chile, Santiago, Chile
5Tectonics Special Research Centre, School of Applied Geology, Curtin University of Technology, Perth, WA 6102, Australia
6Department of Mineralogy and Petrology, University of Padua, Italy
7Department of Geology, James Cook University, Townsville, Australia
8Department of Geology, Utrecht University, Utrecht, Netherlands
9Laboratory for Isotope Geology, Swedish Museum of Natural History, Stockholm, Sweden

ABSTRACT

In a scanning electron microscope (SEM) an electron beam sets up an omni-directional source of scattered electrons within a specimen. Diffraction of these electrons will occur simultaneously on all lattice planes in the sample and the backscattered electrons (BSE), which escape from the specimen, will form a diffraction pattern that can be imaged on a phosphor screen. This is the basis of electron backscatter diffraction (EBSD). Similar diffraction effects cause individual grains of different orientations to give different total BSE. SEM images that exploit this effect will show orientation contrast (OC). EBSD and OC imaging are SEM-based crystallographic tools.

EBSD enables measurement of the crystallographic orientation of individual rock-forming minerals as small as 1 µm, and the calculation of misorientation axes and angles between any two data points. OC images enable mapping of all misorientation boundaries in a specimen and thus provide a location map for EBSD analyses. EBSD coupled to OC imaging in the SEM enables complete specimen microtextures and mesotextures to be determined. EBSD and OC imaging can be applied to any mineral at a range of scales and enable us to expand the microstructural approach, so successful in studies of quartz rocks, for example, to the full range of rock-forming minerals. Automated EBSD analysis of rocks remains problematic, although continuing technical developments are enabling progress in this area.

EBSD and OC are important new tools for petrologists and petrographers. Present and future applications of EBSD and OC imaging include phase identification, studying deformation mechanisms, constraining dislocation slip systems, empirical quantification of microstructures, studying metamorphic processes, studying magmatic processes, and constraining geochemical microsampling. In all these cases, quantitative crystallographic orientation data enable more rigorous testing of models to explain observed microstructures.

INTRODUCTION

A complete petrographic description of any rock comprises observations at the centimetre to angstrom scale, against which petrogenetic models are tested. Such data underpin many aspects of earth sciences. Petrographic observations include (1) spatial distribution, size and shape of phases; (2) the composition of phases and the variation of composition within phases; (3) the crystallographic orientations of phases and variation of orientation within phases; (4) the geometry and structure of subgrain boundaries; (5) the geometry and structure of boundaries between grains of the same phase; and (6) the geometry and structure of boundaries between different phases; and the geometry and structure of triple junctions.

By virtue of widespread availability, low cost, and versatility, transmitted and reflected light microscopy have served, and will continue to serve, as the mainstay of petrographic data collection. However, some data are inaccessible using light optics and, increasingly, more demanding scientific objectives necessitate that certain data be collected with greater thoroughness and precision than is possible with light microscopy.

*E-mail: davep@liverpool.ac.uk